Mataura Catchment Strategic Water Study

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Executive Summary

Study background

Recent years have seen a significant increase in the volume of water allocated for consumptive use in the Mataura catchment, primarily associated with the expansion of pasture irrigation. Over this period significant changes have also occurred in terms of land use and land use intensity. Combined, these factors have increased pressure on the overall quality and quantity of water resources in the catchment.

The Mataura Catchment Strategic Water Study was initiated by Environment Southland to identify potential options for future water resource management which could potentially provide for future water demand while enhancing the social, cultural and environmental values associated with the Mataura River.

Water resources of the Mataura catchment

The Mataura catchment extends over an area of approximately 5,400 square kilometres from headwaters south and east of Lake Wakatipu to the south coast at Fortrose. The catchment experiences a range of climate conditions reflecting the transition from a marine-dominated climate near the south coast to more sub-alpine conditions in the upper catchment.

The Mataura River carries a median discharge of approximately 70 m^3/s in its lower reaches. River flows exhibit significant seasonality with highest discharge typically occurring in spring and lowest flows during late summer. Major tributaries include Roberts Creek and Eyre Creek in the upper catchment, the Waikaia River, Waimea Stream and Waikaka Stream in the middle catchment and the Mimihau Stream and Mokoreta River in the lower catchment.

The Mataura catchment also contains a significant groundwater resource hosted in alluvial gravel deposits along the riparian margins of the Mataura and Waikaia Rivers. Extensive interaction occurs between the river and these aquifer systems with alternate reaches gaining or losing flow depending on the local hydrogeological setting. Baseflow (groundwater) discharge to the river helps maintain river flows during periods of low rainfall and exerts a significant influence on surface water quality (particularly in terms of nutrients) during periods of low flow.

Current Water Resource Management

The Water Conservation (Mataura River) Order 1977 (referred to in this report as the MCO) establishes the '*nationally outstanding*' character of the fisheries and angling amenity within portions of the Mataura River system[1] and provides a basic framework for management of water quality and quantity in the catchment. Key provisions of the MCO include:

- A prohibition on damming of the main stems of the Mataura and Waikaia Rivers;
- A simple proportional allocation for consumptive use of 5 percent of the naturalised flow above the Mataura Island Bridge and 10 percent downstream of this point;
- Three water quality standards that must be met by point source discharges after reasonable mixing in different parts of the '*protected waters*'.

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[1] Referred to as the '*protected waters*'

Provisions of the MCO are essentially complemented by the Regional Water Plan (RWP) which establishes objectives, policies and rules covering activities outside the direct scope of the MCO.

Current Water Allocation

The volume of water allocated for consumptive use in the Mataura catchment has increased significantly over the past 10 years from approximately 100,000 m^3/day in 2000 to around 300,000 m^3/day in late 2010. A significant proportion of this increase is associated with the expansion of pasture irrigation from approximately 200 ha to 5,400 ha over the same period. Allocation for other uses including industrial and municipal supplies also increased in recent years, but to a lesser degree than irrigation.

The increase in water allocation from 2000 to 2010 has been almost exclusively from groundwater which currently comprises approximately 85 percent of all allocation. However, when potential effects of groundwater abstraction on surface water[2] are taken into account, approximately 40 percent of the total allocation is attributed to surface water. Based on this calculation, the Mataura River is currently considered to be fully allocated under the MCO provisions (in terms of direct surface water and hydraulically connected groundwater takes) at flows below mean annual low flow (MALF) across a majority of the catchment. This means that further allocation for consumptive use is only available at moderate to high river flows.

Current Water Use

Water use compliance information indicates that current water use is significantly lower than allocated rates and volumes. On a seasonal basis, few consents utilise anywhere near their full allocated volumes, with typical use in the range of 30 to 50 percent of seasonal allocation. The available data also suggest that short term (i.e. instantaneous and/or daily) abstraction, although proportionally higher than seasonal use, is again significantly less than allocated rates/volumes.

Future water use

Potential future water demands were estimated over a nominal 20-year planning horizon based on ‘conservative’ and ‘accelerated’ estimates of future irrigation, municipal and industrial demand growth. These scenarios are intended to provide upper and lower bound estimates of potential growth in water demand in the absence of regulatory constraints on water use. In reality, the extent to which these demands can be met largely depends on the regulatory regime in place. Given the current level of allocation under the MCO regime, these estimates are best viewed in terms of potential future shortfalls in supply.

Results of the assessment suggest irrigation is likely to be the primary driver of future water demand in the Mataura catchment. However, lignite mining and secondary processing may also make a significant contribution to future water demand. Based on estimates of future irrigation, industrial and municipal demand growth, potential supply shortfalls in 2030 are estimated to range between 400,000 and 800,000 m^3/day.

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[2] Referred to as stream depletion

Factors influencing future water demand and availability

Analysis of historical climate data suggests natural climate variability, particularly in terms of rainfall, has a significant influence on water demand and availability in the Mataura catchment. During El Niño conditions westerly airflows typically increase and rainfall is above average over southern New Zealand whereas during La Niña conditions westerly airflows decrease and rainfall is generally below average. Historical data illustrate that the occurrence of historical 'drought' events in Southland are primarily associated with La Niña conditions.

However, possibly of greater significance in terms of potential future water demand and availability than individual El Niño/La Niña events are decadal-scale climate variations which are observed in historical climate (particularly rainfall) data from the Southland Region. These variations, associated with a phenomenon termed the Interdecadal Pacific Oscillation (IPO), influence sea surface temperatures and atmospheric circulation patterns across the Pacific region on a timescale of the order of 20 to 30 years. Warm (positive) phases of the IPO tend to associated with an increase in the frequency of El Niño events, while cool phases typically result in more frequent La Niña conditions. Climate indices suggest a return to the cool phase of the IPO since 2000 with a corresponding increase in the frequency of summer dry conditions in Southland compared to the two preceding decades. However, conditions over this period still remain appreciably wetter than those experienced over the last negative IPO phase from the early 1950's to late 1970's.

Projected impacts of climate change indicate that the Southland Region will experience warmer temperatures over the next 30 years accompanied by an increase in westerly airflows and higher rainfall. However, in all except the most extreme modelled scenarios, changes in water demand and availability resulting from climate change are likely to be significantly less than natural variability resulting from short to medium-term variations in atmospheric circulation

Costs and benefits of future water use

A number of scenarios were modelled to investigate the effect of supply reliability (essentially an outcome minimum flows and total allocation) on the economics of irrigation under different allocation scenarios. Results of this assessment suggest that, under the current MCO flow regime, existing allocation is approaching the point where additional abstraction for irrigation (from the river or hydraulically connected groundwater) is unlikely to be economically viable. Therefore, while the MCO does not prescribe a maximum allocation limit, this analysis suggests that the catchment is close to the point where the water resource can be considered fully allocated with respect to future run-of-river irrigation development.

Further modelling was undertaken to evaluate the viability of water storage as an option to improve supply reliability. This analysis indicated that due to the relatively modest increase in net benefit derived from irrigation, storage is only likely to be viable where it can be established on a very low unit cost basis or where water use provides a sufficiently positive net benefit (e.g. in the case of sustained high agricultural commodity prices for pasture irrigation or higher value alternative uses).

Costs and benefits of irrigation

The total net benefit from existing irrigation in the Mataura catchment is calculated as being of the order of $2.6 million in direct benefit, which equates to approximately $15.4 million in GDP. Under the alternative management scenarios considered (roughly approximating 50 percent of the conservative growth scenario) net benefit would potentially increase to approximately $5.5 million, resulting in an additional $37 million in GDP, $20 million in household income and 490 equivalent full-time jobs.

Lignite mining and processing operations could potentially have an effect that dwarfs other economic activity in the catchment. However, the exact size and nature of any such operations is yet to be determined.

Water quality modelling of projected land use associated with the 2030 ‘conservative’ and ‘accelerated’ growth scenarios by NIWA using the CLUES model suggest that potential effects associated with land use intensification can be significantly offset by adoption of best management practices. While there are limitations in the modelling approach utilised, the result does suggest that land management practice rather than land use *per se* is the most significant factor influencing water quality outcomes.

There are very significant environmental, social and cultural values associated with the Mataura River. While it appears that the extent of any impacts associated with potential future water resource development scenarios analysed are likely to be relatively minor, there needs to be careful consideration of any proposals that substantially alter the environment of the Mataura catchment to ensure the associated environmental costs do not outweigh economic benefits derived.

Options for future resource management

A range of options for future water resource management in the Mataura catchment were considered including:

1. Retaining the status quo;
2. Improving technical water use efficiency;
3. Improving allocative efficiency;
4. Development of water storage
5. Amending the existing regulatory framework;

Retention of status quo management framework

The MCO and RWP currently form a framework for water resource management in the Mataura catchment and provide a basic framework for managing the quality and quantity of water resources in the catchment to maintain the nationally significant fisheries and angling amenity values established by the MCO. However, practical experience highlights some potential shortcomings in the current management approach including the scope and application of existing provisions, the overlap between the MCO and RWP, linkages between the flow allocation methodology and the environmental values being managed, and the requirement for subjective interpretation of management provisions. In particular, management of groundwater /surface water interaction in terms of both water quality and quantity presents a particular ‘weak point’ in the current management regime.

Future water resource management in the Mataura catchment is likely to see increased requirements for a comprehensive, effective and integrated policy framework to ensure sustainable management of the quantity and quality of the water resource. The ability of the current management framework to provide an effective means of dealing with increasingly complex (and evolving) management issues is constrained by both the scope and nature of existing provisions as well as the subjective and somewhat uncertain nature of their application. The resulting uncertainty and lack of clarity in the resource management process is reflected in the relatively high number of Environment Court appeals on resource consent applications in the Mataura catchment in recent years.

Improved technical and allocative efficiency

Improved technical and allocative efficiency are suggested as options that should form part of best practice regardless of the regulatory framework under which they apply. Both are considered important elements of water resource management to enable efficient and equitable use, and encourage conservation and sustainable management of water resources.

Improved technical water use efficiency is a means to ensure that water available for allocation is used in a manner which results in optimum benefit per volumetric unit for a range of end uses. While incentives exist for individual water users to improve technical water use efficiency, it is unlikely to enable any appreciable volumes of water to be made available for consumptive use under the current management framework.

Options to improve allocative efficiency considered include better alignment between allocated volumes and actual use, refinements to methods used to calculate stream depletion effects to better reflect actual water use and options for enhancing water transfer between individual users. While these measures have the potential to enable modest increases in water availability under the current management framework, development and implementation of such options may be relatively complex and require considerable effort which may not be commensurate with the overall benefits arising.

Water Storage

Water storage provides an option to increase both water availability and supply reliability in the Mataura catchment. However, on the basis of economics alone, modelling suggests that storage only provides significant net benefits (in terms of irrigation) when per unit costs are low or economic returns can be sustained at high levels for an extended period. The potential for development of water storage to improve supply reliability is further complicated by a range of regulatory and technical constraints that are likely to serve to increase overall storage costs. The most viable storage options are most likely to be relatively small on-farm storages constructed in locations where topography and geology can be utilised to minimise construction costs.

Due to the nature of the hydrogeological setting in the Mataura catchment alternative storage options such as managed aquifer recharge (MAR) are unlikely to present a practical means of addressing potential supply shortfalls.

Amendment of the existing regulatory framework

Amendment of the existing regulatory framework would provide an opportunity to increase water availability in the Mataura catchment and address some of the shortcomings inherent in the existing management regime. Of the options considered, adoption of the RWP as the primary regulatory instrument would essentially maintain existing MCO provisions with the exception of flow allocation which would be managed utilising a science-based methodology to provide for nominated ‘critical values’. This approach would also enable a degree of flexibility to allow future management to adapt to changing issues and incorporate improved scientific information and management methodologies through the RMA Section 65 plan change process.

However, the water allocation provisions of the RWP are not without their own limitations and a range of options are identified that could be utilised to develop a more transparent and effective regulatory framework.

Any consideration of changes to the existing regulatory framework needs to be cognisant of the provisions of RMA Section 216 which relates to the amendment or revocation of Water Conservation Orders. It is noted that this process is largely untested and, based on the limited existing case law, would likely have to meet a high threshold in terms of maintaining the overall conservation values of the existing MCO in order to successfully proceed.

Summary

Significant environmental, social, cultural and economic values are attributed to the water resources of the Mataura catchment. The MCO establishes the ‘nationally outstanding’ character of the fisheries and angling amenity values associated with the catchment and provides a basic framework for the management of water quality and quantity. However, based on recent experience, the ability of the current management framework to provide an effective means of dealing with increasingly complex (and evolving) management issues is constrained by both the scope and nature of existing provisions as well as the subjective and somewhat uncertain nature of their application.

Under the MCO flow allocation provisions there is limited scope for further consumptive water use due to the low reliability of the available allocation. Analysis of future irrigation, industrial and municipal water supply requirements suggests a significant shortfall in the volume of water available to meet these aggregate demands over a nominal 20 year planning horizon.

Options to address potential supply shortfalls through improved technical and allocative efficiency or development of water storage infrastructure are likely to be constrained by technical, economic, and regulatory considerations and are unlikely to significantly address potential supply shortfalls. Amendment of the existing regulatory framework would provide an opportunity to increase water availability and develop a more comprehensive, science-based management framework. This could enable provision of water to meet at least a portion of potential future water demands and improve transparency and certainty in the resource management process. However, any such development would need to ensure that conservation purpose of the MCO is maintained under any alternative management regime.

Table of Contents

List of Figures

List of Tables

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1. Introduction

1.1. Background to Study

In 2003 the Southland Water Resources Study (Aqualinc and MWH, 2003) identified the Mataura catchment as the area of Southland with the greatest potential future water demand. Irrigation development in this area over the past five years has followed a trend roughly half way between the conservative and accelerated growth forecasts outlined in the initial SWRS assessment. Cumulative allocation of groundwater and surface water in the catchment has now reached a point where, under the current regulatory framework, surface water and hydraulically connected groundwater resources upstream of Gore are approaching full allocation (or at least a point where the reliability of supply for the remaining allocation is likely to significantly constrain future development).

Management of water resources in the Mataura catchment is also complicated by the overlap between the provisions of the Water Conservation Order (Mataura River) 1977 (referred to as the MCO) and the Regional Water Plan (RWP) which recently became operative. This overlap, combined with the relatively subjective interpretation of existing management provisions means the resource management decision-making process is not necessarily straight-forward or transparent. There are also a range of pressures on the water resources of the Mataura catchment, such as land use intensification, not considered at the time the MCO was developed that are not particularly well addressed by the existing management framework.

In recognition of the potential future demand for water in the Mataura catchment as well as some of the limitations inherent in the existing management framework, Environment Southland lodged an application with the Ministry of Agriculture and Forestry (MAF) seeking support from the Community Irrigation Fund (CIF) for a strategic evaluation of future water resource management in the Mataura catchment in early 2010. The application was approved in May 2010 with work commencing in October 2010.

1.2. Study Objectives

Overall objectives for the study were to identify potential options for future water resource management which can provide for future water demand while enhancing the social, cultural and environmental values associated with the Mataura River.

Specific objectives included:

- A re-assessment of potential future water demand in the Mataura catchment;
- Identification and evaluation of technical and regulatory constraints on water availability under the existing management regime;
- Identification of potential costs and benefits associated with future water resource development in the Mataura catchment
- Evaluation of options for addressing potential supply shortfalls through a combination of infrastructure development and/or amendments to the existing regulatory framework

1.3. Methodology

The following methodology was utilised for development of the report:

- A review of current water resource management in the Mataura catchment was undertaken including the background, nature and scope of existing management provisions. The review also provided analysis of existing allocation for consumptive water use in the catchment along with a detailed assessment of actual water use based on available compliance monitoring records;
- To provide context for consideration of past and potential future water management a review of factors influencing potential water demand and availability in the Mataura catchment was undertaken including both short and medium-term climate variability as well as climate change impacts and afforestation. The assessment also considered the drivers for uptake of irrigation;
- Potential future water demands over the next 20 years analysed in terms of ‘conservative’ and ‘accelerated’ growth scenarios based on extrapolation of historical water allocation trends and feedback from major users in the catchment. Projections of land use change associated with potential increases in irrigated area were prepared for application of water quality modelling undertaken by NIWA as part of a complimentary project;
- Potential irrigation water requirements were modelled using a soil water balance model and results of this assessment utilised to inform a farm-systems model to evaluate the economic viability of irrigation under the potential supply reliability outcomes of various alternative water allocation scenarios;
- Results of on-farm economic modelling of irrigation development were extended to provide an assessment of potential regional-scale economic and social outcomes under the status quo and alternative allocation scenarios.
- Potential environmental costs associated with future water resource development were analysed based on results of water quality modelling and application of existing studies considering wider recreational and environmental values;
- Various alternative management options were considered as an alternative to status quo management framework as a means to achieve the study objectives. Options considered included measures to improve technical and allocative efficiency, development of an alternative regulatory framework and application of water storage.

Project oversight was provided by a project Steering Group convened by Environment Southland. This group comprised from a range of stakeholders including representatives from the Environmental, Primary Industry, Local Government and Industry sectors. Feedback from the Steering Group was utilised to identify key management values associated with the Mataura catchment as well as to shape and provide feedback on the alternative management options considered in the report.

1.4. Limitations

The report utilises a range of modelling approaches in an attempt to quantify future water demand and potential costs and benefits associated with water resource development. As with any modelling approach which attempts to incorporate potential behavioural responses, the results presented should be treated as indicative rather than absolute. Where possible assumptions inherent in the modelling approaches adopted are acknowledged and results presented in terms of a range, reflecting uncertainties inherent in both the base data and analysis methodology.

Similarly, in terms of analysis of possible management options, the report does not attempt to promote any particular, rather the analysis is presented in a manner is intended to highlight potential advantages and disadvantages of each option considered to inform consideration of future water resource management in the Mataura catchment.

2. Climate and Water Resources of the Mataura Catchment

The Mataura River is the second largest catchment in the Southland Region (after the Waiau River) covering an area of approximately 5,400 square kilometres, extending from alpine headwaters south and east of Lake Wakatipu, to the sea at Fortrose on the south coast. **Figure 1** shows the catchment boundary and primary stream network in the Mataura catchment.

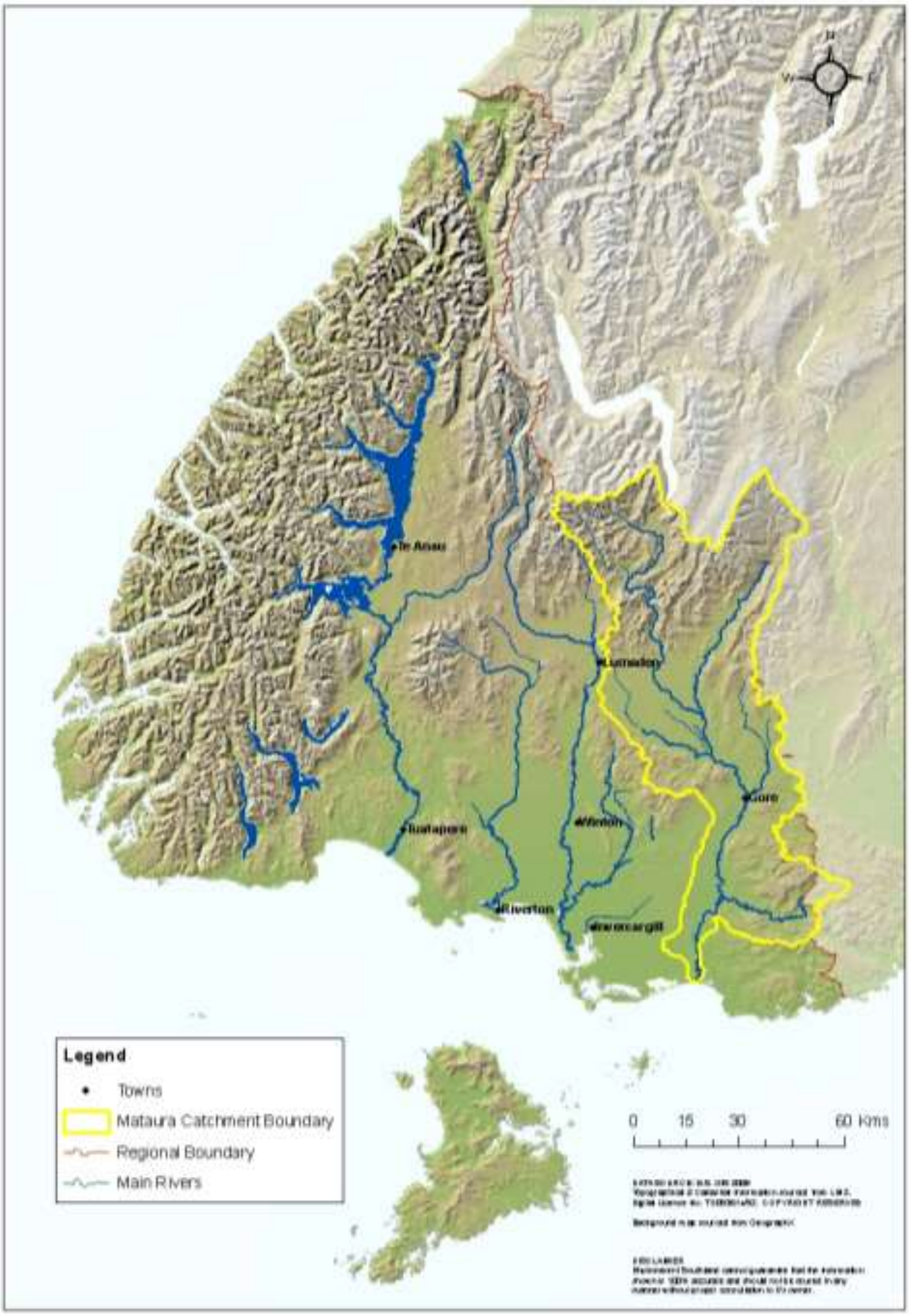

Figure 1. Location of the Mataura Catchment

2.1. Climate

Weather patterns over southern New Zealand are characterised by westerly airflows and the general eastward progression of associated weather systems. Interaction between the prevailing weather patterns and the mountainous terrain results in considerable rainfall variability across the Southland Region. The mountains of Fiordland form a partial barrier to the prevailing westerly airflow and consequently receive extremely high rainfall totals which have been measured in excess of 10,000 mm per year. To the east, the topography of Southland is relatively complex with large mountain ranges separated by inland basins, river valleys and alluvial plains. This topography results not only in orographic enhancement of rainfall on the ranges but significant spill-over and rain-shadow effects in inland valleys.

In general, the Mataura catchment can be divided into three climate zones; coastal areas south of the Hokonui Hills, the Waimea Plains extending between Gore and Lumsden and the Upper Mataura valley which lies at the southern end of the Wakatipu Basin. A majority of climate parameters reflect the transition from a more marine-dominated climate near the south coast to more sub-alpine conditions in the upper catchment. In the lower catchment limited shelter is afforded from the prevailing westerly conditions and consequently rainfall tends to be slightly higher and seasonal temperature variations moderated by proximity to the coast. Inland areas tend to exhibit lower and more temporally variable rainfall, lower wind run and relative humidity and greater seasonal temperature extremes.

Figure 2 shows a plot of mean monthly temperatures at Queenstown, Gore and Invercargill representative of the upper, middle and lower catchment climate zones respectively[3]. The figure highlights the significantly greater (approximately 40 percent) seasonal temperature variability observed in upper catchment compared to coastal areas.

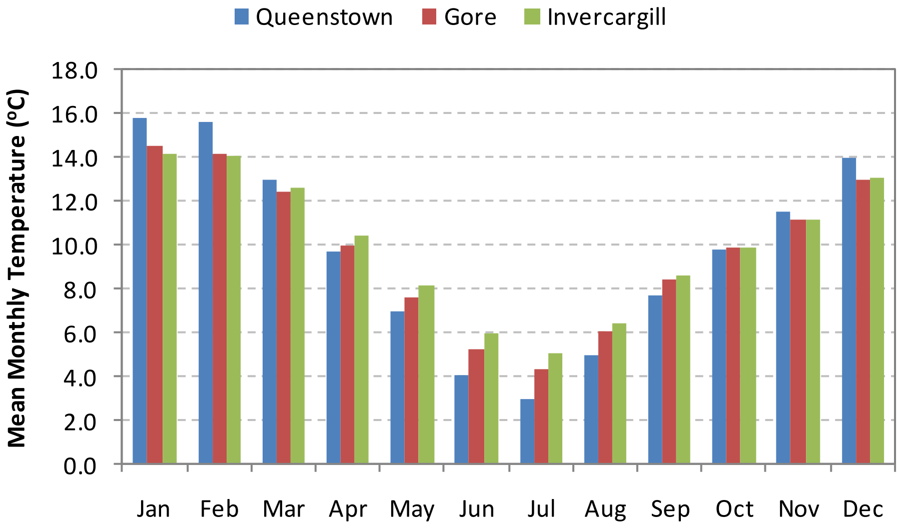

Figure 2. Mean monthly air temperatures across the Mataura catchment.

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[3] Data sourced from the NIWA National Climate Database (http://www.cliflo.niwa.co.nz)

Figure 3 shows the distribution of average annual rainfall across the Mataura catchment[4]. The data show annual totals of between 900 to 1,000 mm in the Upper Mataura valley increasing to around 1,200 mm on the surrounding hills. In mid-catchment areas annual rainfall totals are typically around 900 mm across much of the Waimea Plains decreasing to less than 800 mm in the Riversdale/Otama area. In the lower catchment annual rainfall increase steadily from around 950 mm at Gore to 1,150 mm along the south coast with totals in excess of 1,400 mm recorded in the Catlins area.

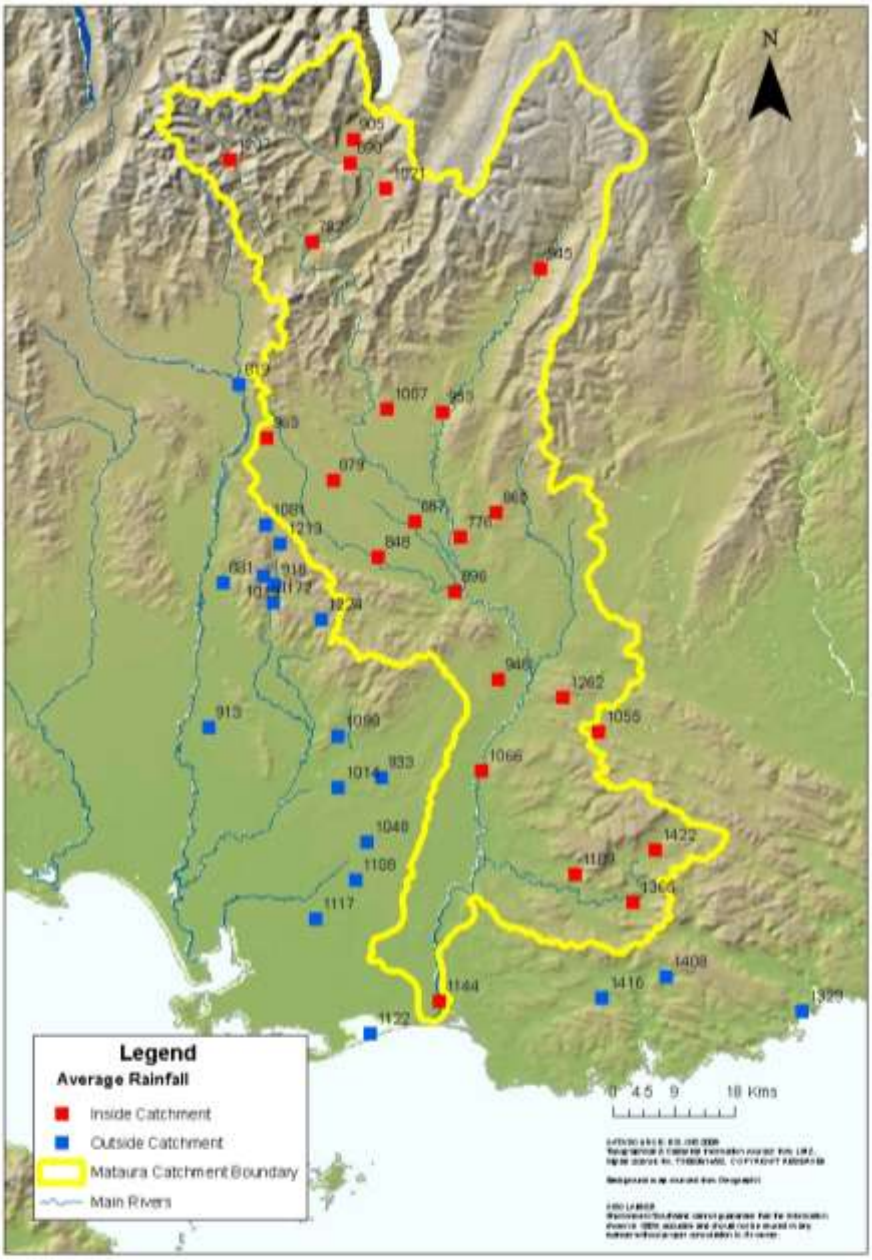

Figure 3. Mean annual rainfall in the Mataura catchment.

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[4] Includes data for rainfall sites with >10 years of record sourced from Environment Southland and the NIWA National Climate Database

Figure 4 shows a plot of mean monthly rainfall from three sites distributed across the Mataura catchment. The data show a relatively consistent seasonal variation in monthly rainfall across the catchment with rainfall highest during the summer (December/January) and lowest in winter (July/August) with a period of slightly wetter conditions occurring during late autumn and early winter (May/June). Monthly rainfall totals are relatively consistent across the middle and upper reaches of the catchment (Fairlight and Mandeville) but increase by around 20 percent in the lower catchment.

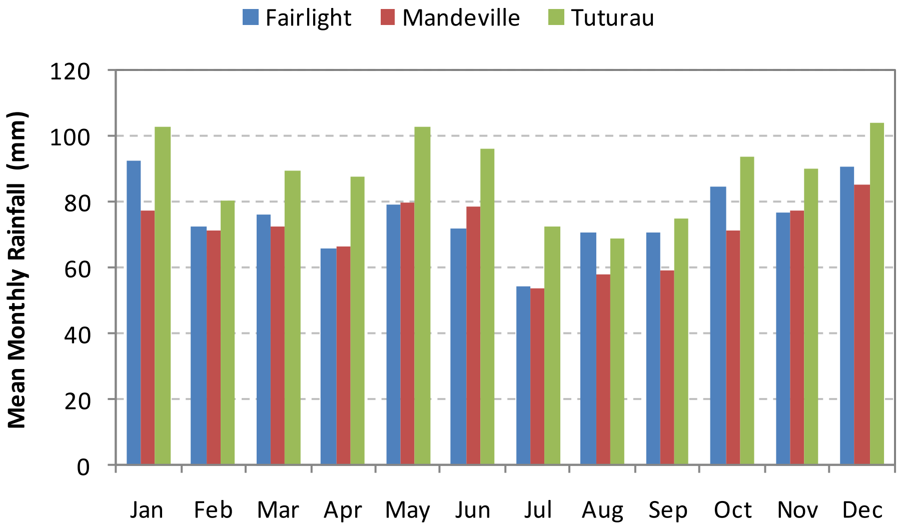

Figure 4. Mean monthly rainfall across the Mataura catchment

2.2. Surface Water

From a hydrological perspective the Mataura catchment can be divided into three distinct sections:

- The steep alpine headwaters extending from the upper catchment to Garston
- The middle reaches between Garston (altitude ~300 m asl) and Gore (altitude ~50 m asl)
- A lowland section between Gore and the estuary at Fortrose

The headwaters of the Mataura catchment drain the upper slopes of the Eyre Mountains and the western side of the Garvie Mountains. The topography of this area is extremely rugged reaching a maximum elevation of approximately 2,000 metres. Much of this upper catchment area has seasonal snow and ice cover which supplements river flows during the spring melt. The middle reaches of the river flow through the Upper Mataura Valley from Garston to Parawa before entering a narrow gorge through the Mataura Range and emerging on the Waimea Plain at Cattle Flat. The river then traverses the Waimea Plain before crossing the exposed bedrock of the Murihiku Escarpment at Gore and entering the relatively flat lowland section which extends to Toetoes Estuary along the south coast.

The Waikaia River, the largest tributary of the Mataura River, extends across a catchment area of approximately 1,830 square kilometres from headwaters in the Old Man and Umbrella Ranges, joining the Mataura River approximately 5 kilometres north-east of the Riversdale township. The Waikaia River carries a discharge approximately equal to the Mataura, immediately upstream of their confluence. Other major tributaries include Roberts Creek, Eyre Creek and the Nokomai River in the upper catchment, the Waimea and Waikaka streams in the middle catchment and the Mokoreta and Mimihau rivers in the lower catchment.

Major spring-fed streams in the Mataura catchment include Brightwater Spring and Parawa Creek in the upper catchment, the Meadow Burn in the middle catchment and Clear Creek and Ives Creek in the Lower catchment.

Figure 5 identifies the major tributaries in the Mataura catchment and shows the location of key flow monitoring sites. **Table 1** provides summary flow statistics for the flow monitoring sites identified.

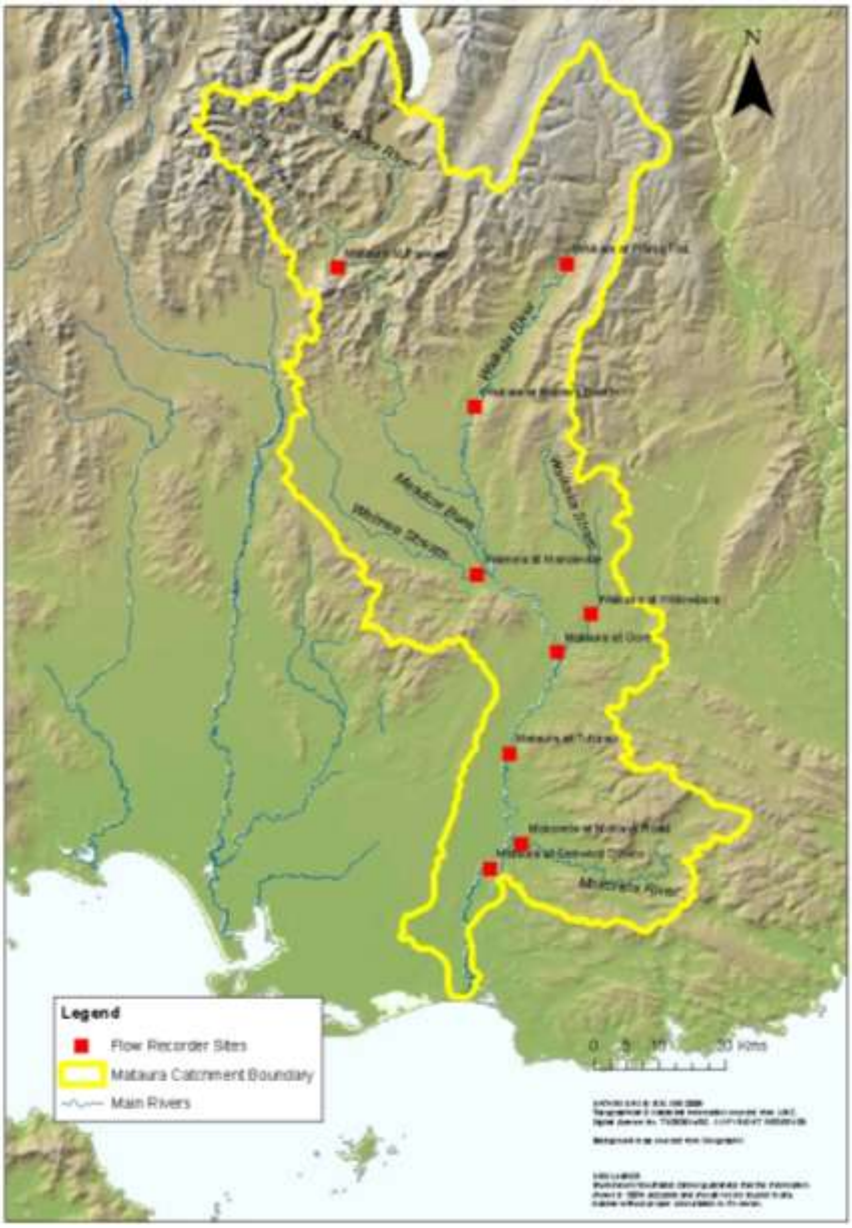

Figure 5. Location of major tributaries and flow recorder sites in the Mataura catchment

Table 1. Summary flow statistics for monitoring sites located in the Mataura catchment (Source: http://www.es.govt.nz/river-rainfall)

Site	**Mataura at Parawa**	**Mataura at Gore**	**Mataura at Tuturau**	**Mataura at Seaward Downs**	**Waikaia at Pianio Flat**	**Waikaia at Mahers Beach**	**Mokoreta at McKays Road**	**Waikaka at Willowbank**	**Waimea at Mandeville**
Catchment Area (km^2)	801	3524	4352	5109	493	1144	418	801	801
Mean Flow (m^3/s)	18.68	49.28	71.90	89.95	12.37	24.41	9.79	18.68	18.68
Median Flow (m^3/s)	13.09	35.14	55.75	69.7	8.60	17.64	6.28	13.09	13.09
Ratio of median to mean flow	0.70	0.71	0.78	0.77	0.70	0.72	0.64	0.70	0.70
Maximum recorded flow (m^3/s)	646	2288	2407	2550	551	850	292	646	646
Minimum recorded flow (m^3/s)	3.15	7.0	6.2	8.0	1.59	2.44	0.90	3.15	3.15
Flood Flows									
Mean Annual flood (m^3/s)	189	542	615	778	270	349	131	189	189
5-year return (m^3/s)	290	933	1037	1270	377	509	166	290	290
10-year return (m^3/s)	372	1251	1380	1669	4.63	645	195	372	372
20-year return (m^3/s)	450	1556	1709	2053	546	775	223	450	450
50-year return (m^3/s)	552	1951	2135	2549	654	945	260	552	552
Low Flows									
7-day MALF (m^3/s)	5.98	17.57	18.94	22.35	3.14	5.52	1.76	5.98	5.98
Specific yield (L/s/km^2)	7.5	5.0	4.4	5.1	6.4	4.8	4.2	7.5	7.5
5-year return (m^3/s)	4.70	11.05	11.55	13.80	2.09	3.56	1.16	4.70	4.70
10-year return (m^3/s)	4.35	9.60	9.90	12.30	1.87	3.06	1.00	4.35	4.35
20-year return (m^3/s)	4.00	8.08	8.25	10.70	1.71	2.70	0.87	4.00	4.00
50-year return (m^3/s)	3.51	6.10	6.25	8.70	1.55	2.34	0.73	3.51	3.51

2.3. Groundwater

The Mataura catchment contains a significant groundwater resource primarily hosted in the relatively thin alluvial gravel deposits that mantle the Southland Plains and inland basins. A more limited groundwater resource also occurs within the Tertiary lignite measure sediments (mudstone, sand, gravel and lignite) that underlie the Waimea Plains and lower catchment as well as in the greywacke and schist basement rocks that form the surrounding hills and mountains.

Until relatively recently (post-2000) the groundwater resources of the Mataura catchment were relatively poorly defined with resource development mainly limited to abstraction from shallow bores for domestic, stock and municipal supplies. Knowledge of the resource has increased significantly in recent years due to an increase in groundwater resource development, primarily to enable pasture irrigation in middle and upper catchment areas.

The groundwater resources in the Mataura catchment are typically hosted in two main hydrogeological settings. Terrace aquifers occur along the outer margins of the Mataura Valley within remnants of moderately to poorly sorted fluvioglacial outwash gravels deposited during the last glaciations. These aquifer systems are typically recharged by local rainfall and infiltration of runoff from the surrounding foothills. Higher permeability riparian aquifers occur along the margins of the Mataura and Waikaia Rivers in mid and upper catchment areas where the major river systems have entrenched into, and reworked, the older glacial outwash gravel deposits. These riparian aquifer systems typically exhibit a high degree of hydraulic connection with the main river systems and are the primary groundwater resource utilised for large-scale abstraction in the Mataura catchment.

A largely undefined groundwater resource also occurs in the Tertiary East Southland Group lignite measure sediments (mudstone, sand, gravel and lignite) that underlie the alluvial gravel deposits across the Waimea Plains and in the area south of the Hokonui Hills. A limited groundwater resource is also present in fractured rock aquifers in the greywacke and schist basement rocks which form the foothills and mountains defining the Mataura catchment.

Figure 6 shows a schematic cross section of the typical hydrogeological setting present throughout the Mataura catchment.

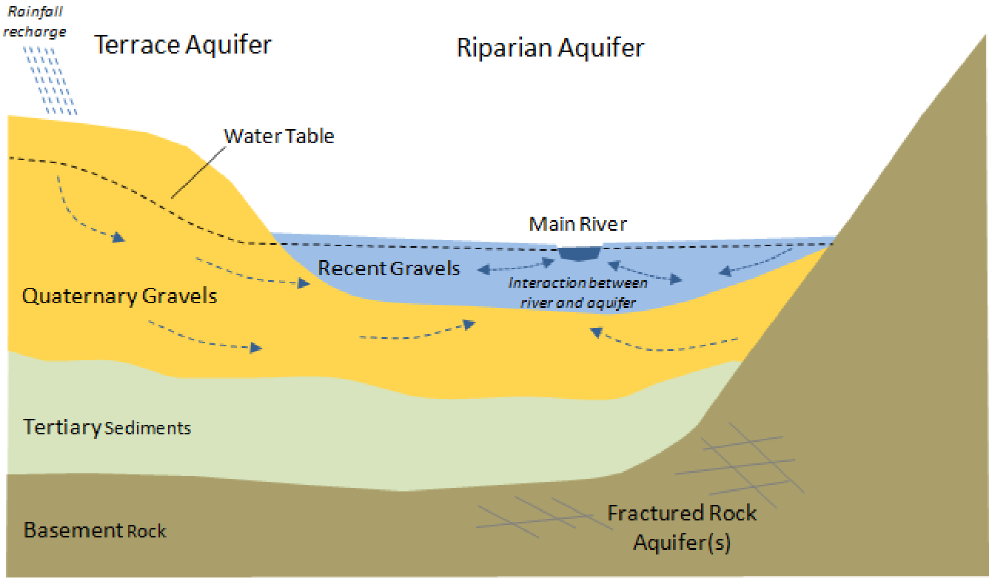

Figure 6. Schematic hydrogeological cross section in the Mataura catchment

For the purposes of resource management the Regional Water Plan divides the groundwater resources of the Mataura catchment into the 13 separate groundwater management zones shown in **Figure 7** below. Each groundwater zone essentially represents a separate groundwater flow system differentiated on the basis of geology, geomorphology and known hydrogeological characteristics. Recent drilling investigations have also identified the presence of a high yielding confined aquifer system (the Garvie Aquifer) underlying the Wendonside Terrace. Individual groundwater management zones are in turn classified in terms of five distinct 'aquifer types' which have different criteria for the management of groundwater allocation. The aquifer types recognised include:

- Riparian aquifers - shallow, high-yielding unconfined aquifers along the margins of the main river systems;
- Terrace aquifers - unconfined aquifers hosted in remnant alluvial terraces along the margins of the Mataura Valley;
- Lowland Aquifers - typically low-yielding shallow unconfined aquifers occurring in glacial outwash gravel deposits;
- Confined aquifers - higher yielding waterbearing gravel and/or sand layers occurring at depth within the Quaternary gravel sequence or the underlying lignite measure deposits; and,
- Fractured Rock aquifers - localised aquifers hosted in secondary permeability (joints, fractures and bedding planes) within the basement rocks of the Murihiku, Brooks Street and Caples terranes.

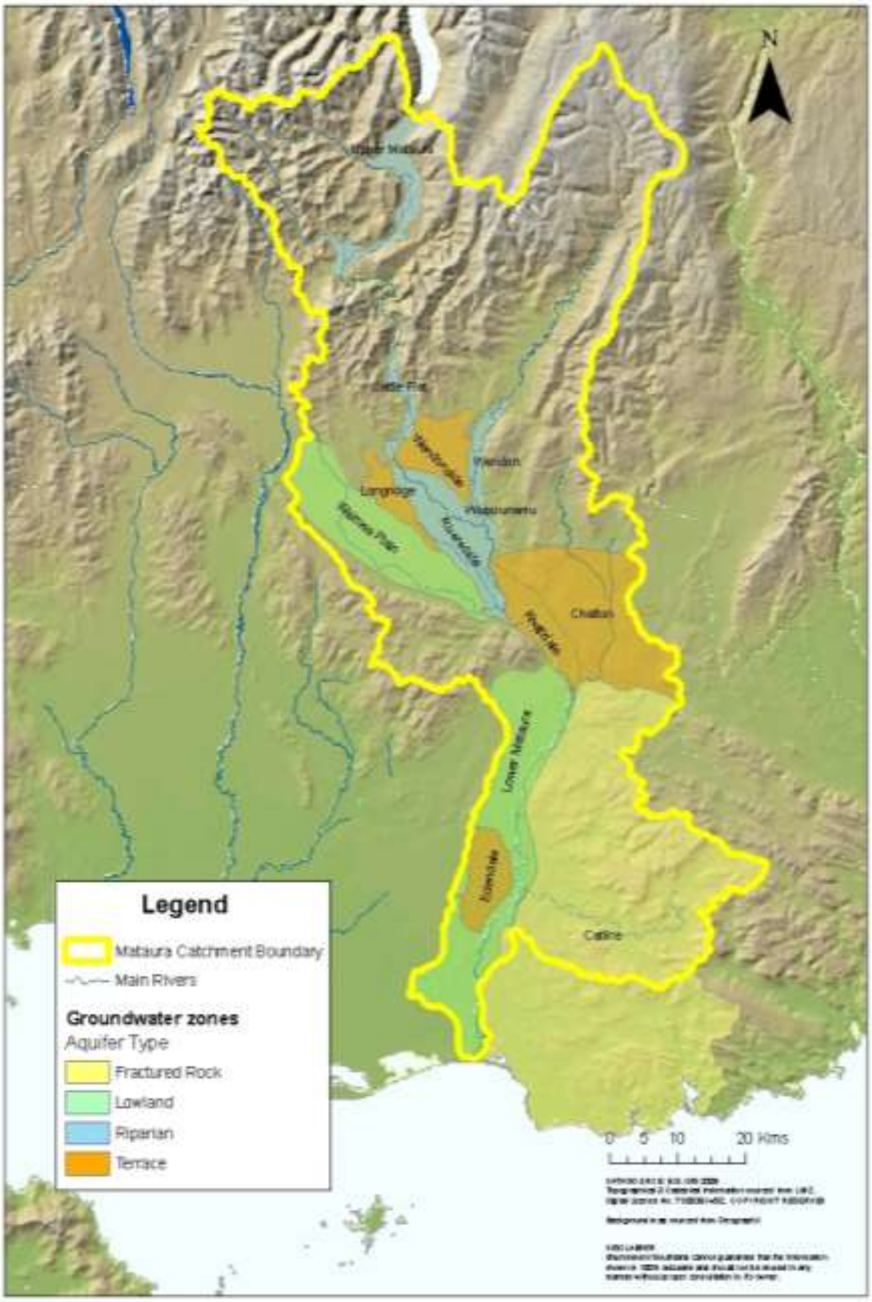

Figure 7. Groundwater management zones in the Mataura catchment

2.4. Groundwater/Surface Water Interaction

Extensive interaction occurs between groundwater and surface water across the entire Mataura catchment. **Figure 8** illustrates the generalised pattern of observed flow gains and losses in the mid and upper sections of the Mataura catchment which are not accounted for by measured tributary inflows including the two major spring-fed tributaries; the Brightwater Spring near Garston and the Meadow Burn near Riversdale.

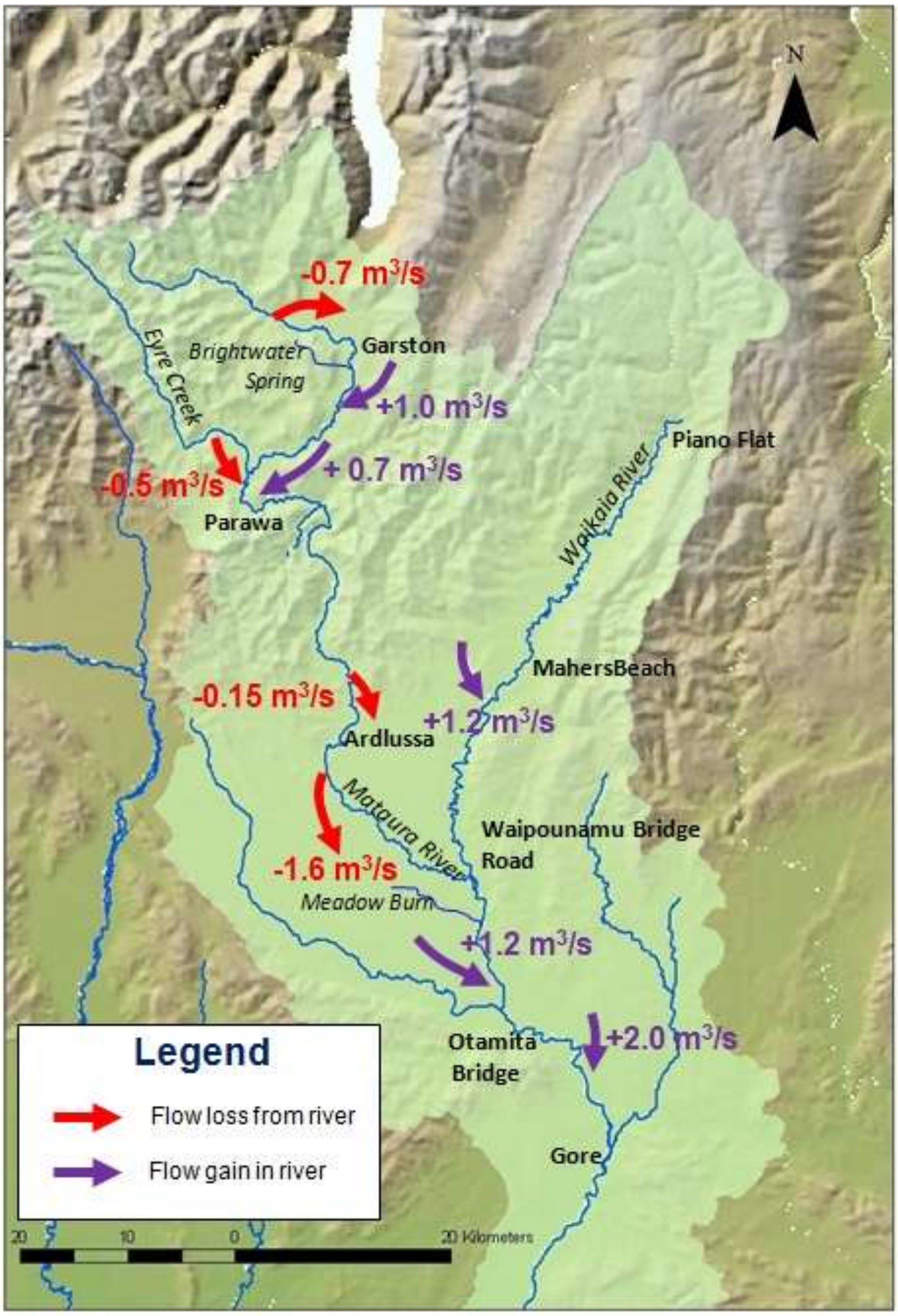

Figure 8. Generalised flow gains and losses observed in the mid and upper reaches of the Mataura catchment

In the upper catchment flow gaugings indicate significant flow loss (>0.7 m^3/s) upstream of Fairlight. The Brightwater Spring which flows into the Mataura River immediately upstream of Garston carries a discharge of approximately 1.5 m^3/s, equivalent to approximately one third of the total discharge at Parawa during periods of low flow. Between Garston and Athol measured flow gains (>0.065 m^3/s/km) are significantly in excess of measured tributary inputs indicating appreciable baseflow discharge from the surrounding riparian aquifer. A similar pattern is observed in the lower section of the Upper Mataura Valley where observed flow gains are in excess of 0.090 m^3/s/km, a significant proportion of which are likely to reflect flow lost from the lower section of Eyre Creek upstream of the SH6 bridge.

In the middle catchment appreciable flow loss occurs from the Mataura River downstream of the point where it emerges from its narrow valley through the Mataura Range between Parawa and Cattle Flat. **Figure 9** illustrates the relationship observed between measured discharge at Ardlussa and the Riversdale Bridge suggesting a relatively constant flow loss of approximately 1.6 m^3/s across this reach during low flow conditions. This flow loss is interpreted to make a significant contribution to the water balance of the adjacent Riversdale groundwater zone. Downstream of this point a flow gain of approximately 1.2 m^3/s is observed between Pyramid and Otamita Bridge with a further 2.0 m^3/s gain observed between the Otamita Bridge and Gore.

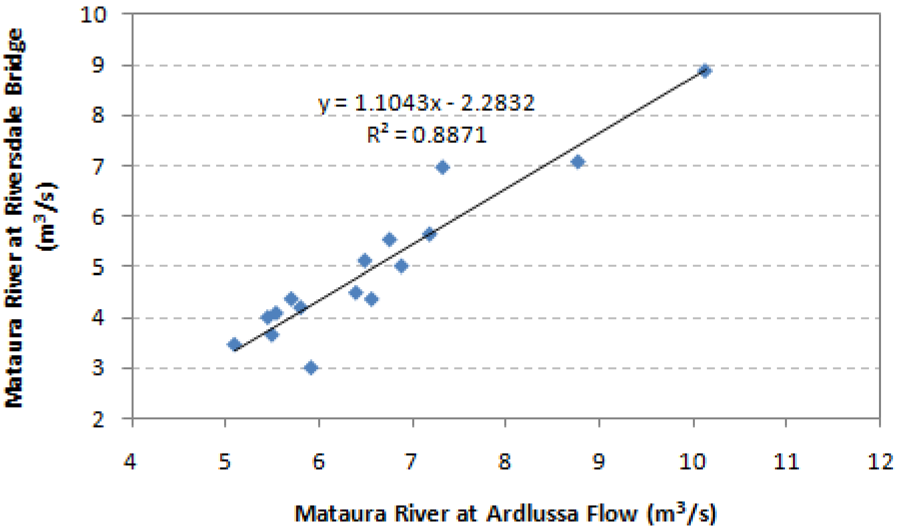

Figure 9. Relationship between measured discharge at Ardlussa and Riversdale Bridge

In the Waikaia catchment a flow gain of approximately 1.2 m^3/s is observed between Mahers Beach and the Mataura confluence. This flow increase is interpreted to largely reflect drainage of groundwater throughflow from aquifers underlying the Wendonside Terrace.

Figure 10 shows a plot of groundwater levels recorded in the Waipounamu groundwater zone and stage height in the Mataura River at Pyramid. These data illustrate the close relationship between groundwater levels and river stage typically observed in riparian aquifer systems as a result of variations in flow into and out of the groundwater system which occur in response to changes in river stage.

In the lower Mataura catchment, the nature and magnitude of groundwater/surface water interaction is uncertain due to the limited concurrent gauging data available. However, several significant spring-fed streams including Clear Creek and Ives Creek occur in the Menzies Ferry area. The springs drain water from the Edendale groundwater zone and provide significant discharge (approximately 1 m^3/s) into the lower reaches of the catchment during periods of low flow.

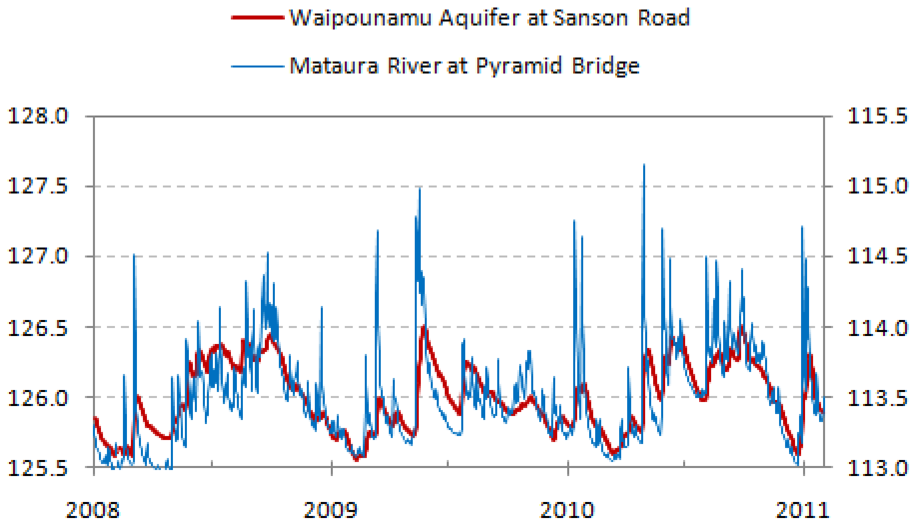

Figure 10. Relationship between groundwater levels in the Waipounamu groundwater zone and stage height in the Mataura River, 2008-2011.

2.5. Water Quality

2.5.1. Groundwater Quality

Groundwater quality in the Mataura catchment is relatively good with a majority of aquifers containing groundwater meeting the Ministry of Health, Drinking Water Standards for New Zealand (DWSNZ) criteria for potable supply. The main groundwater quality issues observed are associated with elevated nitrate-nitrogen concentrations in some shallow aquifer systems and naturally occurring iron concentrations in deeper confined aquifers in the lower catchment.

In terms of nitrate, analysis of available groundwater quality data (Liquid Earth, 2010) indicates median nitrate concentrations in individual groundwater zones ranging between 0.2 to 6.2 mg/L with the highest observed concentrations occurring in the Waimea Plains and Knapdale groundwater zones, both of which are classified as Lowland aquifers. The occurrence of elevated nitrate concentrations in these aquifer systems is largely attributed a combination of recharge source (predominantly rainfall recharge) and relatively low dilution capacity (low aquifer permeability and limited saturated thickness). Of the 23 sites with sufficient data to enable analysis of temporal trends in groundwater nitrate concentration in the Mataura catchment, 9 (40%) exhibited a statistically significant increasing trend, 2 (9%) showed a decreasing trend with the balance showing no observable trend over the period of record (Liquid Earth, 2010).

2.5.2. Surface Water Quality

Surface water quality and associated water quality issues in the Mataura catchment have undergone significant changes over the past 30 years. Whereas point-source discharges and associated effects (BOD, ammonia and dissolved oxygen) in the lower catchment were a major issue in the 1970's, improvements to the quality of wastewater discharges has significantly reduced these effects in more recent years. However, over the corresponding period an increase in contaminants associated with non-point source pollution has been observed. These changes (primarily in terms of nutrient concentrations) are generally inferred to be associated with the intensification of agricultural land use that has occurred across much of the catchment.

In terms of surface water nitrate-nitrogen concentrations, 15 of the 22 sites monitored in the Mataura catchment show statistically significant increasing trends with 20 percent of samples exceeding the chronic aquatic toxicity guidelines (Hickey and Martin, 2009)[5]. Approximately 70 percent of samples at lowland sites (i.e. downstream of Gore) exceed the ANZEEC (2000) guidelines for dissolved reactive phosphorus (DRP) with 39% of samples exceeding the guidelines at upland sites. Analyses indicate nutrient status is phosphorus limited across virtually the entire catchment.

In terms of biotic indices, macroinvertebrate community index (MCI) scores rate sites in the lower Mataura catchment as 'fair' to 'good' condition while upland sites are rated as 'fair' to 'excellent' condition. Of the 13 sites monitored for periphyton, 25 percent of samples breached chlorophyll-a guidelines and 5 percent of samples exceeded AFDM (algal biomass) standards specified in the Regional Water Plan over the 2005 to 2010 period.

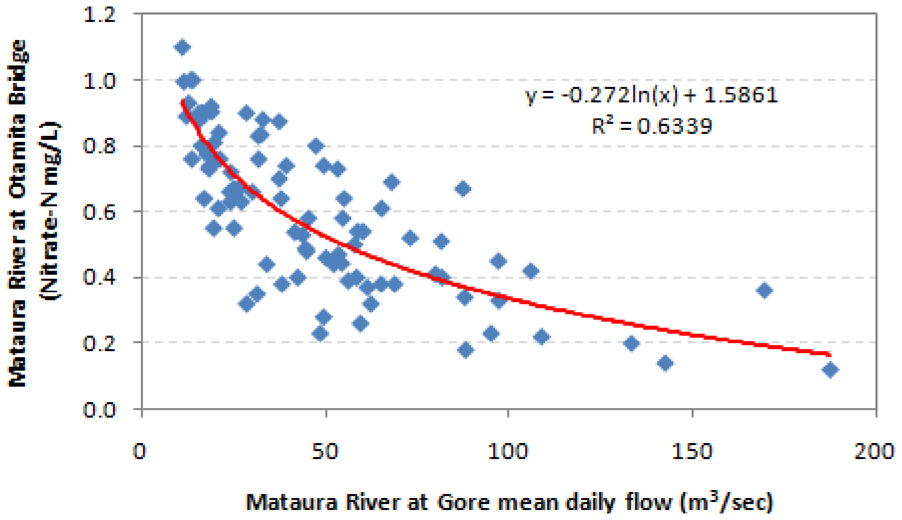

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Figure 11 below. This figure plots nitrate-nitrogen concentrations measured at Otamita Bridge[6] against river flow at Gore. While there is some scatter in the measured data, a clear trend of increasing nitrate concentration at low flows is evident. Given the typically higher concentration of nitrate-nitrogen in groundwater, this relationship is interpreted to reflect the influence of baseflow discharge on surface water nutrient concentrations.

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[5] Overview of Mataura catchment surface water quality provided by Kirsten Meijer, Environment Southland, *pers comm*

[6] The data exclude samples collected during the winter months (June/July/August) when artificial drainage is inferred to make a significant contribution to nitrate-nitrogen inputs to surface water

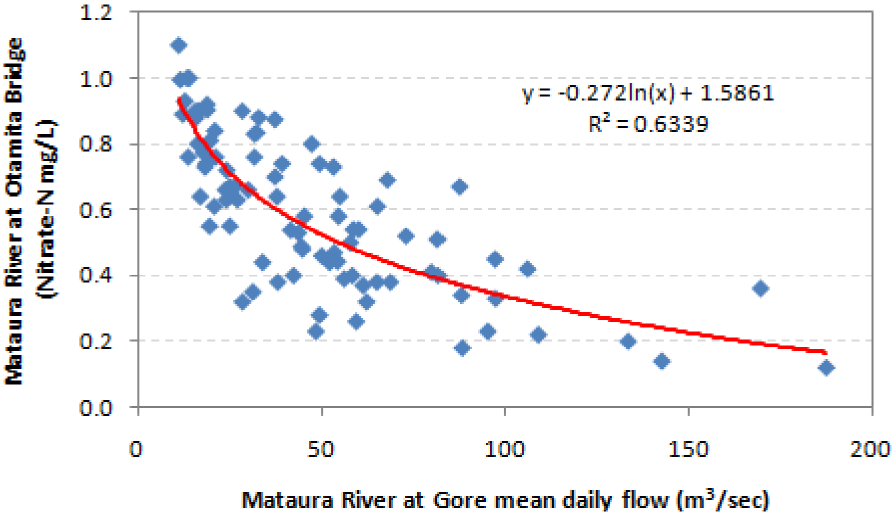

Figure 11. Relationship between nitrate nitrogen concentrations measured at Otamita Bridge (excluding winter data) and flow at Gore

The influence of groundwater baseflow discharge on more general surface water chemistry is illustrated in **Figure 12**. This plot shows temporal variations in discharge and electrical conductivity recorded in the Mataura River at Gore during early 2005. The data show an appreciable downward spike in electrical conductivity during high flow events followed by a gradual increase as flows subsequently recede. This pattern is interpreted to reflect the relatively low amount of dissolved solids in quickflow following rainfall events[7] and the increasing contribution of baseflow discharge (containing higher dissolved solids) during flow recession.

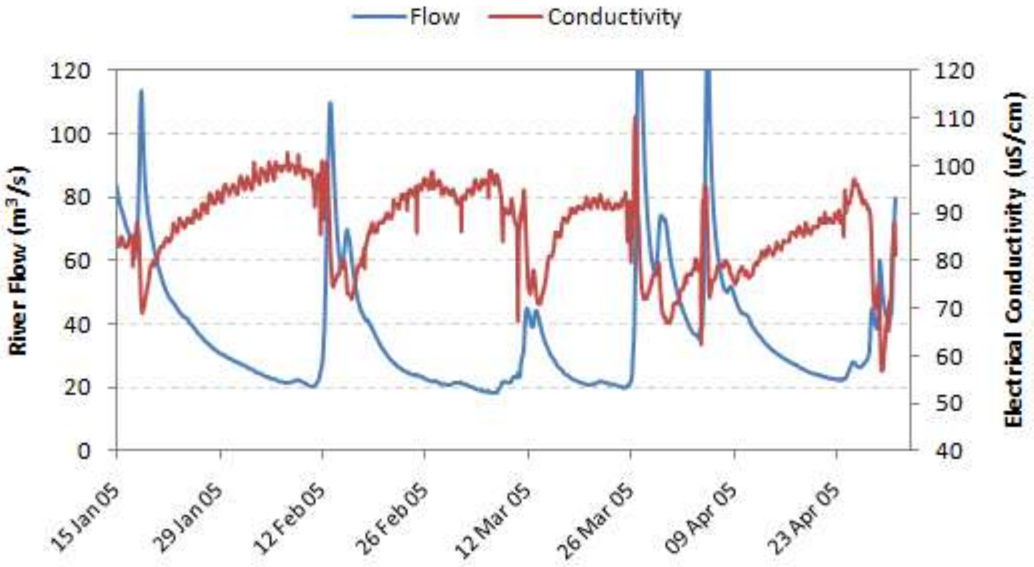

Figure 12. Temporal variations in electrical conductivity (EC) and flow in the Mataura River at Gore, January-April 2005.

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[7] Although it is noted that a upward spike on electrical conductivity often occurs during the initial ‘first flush’ phase of high stage events

3. Current Water Resource Management in the Mataura Catchment

3.1. Legislative Framework

3.1.1. Water Conservation (Mataura River) Order 1997 (MCO)

In July 1984 the Otago Acclimatisation Society, the Southland Acclimatisation Society, the Council of South Island Acclimatisation Societies and the National Executive of New Zealand Acclimatisation Societies jointly lodged an application with the Ministry of Works and Development (the relevant authority at the time) for a National Water Conservation Order (WCO) on the Mataura River under section 20A of the Water and Soil Conservation Act (1967). The initial application sought protection of the river to maintain the outstanding recreational fisheries (fish stocks and fish habitat) values associated with the Mataura River. The application was referred to the National Water and Soil Conservation Authority who, after a process of consultation, prepared a draft WCO which was publically notified in April 1986.

Following notification of the draft WCO, a period of almost three years elapsed before hearing of the application by the Planning Tribunal commenced in January 1990. This delay was primarily the result of legal proceedings associated with the Rakaia River WCO application which was gazetted in October 1988. Following hearing of the Mataura River application, the Planning Tribunal decision recommending granting of the Order was released in May 1990 and the Order finally granted by the Minister for the Environment in July 1997.

Key features of the MCO

The full text of the Water Conservation Order (Mataura River) 1997 is provided in **Appendix A**. The following section highlights key provisions of the Order that determine the scope and extent of its coverage.

Spatial coverage

The spatial extent of the order is defined as being the '*protected waters*' which include:

- The main stem of the Mataura River from its source to its confluence with the sea
- The Waikaia River and its tributaries, the Otamita Stream and all other tributaries of the Mataura River upstream of its confluence with the Otamita Stream
- The Mimihau Stream, and the Mokoreta River and each of their tributaries.

The protected waters are identified as including outstanding fishing and angling amenity features.

The spatial coverage of the MCO is shown in **Figure 13** below. The figure shows the provisions of the MCO apply to the surface water resources across the entire catchment with the exception of smaller streams draining the mid and lower sections of the catchment.

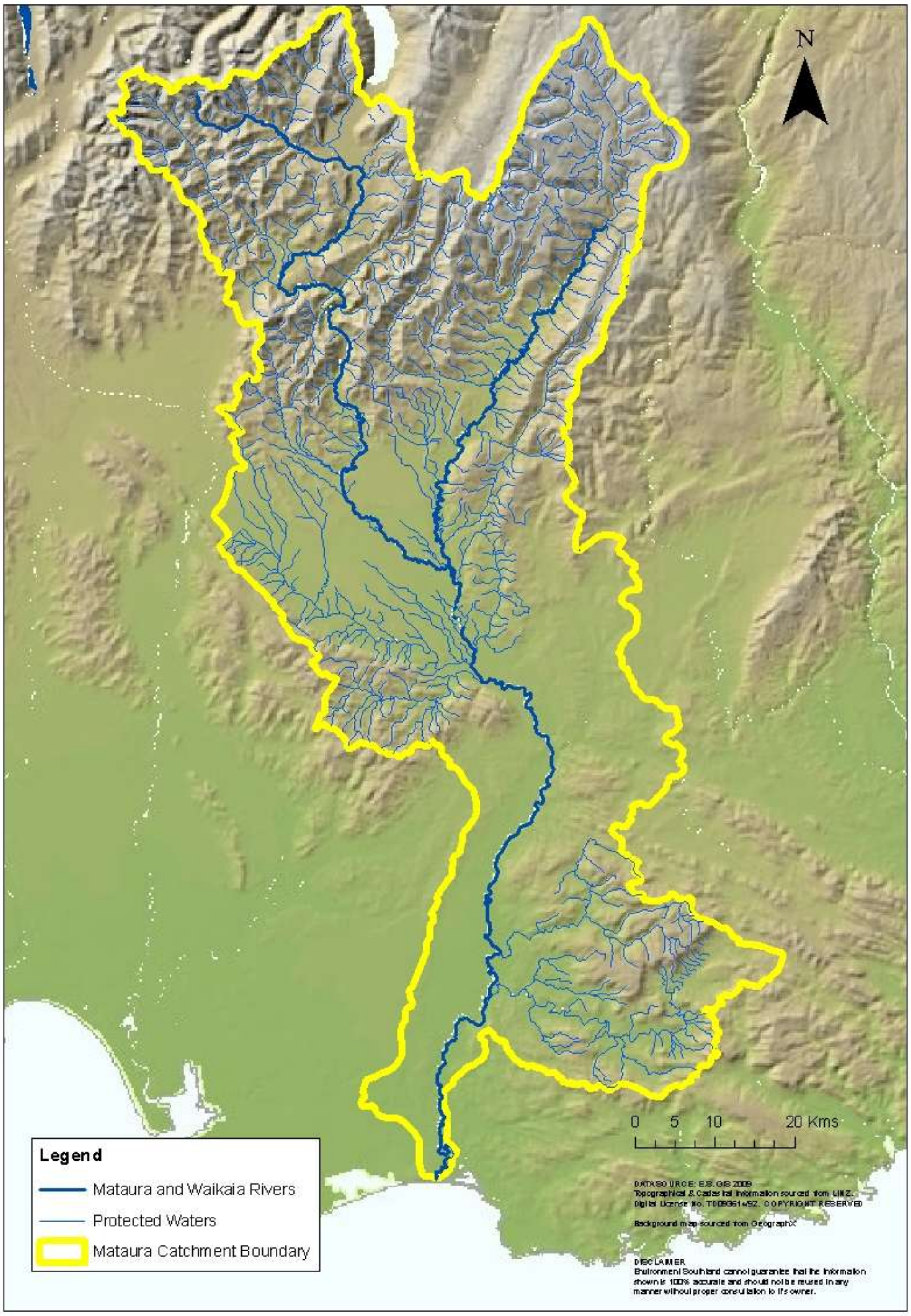

Figure 13. Spatial coverage of the MCO provisions

Allocation for consumptive use

The Order specifies that the minimum rate of flow:

- at any point in the Mataura River and Waikaia River upstream of the Mataura Island Bridge must be 95% of the flow estimated by the Regional Council at that point plus water taken from the protected waters upstream of that point and not returned to the protected waters; and,

- at any point below the Mataura Island Bridge must be 90% of the flow estimated by the Regional Council at that point plus water taken from the protected waters upstream of that point and not returned to the protected waters[8].

These provisions establish a framework for allocation of water for consumptive use whereby flow (at any point where it is measured by the Regional Council) must be maintained above the nominated figures. It is important to note the Order does not establish a minimum flow at which point all consented abstraction must cease, rather it provides for a proportion (either 5% or 10% depending on location) of naturalised flow to be available for consumptive use at all times, with the allocation available varying both spatially down the catchment and temporally in response to natural variations in river flow.

The flow allocation provisions also make allowance for non-consumptive water takes which do not result in a net reduction in river flow. However, as further explained in **Section 8.1**, these provisions are somewhat ambiguous resulting in potential differences in interpretation regarding classification of consumptive and non-consumptive water uses and hence calculation of overall flow allocation.

Prohibition on damming

In order to protect the outstanding values attributed to the catchment, the Order prohibits damming on the main stems of the Mataura and Waikaia Rivers as well as any tributary which forms part of the protected waters if the dam would harm salmonid fish spawning or prevent the passage of salmonid fish.

Water Quality

The MCO provisions establish a basic framework for the management of water quality by establishing a three tier standard for water quality associated with point-source discharges that must be met in the protected waters after reasonable mixing. The standards apply to different sections of the river and cover physical, chemical and microbial parameters including suspended solids, oil, grease, water temperature, acidity or alkalinity, colour and clarity, dissolved oxygen, faecal and total coliform bacteria as well as specifying that discharges must not contain any toxic substances that would make the water unsafe for consumption (by humans or animals) or result in the destruction of aquatic life.

Planning tribunal decision

Key points of note associated with the form and content of the Order outlined in the Planning Tribunal decision (C32/90) of relevance to this report include:

- On the basis of evidence presented the Tribunal considered that '..*the Mataura River system does contain an outstanding fishery and an outstanding angling amenity'*. Both characteristics were considered to be outstanding on a national scale (P39);
- Modifications to the river system[9] including water abstraction, gravel extraction, channel deepening, wastewater discharges and agricultural run-off were considered not to have

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[8] The change in flow allocation provisions below the Mataura Island Bridge was inserted by the Planning Tribunal on the basis of submissions made by Electricorp (the state owned power generation company at the time) in regard possible thermal power station development in the Lower Mataura catchment

[9] At the time the application was heard

adversely affected fisheries or angling amenity values from those occurring in the rivers '*natural state*' (P43);

- The river system functions as a '*one ecological unit*' (P43);
- In terms of management provisions that the '....*the 95% flow allocation and existing water quality classifications (under the Water and Soil Conservation Act, 1967) should be included for the purposes of protecting the outstanding features identified'; and,*
- Although no scientific basis existed for the 95% flow allocation regime adopted (P16), it was considered appropriate to protect the outstanding values of the River while not constraining reasonably foreseeable future uses (P51).

3.1.2. Regional Water Plan for Southland (RWP)

In 1999 Environment Southland commenced the development of a regional water plan with the release of a public discussion document. Based on feedback received on the discussion document the Council developed a Proposed Regional Freshwater Plan which was publically notified in October 2000. In response to significant increases in the demand for consumptive water use as well as improved understanding of the physical nature of the resource and associated management issues, Environment Southland developed a series of variations to the Water Plan commencing in 2004 addressing groundwater (quality and quantity) water quality, water quantity and stock access to surface water. Following planning hearings and resolution of appeals to the Environment Court the Regional Water Plan became operative in its final form in January 2010.

The RWP contains a range of objectives, rules and policies relating to the management of water resources including:

- The taking and use of water (groundwater and surface water);
- Discharges to water;
- Structures in river and lake beds;
- Bed disturbance in rivers and lakes.

Under RMA section 63 a regional plan cannot be inconsistent with a Water Conservation Order. As a consequence, provisions of the RWP only apply to those resource management issues in the Mataura catchment not addressed in the MCO or to those sections of the catchment not covered by the MCO (i.e. areas outside the '*protected waters*'). For example, water quality classifications in the RWP refer directly to the water quality standards specified in Section 7 of the MCO. In the case of water allocation the MCO provisions apply to the main stems of the Mataura and Waikaia rivers while RWP policies and rules apply to allocation from tributary streams and hydraulically connected groundwater .

Key Features of the RWP

<u>Water Allocation</u>

Water allocation policies and rules contained in the RWP are based on the concept of staged management whereby 'default' limits are established to manage the taking and use of water when levels of allocation are low. As levels of allocation increase above nominated thresholds, the activity status of abstraction (under RMA section 87A) changes from restricted discretionary to discretionary and finally non-complying. These changes in activity status increase information requirements to support resource consent applications essentially ‘raising the threshold’ against which subsequent resource consent applications are assessed and/or managed.

The taking and use of surface water is controlled under Rule 18 which establishes criteria for determining activity status of an individual resource consent application based on the level of allocation. Depending on the activity status resource consent application may be classified as restricted discretionary activities provided they comply with default minimum flow provisions (where the level of allocation is less than 10 percent of MALF) or managed as discretionary or non-complying activities which have to be supported by specific technical analysis to determine appropriate minimum flow controls for nominated levels of allocation.

The taking and use of groundwater is managed under Rule 23 which establishes a framework for determining activity status of an individual resource consent based on the levels of allocation from individual groundwater management zones. These groundwater management zones are classified in terms of five different ‘aquifer types’ which have specified limits for classification of activity status based on differing proportions of land surface recharge (for Riparian, Terrace and Lowland aquifers) or aquifer response (Confined aquifers).

Discharges to Water

The RWP establishes water quality classifications for surface water bodies based on a range of factors including the physical and hydrological characteristics as well as existing water quality. A series of policies and rules are specified for discharges (both point and non-point source) which are intended to require higher standards to be achieved in geographical areas with higher water quality. The RWP establishes rules specifying activity status and associated standards for the management discharges into (or on to) land, or into surface water from sources such stormwater, agrichemicals, treated wastewater, fertiliser and sediment and contains a range of provisions relating to stock access. Policies outlined include water quality standards applying to different water quality classifications and methods for achieving specific objectives relating to the maintenance or enhancement of existing water quality.

The RWP identifies the Drinking Water Standards for New Zealand (2005) as the primary standard for management of groundwater quality and outlines a series of objectives and policies intended to ensure all aquifers meet this standard.

Bed disturbance and structures

The RWP outlines a range of objectives, policies and rules intended to manage activities in rivers, streams and lakes to avoid adverse effects on the aquatic environment and ensure structures do not present a hazard in terms of erosion, navigation safety or public access.

3.2. Current Allocation

Water allocation in the Mataura catchment is managed by Environment Southland in accordance with relevant provisions of the MCO and RWP.

Surface water allocation from the main stems of the Waikaia and Mataura rivers is managed in terms of the MCO 5 percent flow allocation (or 10 percent downstream of the Mataura Island Bridge) while on smaller tributaries, where the MCO allocation does not apply, surface water allocation is managed in accordance with Rule 18 of the RWP.

Groundwater allocation is managed in terms of Rule 23 of the RWP which establishes the staged management framework based on allocation as a percentage of aquifer recharge. Rule 18 of the RWP also requires the volume of stream depletion calculated following the methodology outlined in Policy 29 to be deduced from the groundwater allocation volume for an individual groundwater management zone and added to the total for the relevant hydraulically connected surface water body (river, stream or lake).

As a result, there are essentially three types of water allocation in the Mataura catchment:

- Surface water allocation - direct takes from surface waterbodies (rivers, streams and lakes);
- Stream depletion - the calculated effect on surface waterbodies resulting from hydraulically connected groundwater takes; and,
- Groundwater abstraction - the cumulative total groundwater abstraction for each groundwater management zone less the calculated stream depletion effect for individual groundwater management zones.

In assessing current levels of allocation in the Mataura catchment, it is also important to note differences in the manner in which the rate and volume of water abstraction are controlled via resource consent conditions. Due to the nature of potential effects, resource consents for surface water abstraction typically control the instantaneous rate of abstraction. In contrast, groundwater takes are generally managed in terms of controls on abstraction rate (in terms of the instantaneous and/or daily abstraction rate) to manage short-term effects such as stream depletion and well interference, and an overall seasonal allocation to manage longer-term effects on aquifer sustainability. As a result, it is not always straightforward to assess the cumulative rate and/or volume of surface and groundwater allocation.

At the current time cumulative allocation for consumptive use from groundwater and surface water totals approximately 310,000 m^3/day. **Figure 14** shows a breakdown of this total by allocation type. The figure shows approximately 80 percent of total allocation is from groundwater. However, when stream depletion effects are accounted for this total reduces to approximately 60 percent of total allocation.

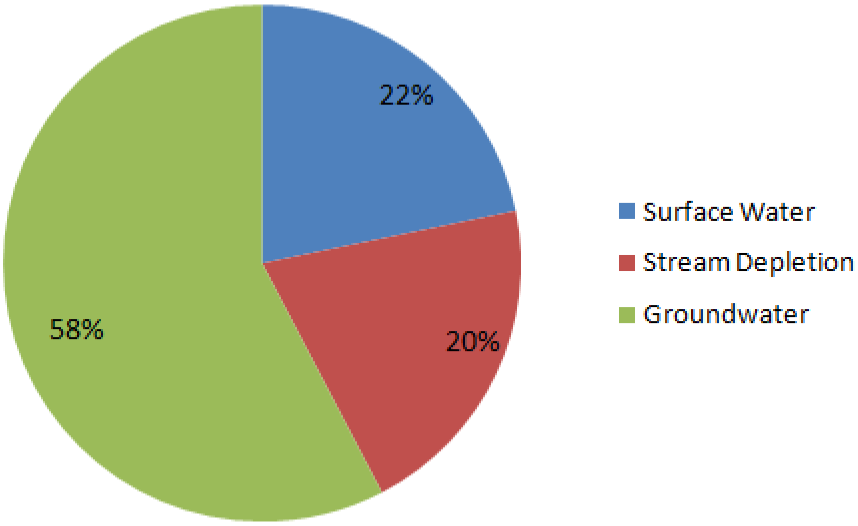

Figure 14. Proportion of water allocated for consumptive use in the Mataura catchment, January 2011

As illustrated in **Figure 15** cumulative allocation for consumptive water use in the Mataura catchment has increased significantly since 2000, primarily driven by an increase in groundwater allocation for pasture irrigation. The graph shows a significant increase in groundwater allocation between 2002 and 2005 primarily associated with development of large-scale takes along the riparian margin of the Mataura River in the Upper Mataura, Waipounamu and Riversdale groundwater zones. The subsequent decline in the rate of increase during 2006 and 2007 is inferred to reflect the application of progressively higher minimum flow cut-offs on hydraulically connected groundwater takes from these aquifer systems. The subsequent increase in groundwater allocation from 2008 to 2010 is largely associated with development of a confined aquifer system (the Garvie Aquifer underlying the Wendonside terrace) and applications willing to accept a minimum flow cut-off (and associated supply reliability) close to or exceeding mean annual low flow (MALF) at Gore.

Figure 15 also shows surface water allocation has remained relatively static since 2000. It is also noted that a significant proportion of the existing surface water allocation is associated with industrial water lakes in the lower catchment which, under the current interpretation of the flow allocation provisions of the MCO, may be considered non-consumptive and therefore not counted as part of the cumulative allocation. This issue of net-use under the MCO is further addressed in **Section 8.1**.

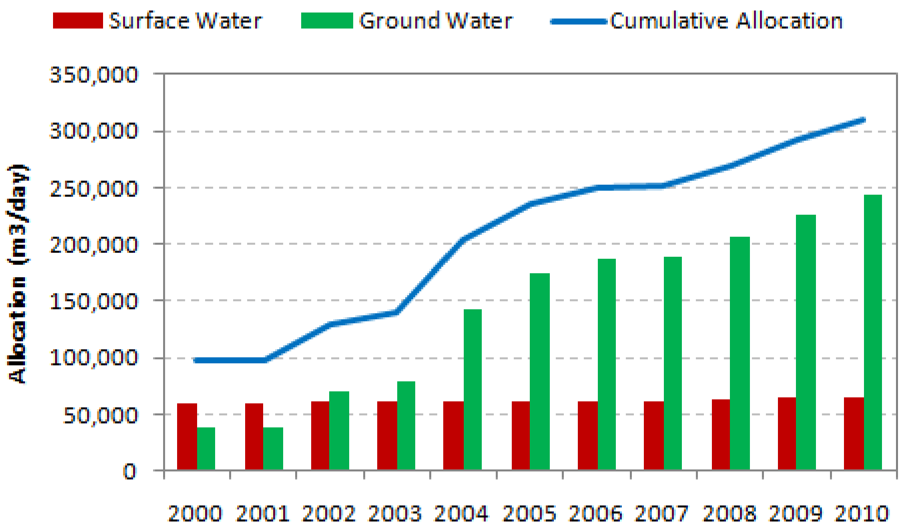

Figure 15. Cumulative allocation in the Mataura catchment, 2000-10

3.2.1. Surface Water Allocation

Figure 16 shows the current distribution of consented surface water abstraction in the Mataura catchment. The figure shows a majority of large-scale abstraction occurs in the mid and lower reaches between Gore and Mataura with relatively few smaller-scale takes distributed across the remainder of the catchment.

Table 2 provides a breakdown of current surface water allocation in the Mataura catchment by usage category. The data show cumulative (2010) surface water allocation in the catchment currently totals approximately 130,000 m^3/day which is comprised of almost equivalent contributions from direct surface water takes (65,000 m^3/day) and stream depletion from hydraulically connected groundwater takes (64,000 m^3/day). The cumulative volume of surface water allocation (including stream depletion effects) is similar in the middle and lower reaches of the catchment (approximately 55,000 m^3/day or 640 L/s) with a further 17,500 m^3/day (200 L/s) allocated in the upper catchment. In terms of cumulative allocation, the figures show stream depletion effects predominate in the mid and upper reaches of the catchment with significantly more direct surface water allocation in the lower catchment.

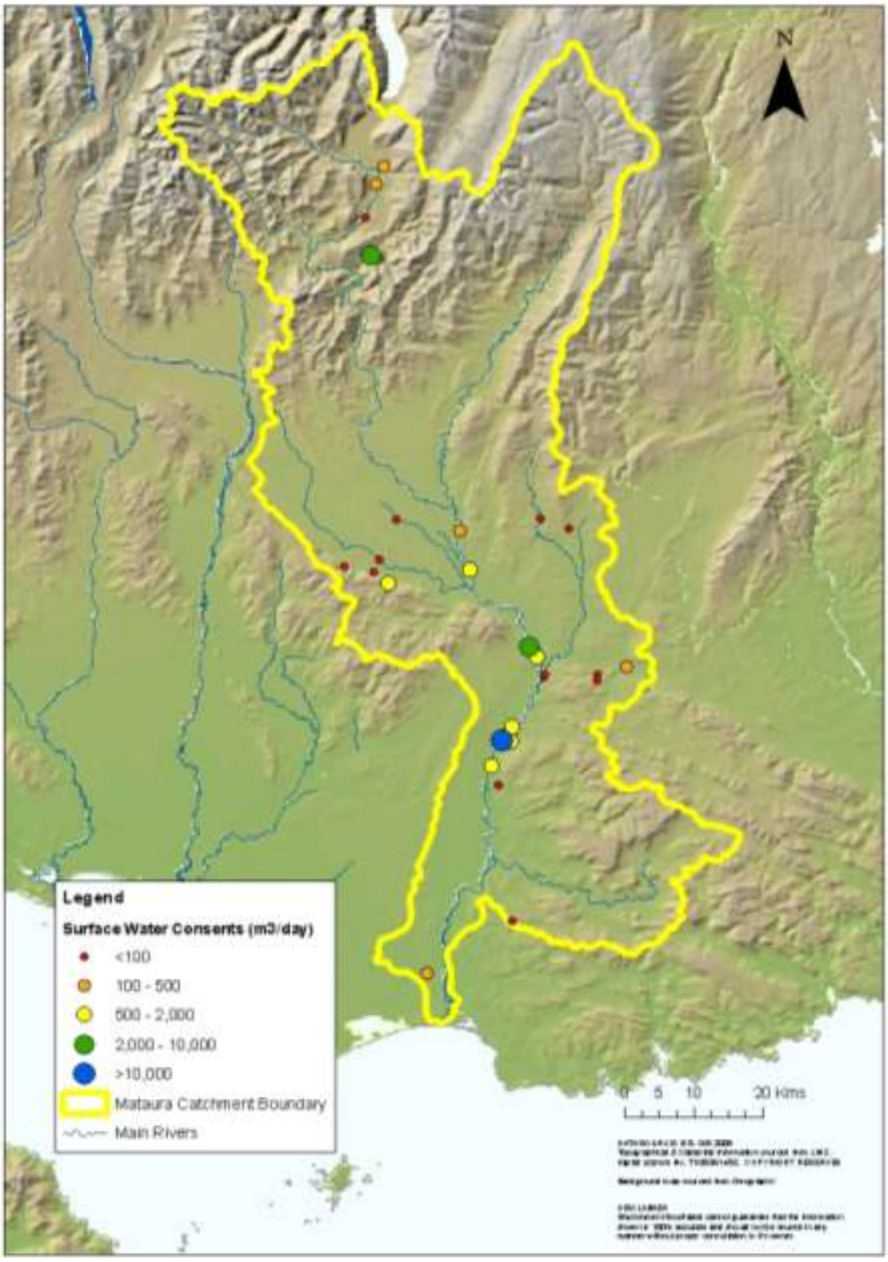

Figure 16. Location of consented surface water takes in the Mataura catchment

Table 2. Current (2010) surface water allocation (m^3/day) in the Mataura catchment by usage type (excluding hydraulically connected groundwater takes)

Catchment	Irrigation	Public Supply	Dairy	Industrial	Mining	Storage	Total	Stream Depletion	Total
Upper Mataura	667				432	3,168	4,267	13,228	17,495
Mid-Mataura	1,296	3,751	1,587	365			6,999	50,466	54,692
Lower Mataura		4,101	410	49,551	336		54,398	432	54,830
Total	**1,963**	**7,852**	**1,997**	**49,916**	**768**	**3168**	**65,398**	**64,126**	**129,524**

Figure 17 illustrates the current distribution of surface water allocation between water usage categories for both direct surface water takes and cumulative surface water allocation (i.e. when stream depletion effects are included). These data show that industrial water use accounts for approximately three quarters of direct surface water allocation with public supply (including consents for emergency supplies to supplement existing GDC groundwater supplies) totalling a further 13 percent of total allocation. However, as a majority of calculated stream depletion effects result from hydraulically connected groundwater takes for irrigation in the mid to upper catchment, industrial takes only contribute approximately 40 percent of total cumulative surface water allocation.

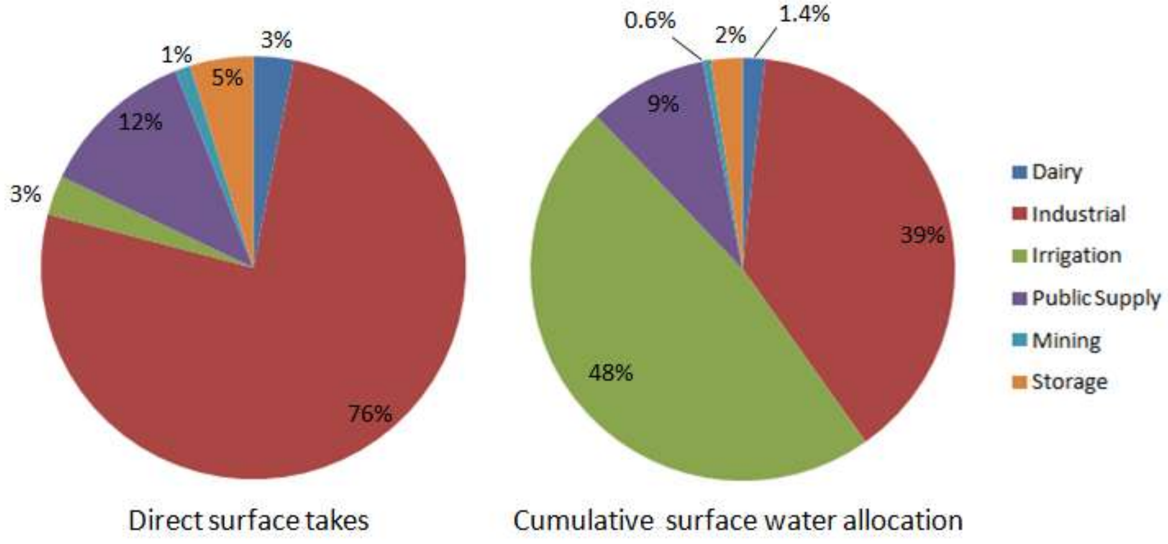

Figure 17. Percentage of surface water allocation for consumptive use in the Mataura catchment by usage category, with and without inclusion of stream depletion effects

3.2.2. Groundwater Allocation

As previously noted, groundwater allocation in the Mataura catchment has increased significantly over the past 10 years, primarily driven by an increase in pasture irrigation. **Figure 18** plots the location of current consented groundwater takes in the Mataura catchment and illustrates clustering of large-scale takes (>2000 m^3/day) along the riparian margin of the Mataura River through the middle and upper reaches of the catchment, and in the Edendale groundwater zone in the lower catchment.

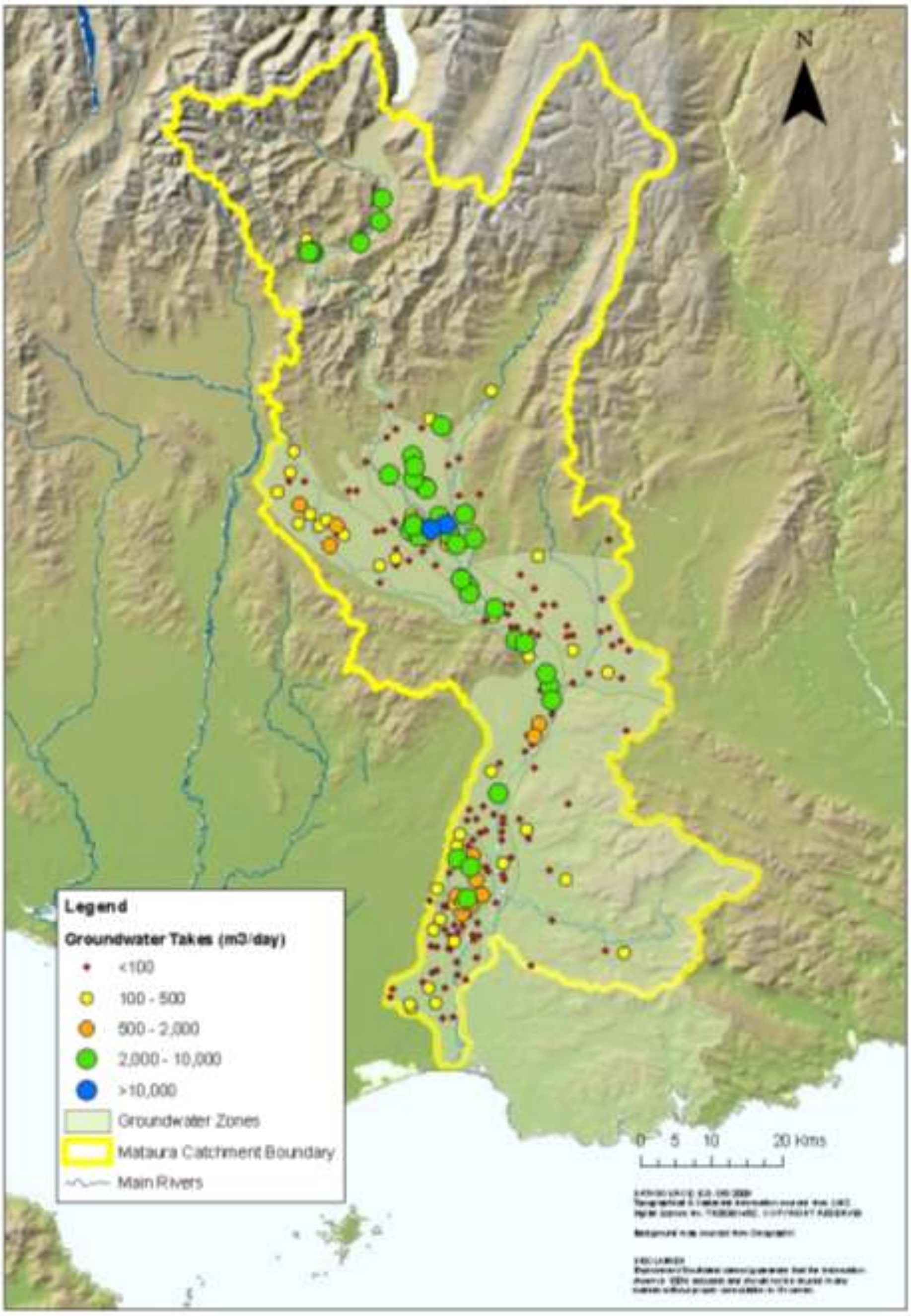

Figure 18. Location of current (2010) consented groundwater takes in the Mataura catchment

Table 3 provides a listing of current (2010) groundwater allocation in the Mataura catchment. Total groundwater allocation in terms of instantaneous and daily abstraction is shown for each groundwater zone along with seasonal allocation allowing for calculated stream depletion effects. The data show the most highly allocated aquifers systems are the Edendale groundwater zone (primarily industrial supply and horticultural irrigation), the Knapdale groundwater zone (pasture irrigation and public supply) and the Riversdale groundwater zone (pasture irrigation).

The potential magnitude of stream depletion effects for groundwater takes along the riparian margin of the Mataura River is particularly evident in the Waipounamu groundwater zone where approximately 78 percent of groundwater allocation is classified as surface water allocation under RWP Policy 29. Overall, approximately 31 percent of total consented groundwater abstraction is included in the cumulative surface water allocation for the Mataura River.

Table 3. Current (2010) groundwater allocation in the Mataura catchment.

Groundwater Zone	Pumping Rate		Seasonal Allocation	
	Instantaneous (L/s)	Daily (m^3/day)	Total Allocation (m^3)	Adjusted for Stream Depletion (m^3)[a]
Cattle Flat	1.0	84	24,411	24,411
Chatton	18	1,581	461,599	461,599
Edendale	414	33,745	5,816,123	5,816,123
Garvie	333	28,800	2,670,780	2,670,780
Knapdale	292	24,695	4,860,420	3,876,880
Longridge	1.9	161	46,954	46,954
Lower Mataura	294	13,147	4,234,116	4,168,860
Riversdale	771	72,122	7,789,723	4,921,474
Upper Mataura	294	25,407	2,482,798	1,101,487
Waimea Plains	83.5	4,592	930,547	930,547
Waipounamu	327	28,266	2,513,369	563,551
Wendon	129.4	11,027	1,083,294	1,083,294
Wendonside	50	4,444	1,591,984	1,591,984
Total	**3009**	**248,071**	**34,506,118**	**27,257,944**

[a] Following the methodology outlined in Policy 29 of the Regional Water Plan

Table 4 provides a breakdown of current allocation in each groundwater zone by usage category. The data show industrial usage is predominately concentrated in the Lower Mataura groundwater zone while irrigation use is primarily distributed across riparian aquifers in the mid to upper catchment as well as the confined Garvie Aquifer underlying the Wendonside Terrace.

Table 4. Groundwater allocation by usage category

Groundwater Zone	Dairy		Industrial		Irrigation		Public Supply		Mining	
	Daily	Annual	Daily	Annual	Daily	Annual	Daily	Annual	Daily	Annual
Cattle Flat	84	24,411								
Chatton	1,581	461,599								
Edendale	1,825	532,923	13,600	4,190,200	16,290	682,050	2,030	410,950		
Garvie					28,800	2,670,780				
Knapdale	1,157	337,844			15,538	1,602,576	8,000	2,920,000		
Longridge	161	46,954								
Lower Mataura	4,171	1,224,955	2,160	581,870	9	771	1,300	416,100	5,508	2,010,420
Riversdale	1,656	483,553			67,766	6,327,970	2,600	949,000	100	29,200
Upper Mataura					25,191	2,482,798				
Waimea Plains	2,242	654,547			2,350	276,000				
Waipounamu	182	53,144			28,084	2,460,225				
Wendon	507	148,044			10,700	935,250				
Wendonside	412	120,304							4,032	1,471,680
Total	13,951	4,080,324	44,560	7,442,850	165,928	8,714,258	13,930	3,610,199	9,8565	3,574,372

Figure 19 compares the relative percentage of total daily and seasonal groundwater allocation for each usage category. The data show that while irrigation accounts for around 80 percent of daily allocation, this total reduces to approximately 51 percent on a seasonal basis. This difference between allocation on a daily and seasonal basis reflects the fact that allocation for irrigation is typically based on an assumption that usage occurs over a restricted duration compared year-round abstraction for industrial and public supply.

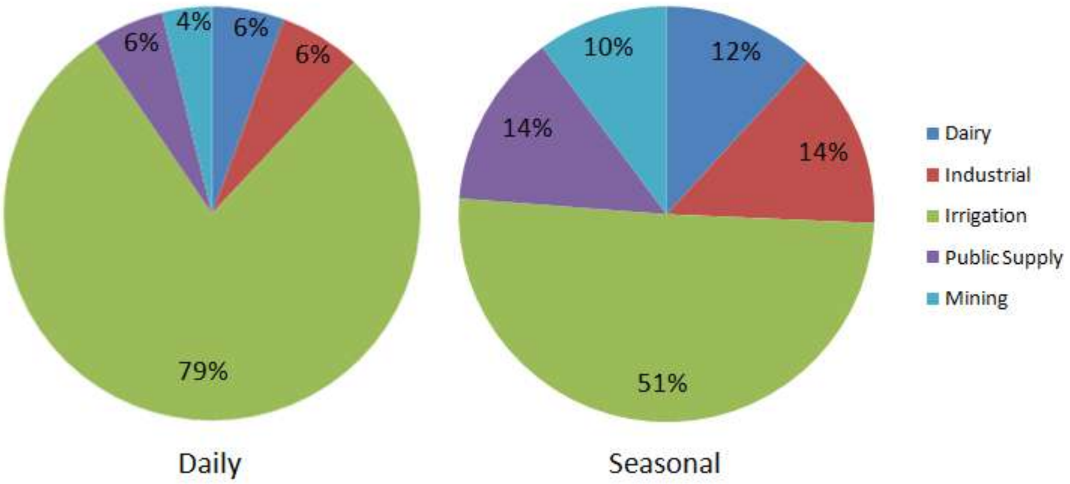

Figure 19. Percentage of groundwater allocation for consumptive use in the Mataura catchment (2010) by usage category in terms of daily and seasonal volumes.

As further illustrated in **Figure 20,** when stream depletion effects are accounted for, the proportion of seasonal allocation for irrigation is further reduced to approximately 40 percent of total allocation. This reflects the location of many large-scale irrigation takes in the highly permeable alluvial gravels along the riparian margin of the Mataura River where groundwater has a direct or high degree of hydraulic connection with surface water.

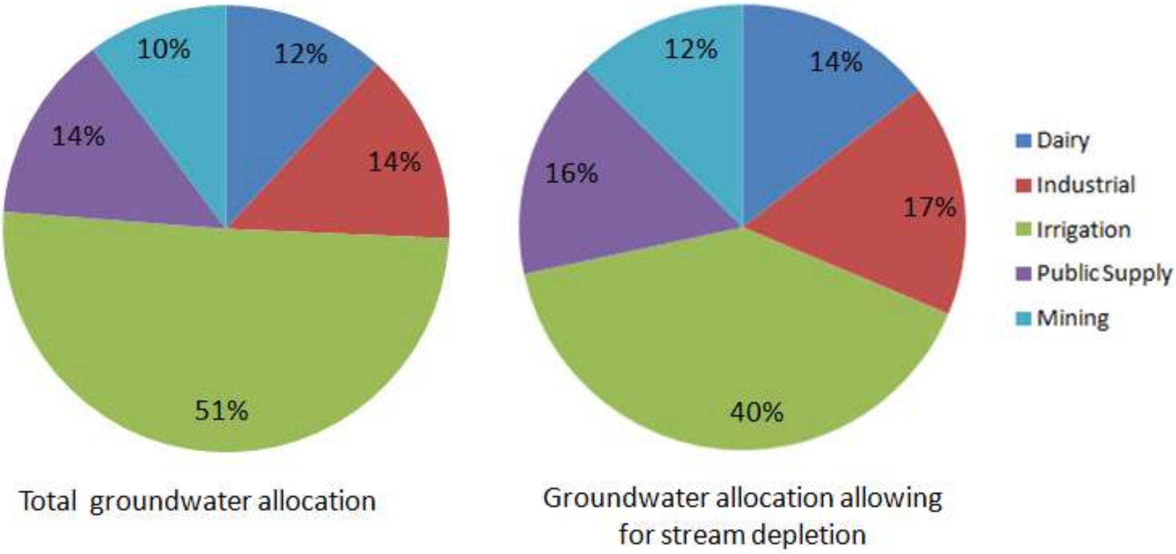

Figure 20. Comparison of the proportion of seasonal groundwater allocation for consumptive use by usage category with and without allowance for stream depletion effects.

3.3. Water Use

A significant proportion of existing surface water and groundwater consents in the Mataura catchment, particularly those granted by Environment Southland over the past 10 years, have conditions requiring the consent holder to record the rate and/or volume of water extraction. This data provides valuable information to assist sustainable management of water resources.

However, a review of available water use compliance information suggests that records of historical water use are incomplete due either to non-supply of data or technical issues associated with data quality. In order to address these issues Environment Southland has initiated an active compliance programme in conjunction with water user groups such as Irrigation Southland to ensure accurate recording of actual water use. Measures undertaken include active compliance enforcement through the issue of abatement notices to individual users for non-supply of data, as well as installation of electronic, and in some cases telemetered, water metering to enable more accurate and timely provision of water use data.

It is noted that in November 2010 the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010 came into force. These regulations, established under Section 360 of the Resource Management Act 1991, require water use to be metered on all water permits greater than 5 L/s. The regulations provide for phased implementation of watering on all takes of between two and six years depending on size and, in conjunction with conditions on existing consents issued by Environment Southland, will require water use to be recorded for all takes >5 L/s by 2016.

The following section provides a summary of available water use data in the Mataura catchment based on a quality controlled water use compliance data set compiled as part of a recently completed State of the Environment report (Wilson, 2011). This data set includes available water meter records for large-scale groundwater takes in the Mataura catchment. More limited information is available to quantify actual surface water abstraction.

Figure 21 provides a summary of actual groundwater use in the Mataura catchment since 2000. These figures cover a majority of large-scale groundwater takes located in the catchment excluding resource consents for dairy supply and comprise three components:

- Actual water use - cumulative groundwater abstraction from consents for which meter records were supplied to Environment Southland;
- Unused allocation - the portion of seasonal allocation not used by consents for which meter records were supplied to Environment Southland;
- Unknown water use - Consents for which no usage records were supplied to Environment Southland. Unknown water use comprises a proportion of actual use and unused allocation.

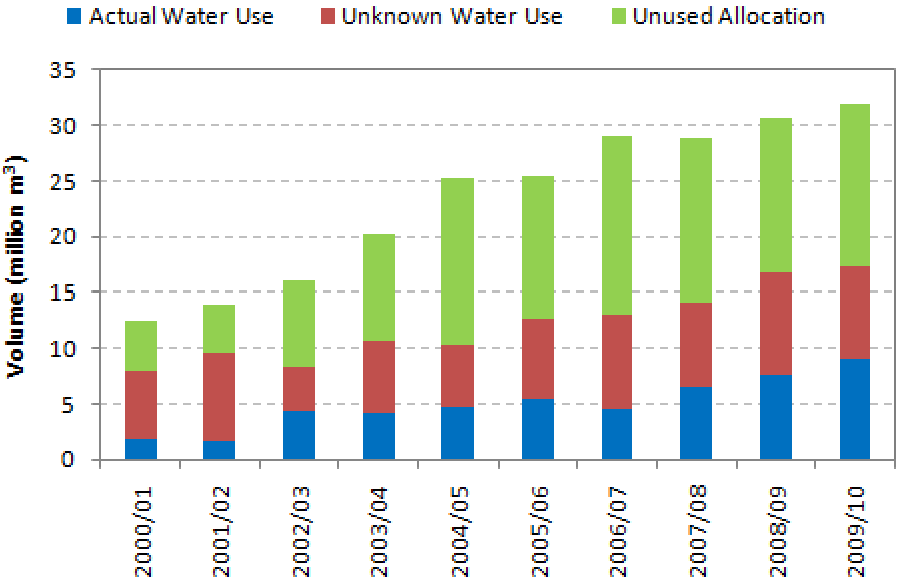

Figure 21. Groundwater use in the Mataura catchment 2000/01 to 2009/10

The shape of the graph reflects the overall increase in groundwater allocation since 2000. Over this period actual groundwater use ranged from 1.8 million m^3/year in 2000/01 to 9.5 million m^3 in 2009/10, averaging 22 percent of seasonal allocation for those consents where water use was recorded. Actual water use peaked at approximately 30 percent of seasonal allocation in the 2009/10. Over this period unknown water use ranged from 25 to 60 percent of total allocation.

Figure 22 shows temporal trends in water use in the Riversdale groundwater zone, the most highly allocated aquifer system in the Mataura catchment. A majority (approximately 98 percent) of total allocation from the Riversdale groundwater zone is for pasture irrigation. The data show actual use climbed steadily from 2000/01 through to 2007/08, before levelling off in the range of 3.2 to 3.6 million m^3 over the past three years (approximately 42 to 46 percent of total allocation). Also noted is the decreasing proportion of unknown water use due to more active compliance by Environment Southland.

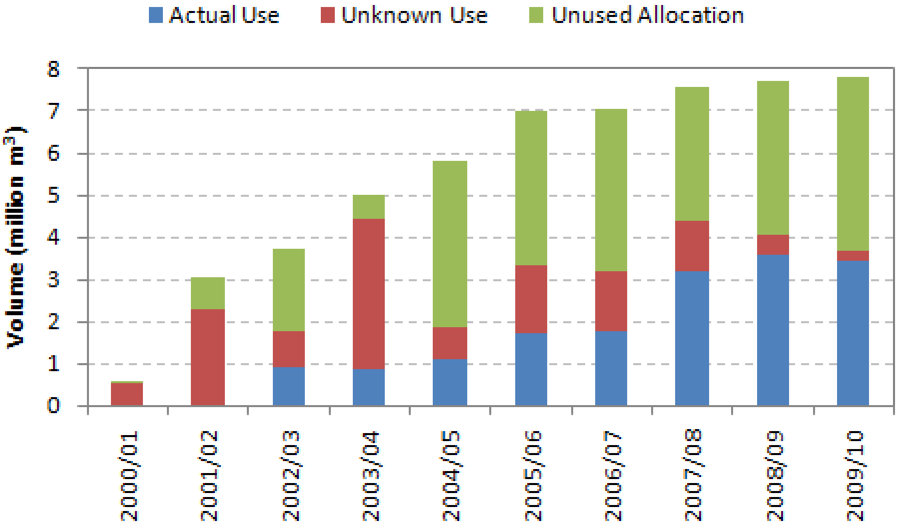

Figure 22. Water use in the Riversdale groundwater zone, 2000/01 to 2009/10

Figure 23 shows a similar plot from the Edendale groundwater zone in the lower catchment. This aquifer system is extensively utilised for industrial supply at the Fonterra Edendale dairy factory. Recent years have also seen a significant increase in the volume of water allocated for horticultural irrigation and public water supply from this aquifer system. The data show actual use increased steadily from approximately 1.4 million m^3 per year in 23000/01 to 2.3 million m^3 per year in 2009/10, representing between 35 to 45 percent of total allocation. The decline in actual use as a proportion of total allocation since 2008/09 reflects the granting of a variation to an existing consent to support an expansion of processing capacity at the dairy factory. It is expected the percentage of actual water use will increase over time as installed capacity of the plant is more fully utilised.

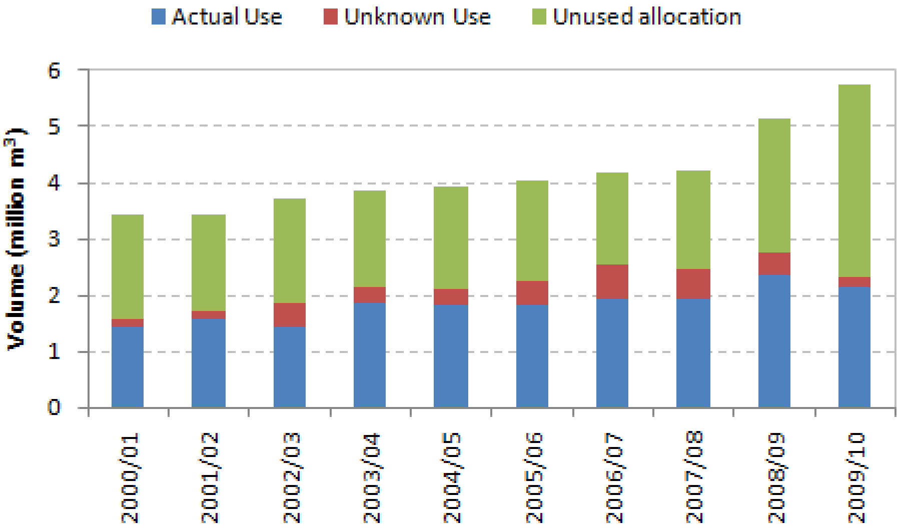

Figure 23. Water use in the Edendale groundwater zone, 2000/01 to 2009/10

3.3.1. Irrigation

Irrigation is the largest single water use in the Mataura catchment. The following section provides analysis of available compliance data to illustrate the nature of irrigation water use in the catchment.

Duration of Abstraction

The duration of abstraction is an important parameter for both managing allocative efficiency (i.e. ensuring the volume allocated to any individual consent matches actual use) and estimating potential environmental effects associated with groundwater abstraction. At the current time seasonal allocation for resource consent for pasture irrigation are typically based on an assumption of a nominal 150 day (i.e. November to April) irrigation season. Similarly RWP Policy 29 calculates potential stream depletion effects over a pumping duration of up to 150 days (depending on classification of hydraulic connection) and a similar duration is typically used for assessment of well interference effects.

Figure 24 shows the average and maximum duration of abstraction for irrigation consents located in the Mataura catchment based on available metering data. The data show that the average duration of abstraction within a single irrigation season typically ranges between 60 and 70 days, reducing to less than 40 days in wetter seasons such as 2004/05 and 2006/07. The maximum duration of abstraction is generally less than 120 days.

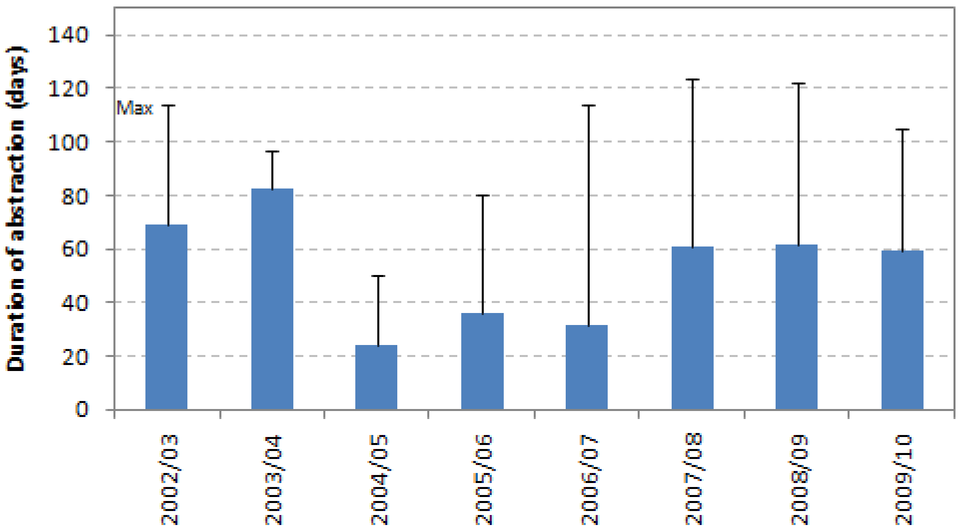

Figure 24. Average and maximum duration of abstraction for irrigation resource consents in the Mataura catchment

Figure 25 provides a plot of abstraction duration for individual resource consents recorded between the 2007/08 and 2009/10 irrigation seasons. Excluding consents not operational in any given season, the data show a relatively normal distribution centred between 70 to 90 days duration with typically less than 15 percent of consents exceeding 100 days abstraction in any given season (including the relatively dry 2007/08 summer).

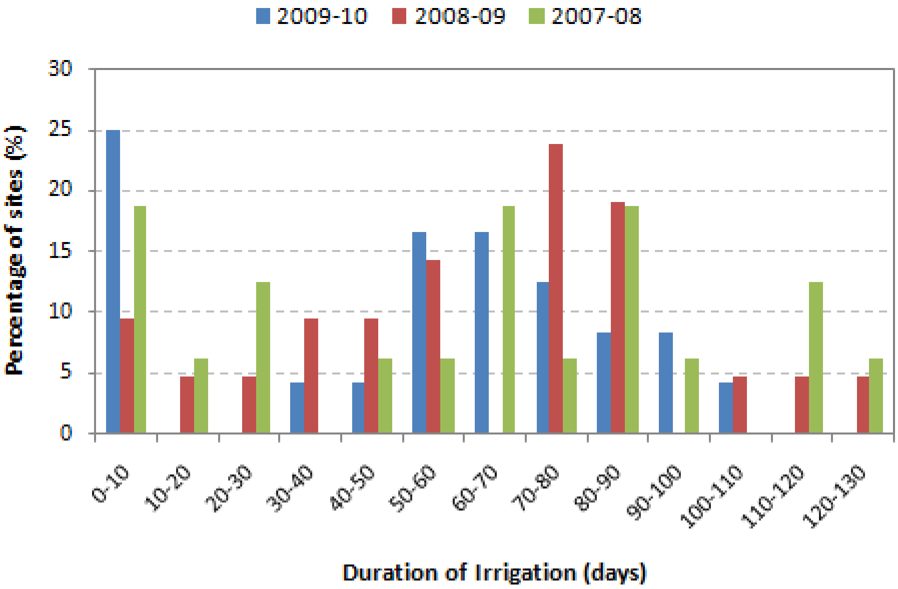

Figure 25. Duration of abstraction for individual resource consents in the Mataura catchment over the 2007/08 to 2009/10 irrigation seasons

<u>Seasonal Use</u>

As previously discussed, seasonal use by individual irrigation consents is typically lower than seasonal allocation. **Figure 26** shows average use by irrigation consents is influenced by seasonal water balance with a minimum seasonal use of around 15 percent of allocation during the relatively wet 2004/05 season increasing to 46 percent of allocation during the 2007/08 year.

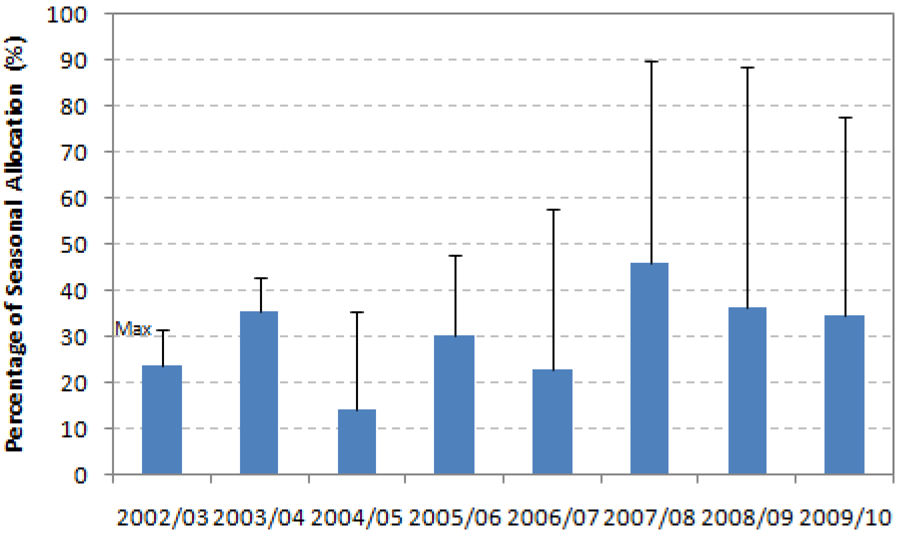

Figure 26. Average and maximum seasonal use for irrigation consents in the Mataura catchment

Figure 27 shows seasonal use for a selected resource consents in the Mataura catchment between the 2006/07 and 2009/10 irrigation seasons. The data indicate seasonal water use is highly variable both between individual consents in any given irrigation season as well as between seasons for individual consents. Overall, the data suggest that actual water use is typically well below seasonal volumes except for selected individual consents with water use highly dependent on management practices adopted on individual properties.

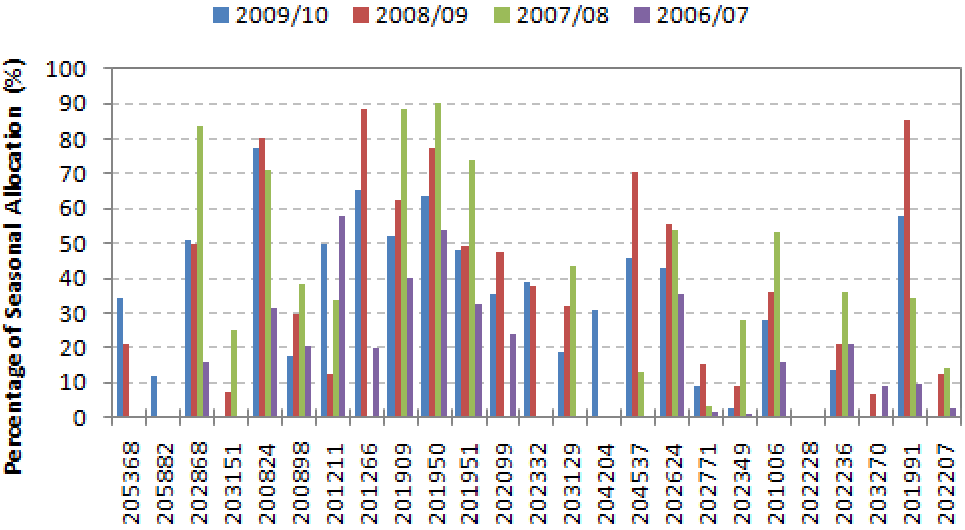

Figure 27. Seasonal use by individual resource consents for the 2006/07 to 2009/10 irrigation seasons

Application Depth

Figure 28 shows the average and maximum depth of irrigation based on available water use data in the Mataura catchment. Calculation of application depth is based on seasonal usage over the irrigated area proposed in individual resource consent applications[10]. The data show the average depth of irrigation varies between individual seasons in response to variations in climate ranging from approximately 45 mm in 2004/05 to 130 mm in 2007/08. Maximum application depths for individual consents range from 125 millimetres to 315 mm.

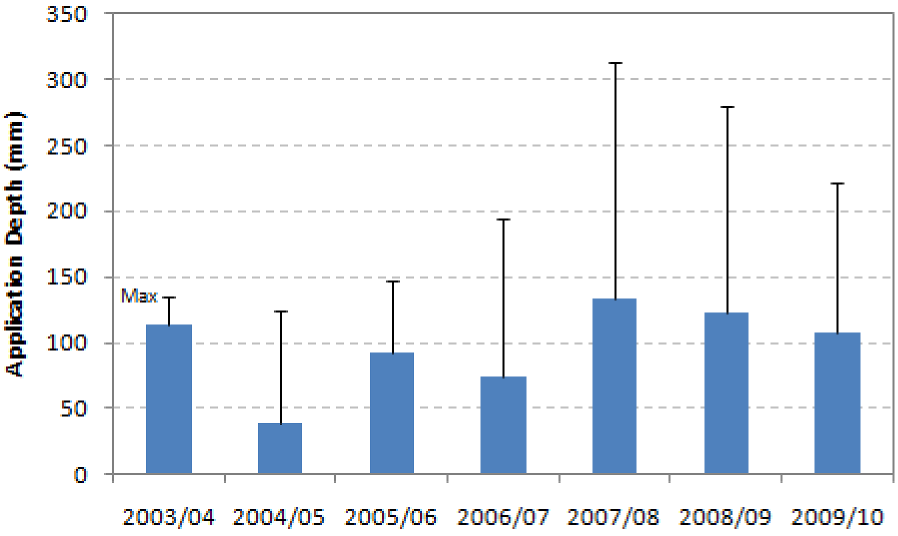

Figure 28. Average and maximum seasonal application depths

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[10] Actual irrigated area is may be less than nominal areas proposed in individual resource consent applications which typically define the maximum area that may be irrigated.

Figure 29 shows application depths for selected resource consents in the Mataura catchment between the 2006/07 and 2009/10 irrigation seasons. Again the data highlight appreciable differences in irrigation practice both between individual consents in any given irrigation season as well as between seasons for individual consents. Overall, the data suggest that typical irrigation practice involves application of between 150 to 200 mm per year, although peak usage on individual properties may exceed 250 mm.

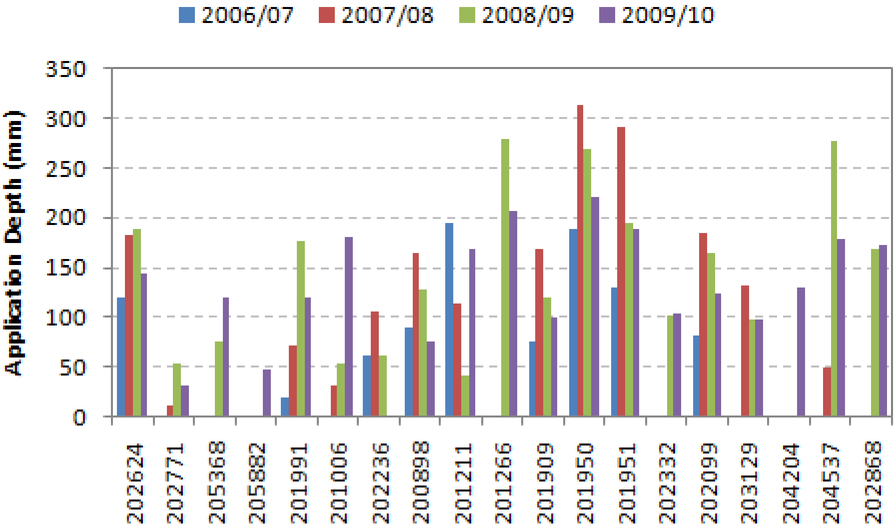

Figure 29. Application depths for individual irrigation consents in the Mataura catchment

Irrigation water use example

Data recorded in the Riversdale area during the 2009/10 season provides a useful illustration of the typical nature of irrigation water use in Southland[11]. Rainfall over this period was characteristic of many summers with average to dry conditions during spring (Sept-Nov) and autumn (Feb-March) interspersed with higher rainfalls during summer (Dec-Jan) and early autumn (April). **Figure 30** shows a plot of monthly rainfall departure at three rainfall sites in the Riversdale area.

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[11] Due to recent improvements in the recording and supply of water use compliance data this period also contains the most comprehensive irrigation water use data set available.

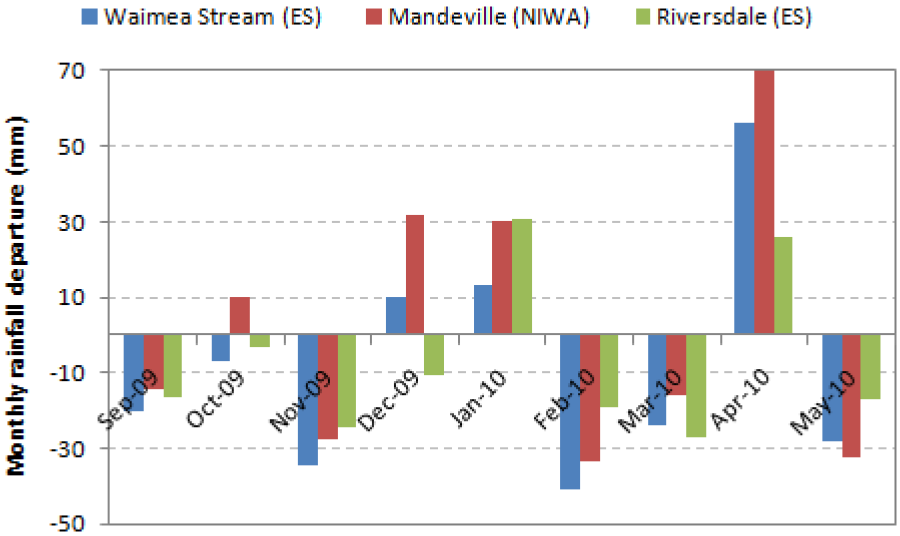

Figure 30. Departure from average monthly rainfall for monitoring sites in the Riversdale area, 2009/10

River flows over this period reflect the rainfall pattern reaching 19.5 m^3/s at Gore (7-day MALF = 17.6 m^3/s) in early December before increasing during December and January (including two high flow events exceeding 300 m^3/s), followed by an extended period of recession during February and March when flows dropped as low as 11.3 m^3/s (close to a 1 in 5 year return period low flow).

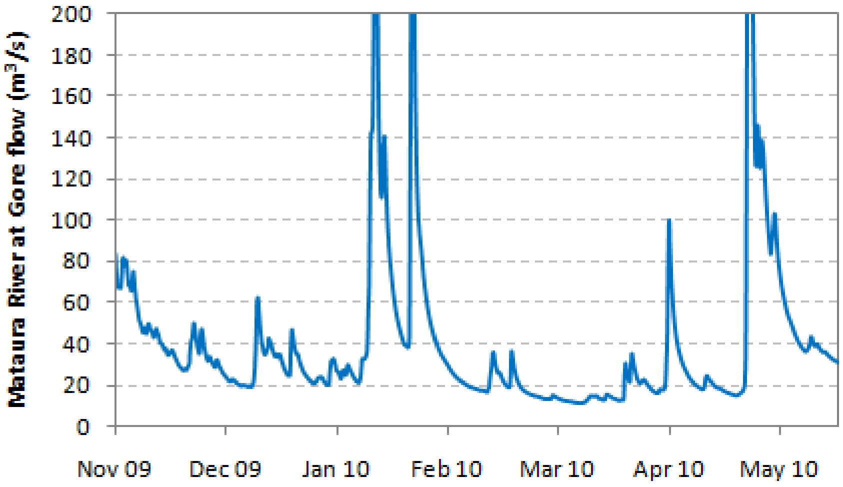

Figure 31. Mataura River at Gore flow (m^3/s), 2009/10

Figure 32 shows the daily pumping record for a selection of resource consents in the Riversdale area during the 2009/10 irrigation season. The figure shows a relatively consistent pattern of irrigation across both dairy and dairy support properties with irrigation commencing in late November 2009 and continued on an intermittent basis until early January. Irrigation then recommenced in late January continuing through February and early March during the period of low rainfall/river flows, before ceasing in mid to late March.

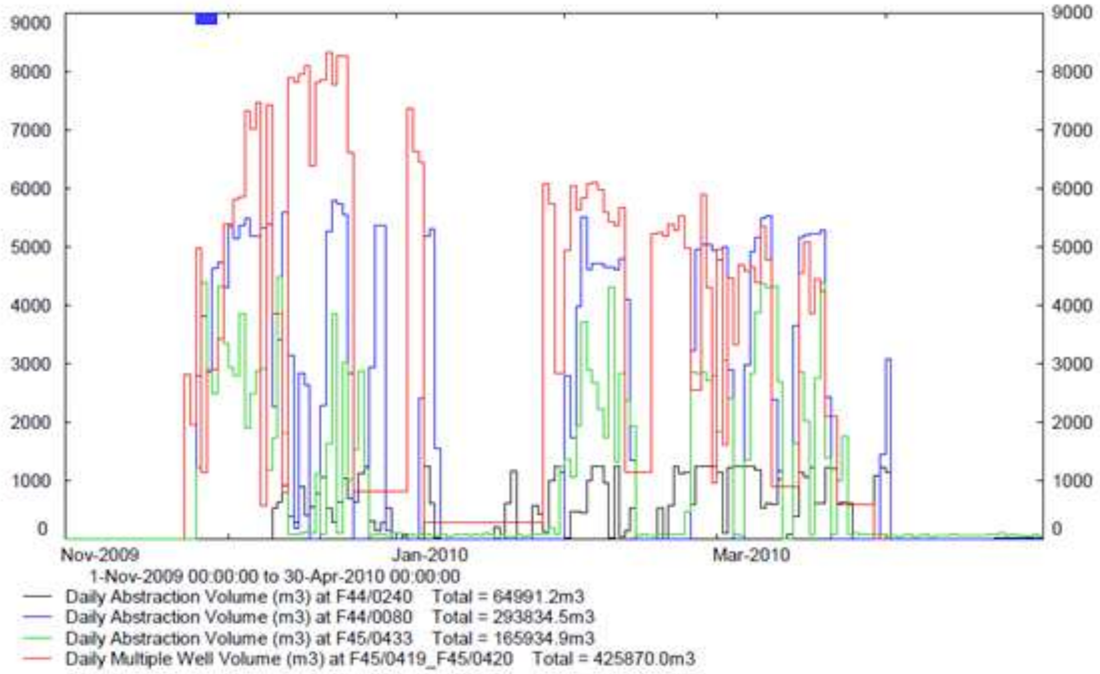

Figure 32. Daily abstraction for resource consents in the Riversdale area, 2009/10

Table 5 provides a summary of irrigation water use data from the 2009/10 irrigation season. Salient points include:

- A majority of consents show relatively consistent timing (generally within a week to 10 days) for the start and finish of the irrigation season.
- For consents where daily abstraction data was recorded, peak daily abstraction ranged from 60 to 100 percent of the consented rate with a significant number of consents having a peak daily abstraction rate between 70 and 90 percent of that specified by consent conditions. This suggests that the maximum daily rate specified for existing consents (typically set on the basis of 4mm/day) is of a similar order to crop requirements;
- Cumulative seasonal use during the 2009/10 season ranged from 18 to 78 percent of consented volumes (typically established on the basis of an application depth between 300 to 350 mm for existing consents) equating to irrigation of between 76 to 221 mm over the nominal irrigated area[12]. The variability in seasonal use suggests that on-farm practice has a significant influence on seasonal water use;
- For consents where daily abstraction data was recorded, the number of days of irrigation ranged between 52 to 98 days, with irrigation occurring for a total of between 80 to 90 days on a number of properties.
- The seasonal average pumping rate (seasonal volume/number of days irrigation) was typically around 50 percent of the peak rate.

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[12] As defined in the initial resource consent application

Table 5. Summary statistics for irrigation consents in the Riversdale area, 2009/10.

Consent No	Allocation (m^3)		2009/10 Irrigation Season						
	Daily	Seasonal	Start Date	Finish Date	Maximum Daily Use (m^3)	Cumulative Volume (m^3)	% of seasonal allocation	Application depth (mm)	Days of Irrigation
201991	3,500	341,250	25/11/09	23/3/10	4,013	197,270	57.8	120	73
202332	720	59,400	20/11/09	15/3/10	667	22,967	38.7	104	52
201211	6,050	589,875	25/11/09	2/4/10	5,782	293,943	49.8	168	72
201951	9,110	888,225	22/11/09	23/3/10	8,330	425,870	47.9	189	89
203129	5,270	513,825	25/11/09	25/3/10	3,570	167,144	32.5	98	80
204204	2,160	210,750	8/12/09	2/4/10	1,253	64,991	30.8	130	80
201006	8,470	825,825	10/11/09	26/3/10	8,330	229,546	27.8	94	81
200824	12,100	875,000	25/11/09	12/3/10	12,162	681,164	77.8	195	98
202099	6,220	606,450	21/11/09	19/3/10		215,200	35.5	123	
200898	7,143	860,000	22/11/09	21/3/10		151,575	17.6	76	
201950	3,750	348,075	20/11/09	20/3/10		221,110	63.5	221	
201909	1,270	152,400	20/11/09	4/3/10		79,497	52.2	99	
204537	3,890	379,350				173,757	45.8	179	

Figure 33 shows a plot of some of the main environmental variables over the 2009/10 irrigation season. The effect of relatively low rainfall during late spring is reflected in the rapid decline in soil moisture from late October through to early December. The data show soil moisture levels were well below field capacity (equal to 38% of the scale shown) by the time most irrigation commenced in late November suggesting that the decision to commence irrigation is based on factors other than maintenance of optimum soil moisture levels.

Similarly, during January 2010, few properties were irrigated despite soil moisture levels remaining well below field capacity. Given the frequent rainfall and relatively cold, unsettled conditions over this period it seems likely that environmental factors other than soil moisture may influence overall management decisions regarding irrigation.

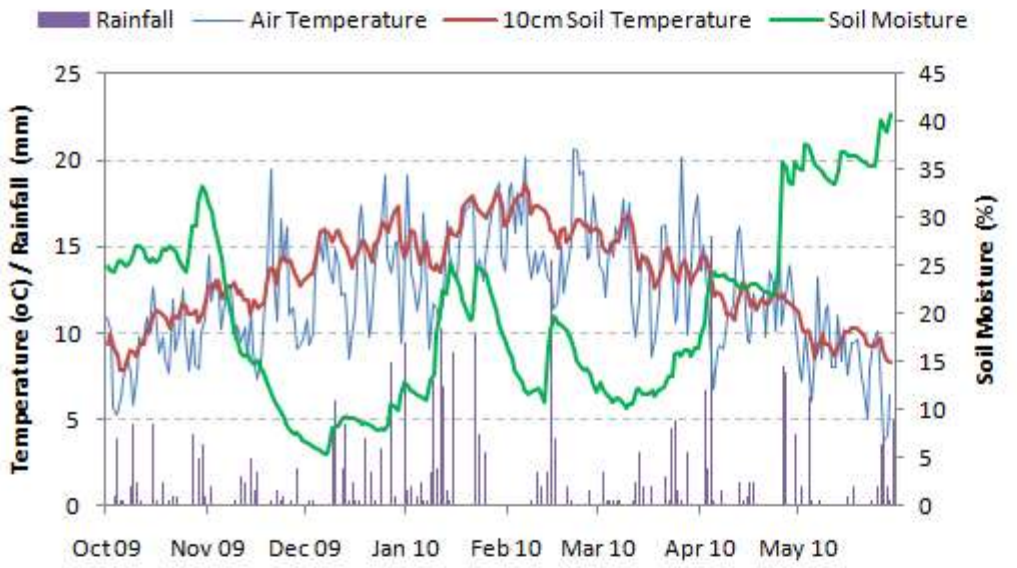

Figure 33. Rainfall, soil moisture, air temperature and soil temperature recorded in the Riversdale area, 2009/10

3.3.2. Permitted Use

Section 14(3)(b) of the RMA allows the taking and use of water for an individual's reasonable domestic needs or the reasonable needs of an individual's animals for drinking water without resource consent provided there are less than minor effects on the environment as a result of the taking or use of the water. The RWP establishes a permitted use threshold for water takes that do not require resource consent of 10,000 L of surface water per day per landholding or 20,000 L of groundwater per day per landholding. All takes exceeding these volumes require resource consent except where a supply was lawfully established as a permitted activity prior to 31 July 2004 and does not exceed rates or volumes of abstraction authorised at that time.

At the current time limited information is available to quantify permitted water use in the Mataura catchment. While it is known that outside of areas serviced by reticulated supplies, groundwater and surface water are extensively utilised for domestic supply and as a source of stock drinking water, the extent and nature of permitted water use is largely unquantified. Previous surveys (e.g. Hamill 1998, Belton et.al 1998) suggest over 50 percent of rural properties utilise groundwater for domestic supply with many others deriving stockwater supplies from groundwater. Groundwater accessed via individual domestic bores is also utilised as the primary source of potable water in townships of Garston, Athol and Riversdale (Balfour, Gore, Mataura, Edendale and Wyndham being serviced by reticulated water supplies). The use of surface water as a source of stock drinking water is unknown but may be declining due to increased use of stockwater reticulation and riparian fencing along rivers and streams.

Overall, it is assumed that although critical to the health and wellbeing of many communities (particularly in rural areas), permitted water use comprises a minor component of overall consumptive water use. For example, Wilson (2011) estimated the volume of water used for domestic supply in the Riversdale groundwater zone to be in the order of 45 m^3/day or less than 0.1 percent of the current consented allocation of approximately 72,000 m^3/day.

4. Factors Influencing Future Water Demand and Availability

The following section provides an overview of a range of factors that have the potential to influence future water demand and availability in the Mataura catchment. These factors include naturally occurring climate variability as well as changes in water demand and availability associated with land use and climate change.

4.1. Climate Variability

Definition of ‘normal’ climate conditions is generally based on an assumption of stationarity whereby climate parameters (such as temperature, rainfall and sunshine hours) vary over the short to medium-term around a long-term average condition. However, analysis of both climate and hydrological records suggest that climate over much of New Zealand is strongly influenced by large-scale changes in atmospheric circulation patterns which occur over a range of time scales (e.g. McKerchar and Henderson (1996), Kidson and Renwick (2002) and McKerchar and Pearson (2003)). Effects of these processes are evident in climate records from the Southland Region which exhibit significant temporal variability, particularly in terms of rainfall, on a multi-decadal timescale.

4.1.1. Short to Medium-Term Climate Variability

The El Niño-Southern Oscillation (ENSO) phenomenon is a source of significant seasonal and inter-annual climate variability across much of New Zealand. ENSO is characterised by a warming (El Niño) or cooling (La Niña) of sea temperatures in the eastern Pacific Ocean off the coast of South America. These changes in sea surface temperatures in turn influence atmospheric pressure and resulting windflow across much of the Pacific area. During El Niño conditions, due to warmer than average sea surface temperatures, surface pressures in the western pacific are high leading in a reduction in the strength of the normal westerly trade winds. Conversely, cool La Niña conditions result in a strengthening of the westerly trade winds. The Southern Oscillation Index (SOI) is a measure of the pressure difference between Darwin and Tahiti and is typically used as the metric for establishing ENSO ‘phase’.

On a more local scale, El Niño conditions are typically characterised by cooler than average sea temperatures around New Zealand and an increase in westerly airflow due to a prevalence of anomalously high atmospheric pressure in the Tasman Sea to the north of New Zealand. During La Niño conditions seas surface temperatures are generally above average with an increase in north-easterly airflow due to the occurrence of high atmospheric pressure anomalies to the east of New Zealand. **Figure 34** shows the generalised pattern of atmospheric pressure anomalies and resulting airflow patterns across New Zealand during El Niño and La Niña conditions.

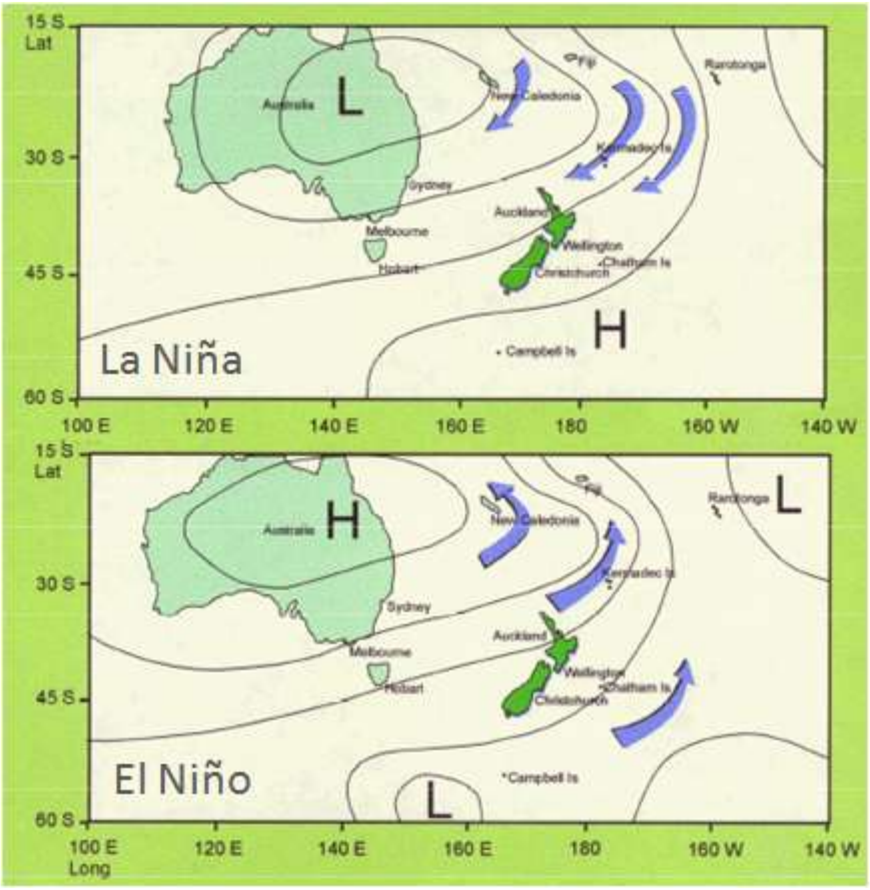

Figure 34. Generalised atmospheric pressure anomalies and resulting airflows across New Zealand during La Niña and El Niño events

Rainfall across New Zealand is strongly influenced by prevailing wind patterns. During El Niño years, New Zealand tends to experience stronger and/or more frequent westerly winds in summer, typically leading to drought in parts of the east coast and increased rainfall in western areas. In winter, winds tend to be more from the south, bringing colder conditions to both the land and the surrounding ocean. In spring and autumn westerly or south-westerly winds tend to be stronger or more frequent. In contrast, La Niña conditions tend to result in increased north-easterly airflow bringing more moist, rainy conditions to the northeast parts of the North Island, and reduced rainfall to the south and south-west of the South Island.

Figure 35 illustrates the effect of El Niño and La Niño conditions on summer rainfall across New Zealand, expressed in terms of the likelihood of above normal rainfall. The maps clearly show the potential for above dry conditions along the east coast of both the North and South Islands is increased during El Niño conditions while southern and western areas are more likely to experience below normal rainfall during La Niña years.

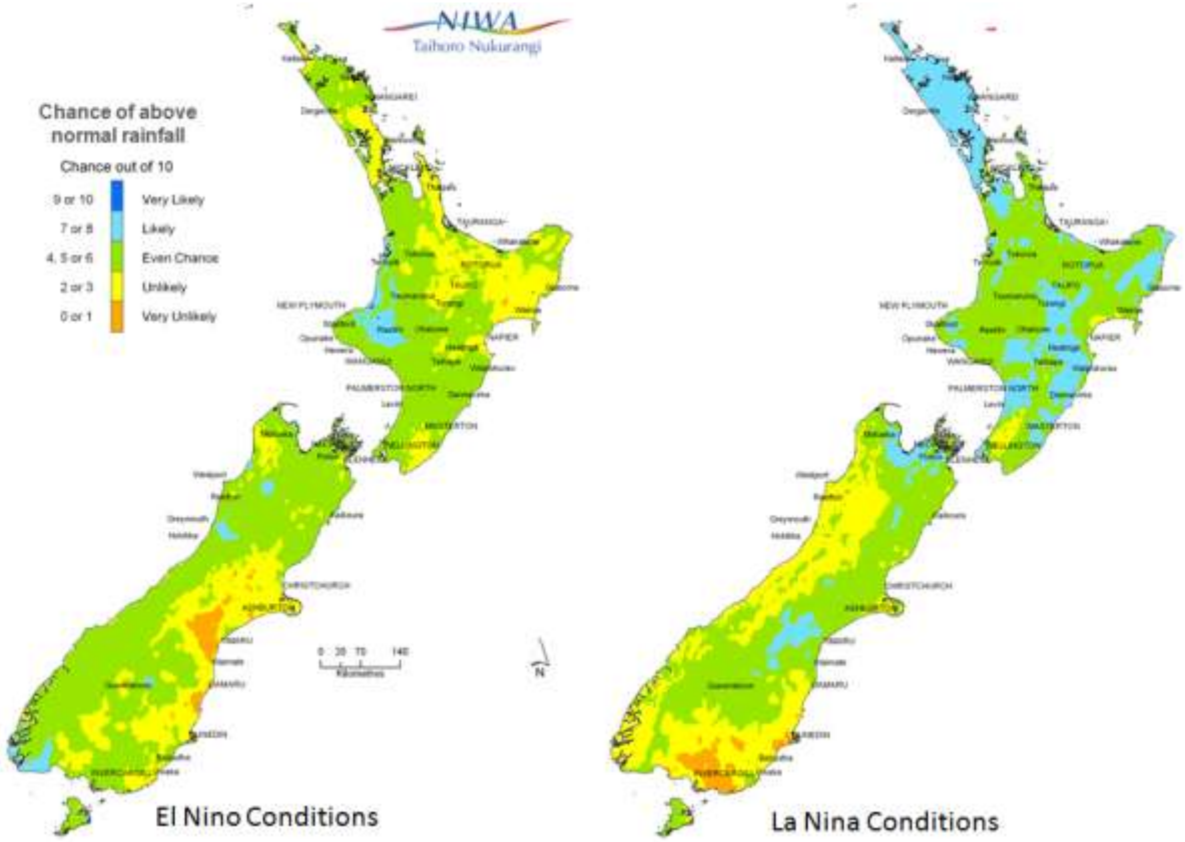

Figure 35. The effects of El Niño and La Niña conditions on the chance of above normal summer rainfall across New Zealand (source: http://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/elnino)

Changes in ENSO phase exhibit a clear influence on inter-annual variation in rainfall in the Southland Region. **Figure 36** and **Figure 37** illustrate the relationship observed between measured SOI values and observed monthly rainfall departure from normal for rainfall sites at Mandeville and Mokoreta. The data are presented in terms of 12 or 15-month moving average values to remove some of the noise apparent at a monthly interval. The data show a clear (inverse) correlation between measured SOI values and seasonal rainfall departure at the two sites with above normal rainfall typically occurring during negative ENSO phase (El Niño) events and below normal rainfall coinciding with positive (La Niña) phase periods. The observed variations in rainfall departure commonly lag the SOI index by between 3 to 6 months, particularly at the Mandeville site. In terms of low rainfall or 'drought' events in Southland, recent analysis by Wilson (2011) (shown in **Figure 38** below), indicates that a majority of historical drought events have occurred during La Niña conditions.

Overall, while variations in ENSO phase do not necessarily explain individual monthly rainfall departures, the occurrence of strong positive (La Niña) or negative phase (El Niño) events appears to exert a significant influence on rainfall in the Mataura catchment at the seasonal to annual scale. On a seasonal basis, available data indicate a significant increase in the potential for above normal rainfall during strong El Niño conditions and drier that average conditions (including 'drought' events) during strong La Niña conditions.

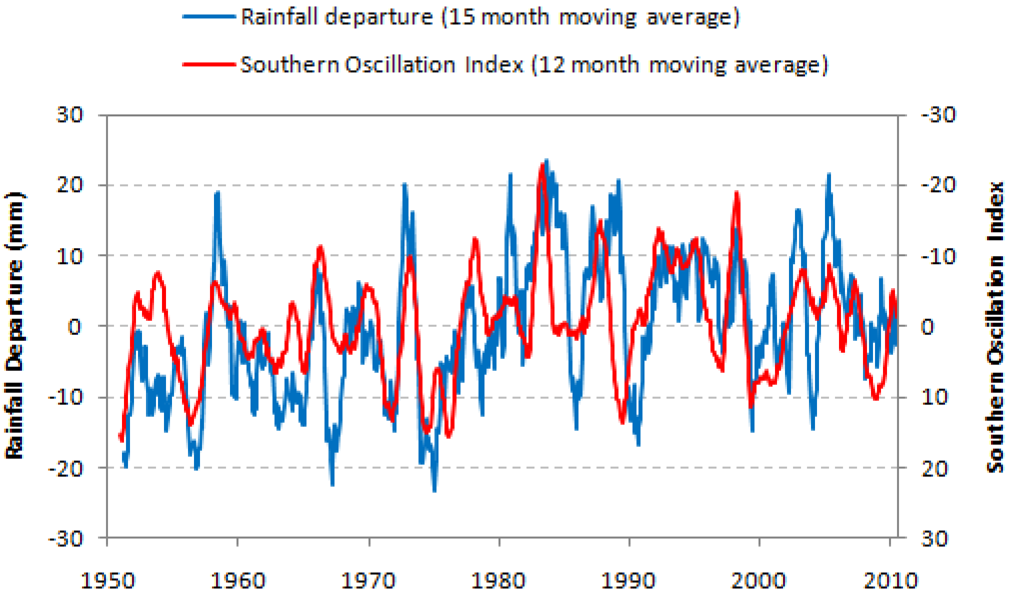

Figure 36. Relationship between rainfall departure at Mandeville and SOI values (note: SOI values inverted to better illustrate inverse correlation) SOI values sourced from http://www.bom.gov.au/climate/current/soihtm1.shtml

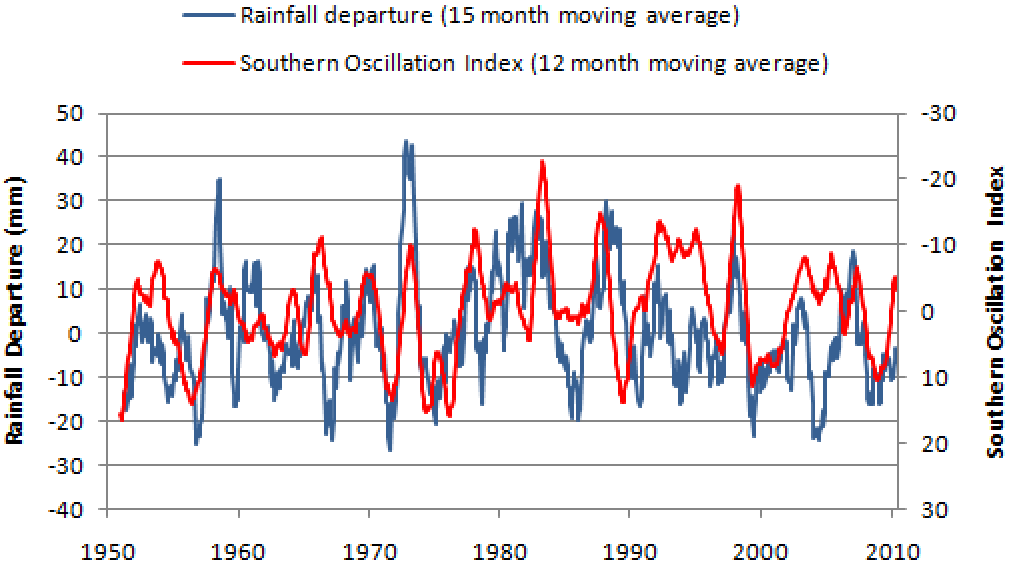

Figure 37. Relationship between rainfall departure at Mokoreta and SOI values (note: SOI values inverted to better illustrate inverse correlation) SOI values sourced from http://www.bom.gov.au/climate/current/soihtm1.shtml

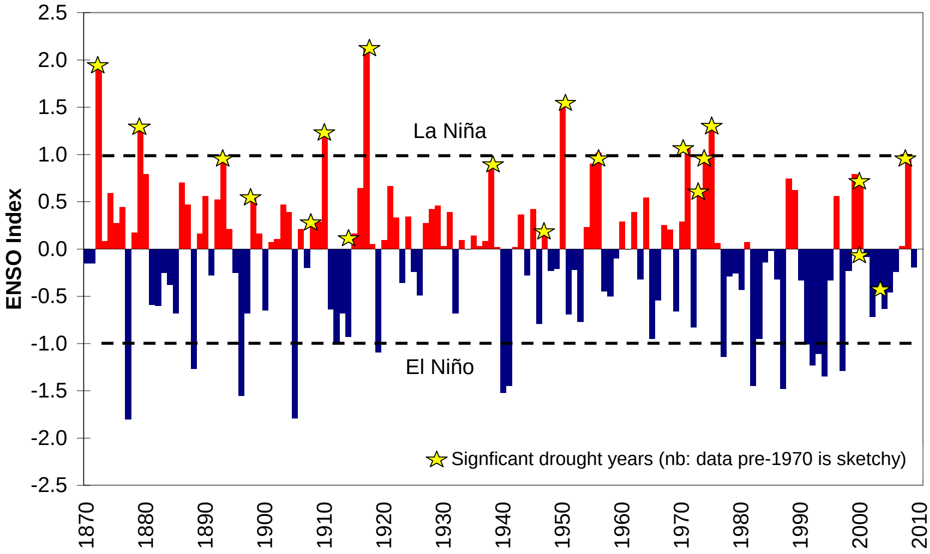

Figure 38. Time series plot of ENSO phase and significant drought events in the Southland Region (from Wilson, 2011)

4.1.2. Decadal-scale climate variability

Possibly of greater significance in terms of potential future water demand and availability than individual El Niño/La Niña events are decadal-scale climate variations which are observed in historical climate (particularly rainfall) data from the Southland Region. These changes have been associated with a phenomenon termed the Interdecadal Pacific Oscillation (IPO) which influences seas surface temperatures and atmospheric circulation patterns across a significant portion of the Pacific region. Shifts in the IPO between the warm (positive) and cool (negative) phases essentially modulate the ENSO cycle and tend to occur every 20 to 30 years. Warm (positive) phases of the IPO tend to associated with an increase in the frequency of El Niño events, while cool phases typically result in more frequent La Niña conditions (Salinger et al, 2001).

As illustrated in **Figure 39**, four phases of the IPO have been identified during the 20th and early 21st centuries; a positive phase occurring from the early 1920's through to the mid-1940's, a negative phase during from 1946 to 1977, another positive phase from 1978 to 1998 with a indications of a return to the negative phase post-1999. During periods of positive phase IPO, rainfall totals, rainfall intensity, flood size and low flow magnitude tend to be significantly greater in Southland than during periods of negative phase IPO (McKerchar and Pearson, 2003).

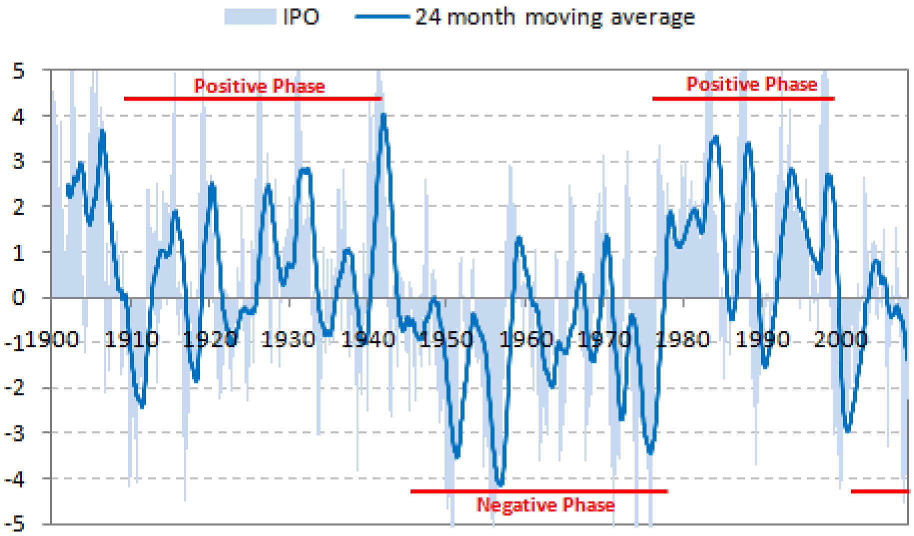

Figure 39. IPO phase 1970 to 2008 (source: www.iges.org/c20c/IPO_v2.doc)

Changes in IPO phase and consequent effects on the frequency of La Niña and El Niño conditions are observed to influence temporal rainfall patterns across New Zealand. **Figure 40** compares mean annual rainfall totals between 1978 and 1998 with those recorded between 1957 and 1977 and shows that rainfall increased across the south and west of the country and decreased along the east coast and in northern New Zealand either side of the 1977/78 IPO phase shift.

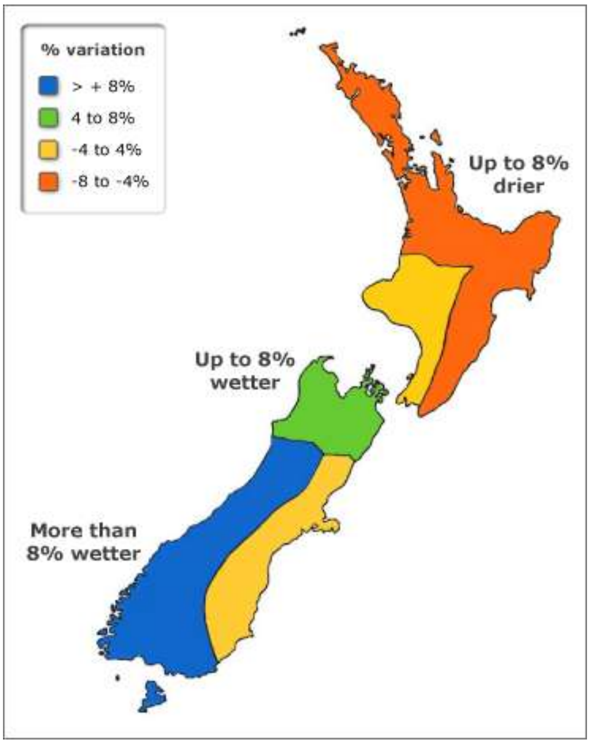

Figure 40. Comparison of mean annual rainfall 1978-98 compared to 1957-77 (source: http://www.teara.govt.nz/en/climate/3/6)

In the Southland Region long-term rainfall records from the Mataura catchment exhibit variability consistent with temporal changes in the IPO index. **Figure 41** plots decadal average annual rainfall totals for four long-term rainfall sites in the Mataura catchment. These data show a clear increase in average rainfall during the 1980's compared to the preceding three decades. Since this time summer rainfall totals declined during the 1990's before reaching totals over the past decade similar to those recorded pre-1980. Temporal variations in seasonal rainfall totals show a similar pattern with totals during the 1980's and 90's appreciably higher than preceding and subsequent decades. These variations are particularly pronounced in summer (December to February) rainfall which increased by up to 50 percent during the 1980's and 90's.

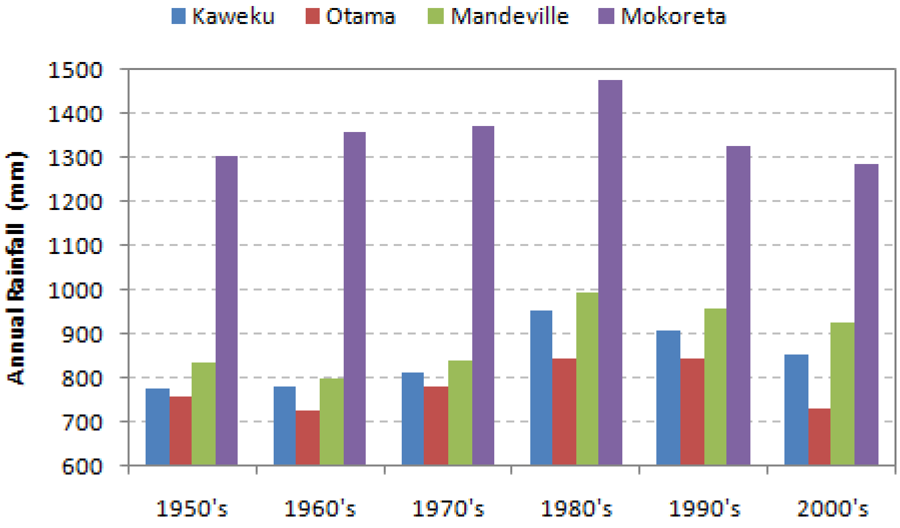

Figure 41. Decadal average summer (Dec-Feb) rainfall totals at four sites in the Mataura catchment

Figure 42 shows a plot of cumulative monthly departure in monthly rainfall at the four sites with the longest continuous rainfall records in the Mataura catchment. Again the data match the IPO cycle and show above average rainfall (positive slope on the graph) from 1930 to the mid-1940's, and again between 1977 and the mid to late 1990's, with below average rainfall occurring from the mid-1940's to the late 1970's and again post 2000.

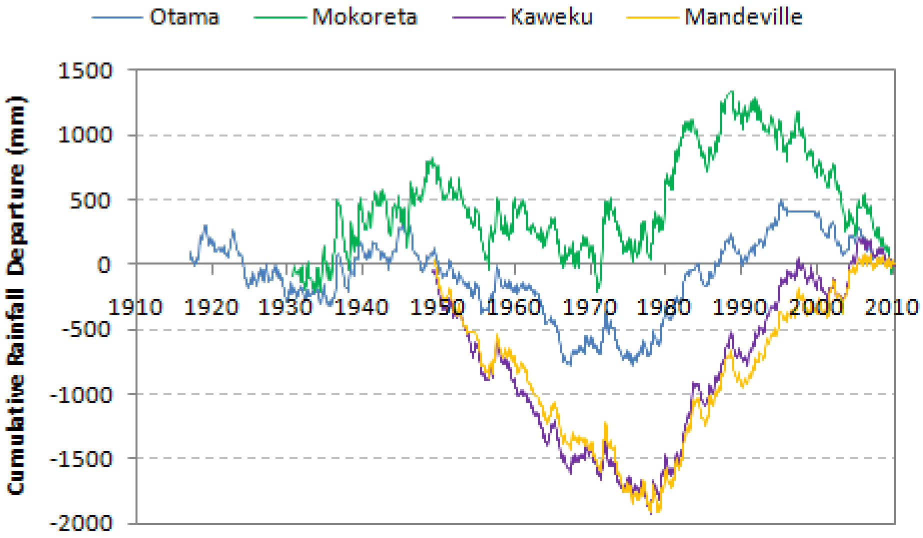

Figure 42. Cumulative departure in mean monthly rainfall at Otama (I58981), Mandeville (I68081), Kaweku (I58961) and Mokoreta (I69411)

Figure 43 illustrates the effect of the observed temporal rainfall variability on overall water balance (rainfall minus evapotranspiration) in the Mataura catchment over the period 1951 to 2010 based on rainfall at Mandeville and evapotranspiration at Gore. The figure shows relatively consistent drier than normal conditions (negative slope) from the 1950's through to the late 1970's followed by consistently wetter than normal conditions (positive slope) through to the late 1990's. Interesting, this analysis suggests that overall water balance has been close to the long-term average (no slope) since 2000 suggesting that conditions over this period, although drier than the preceding two decades, are not as dry as those experienced during the 1950's to late 1970's.

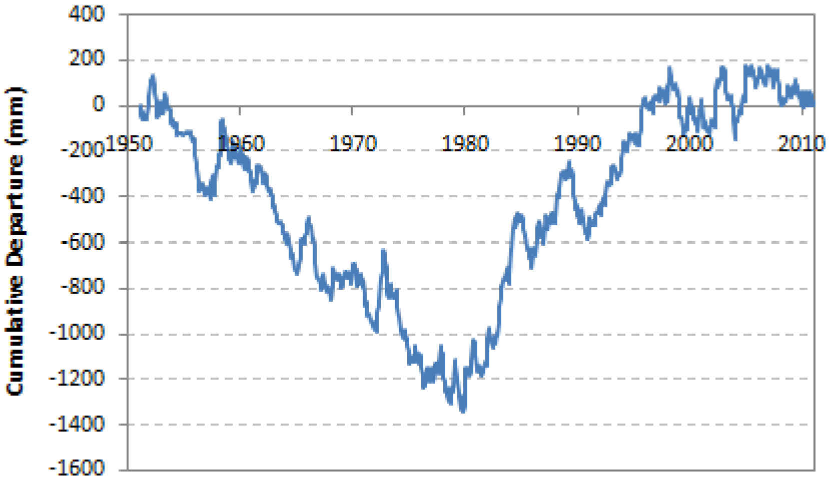

Figure 43. Cumulative departure in monthly water balance (rainfall - evapotranspiration) calculated for Mandeville, 1951 to 2010

Other climate parameters (mean air temperature, evapotranspiration) show a less obvious pattern of temporal variability. The primary temporal trend in these data is an overall increase in both mean air temperature (0.1 °C/decade) and evapotranspiration (1.2 mm/decade) over the period 1950 to 2010 more consistent with climate change effects discussed in the following section.

Overall, analysis of available climate data indicates that rainfall in the Mataura catchment is strongly influenced at an annual to decadal scale by large-scale changes in atmospheric circulation which occur across the Pacific Region. These natural variations are likely to exert a significant influence on future water demand and availability in the Mataura catchment particularly as current indicators suggest a return to drier than average conditions over the short to medium-term.

4.2. Climate Change

A detailed assessment of the potential impacts of climate change on rainfall, river flow and irrigation demand to 2050 was undertaken for the Stage 1-3 report of the Southland Water Resources Study (Lincoln Environmental and MWH, 2003), applying results of two Global Climate Models (CSIRO9 and HadCM2) to the Oreti catchment. Key findings of this assessment include:

- Increases in annual rainfall of between 1 to 2 percent (CSIRO9) and 7 to 13 percent (HadCM2);
- An increase of approximately 1 °C in mean monthly temperature;
- Relatively small increases in wind run; and,
- An increase in average annual evapotranspiration of approximately 4 percent.

Application of the modelling results to the Oreti catchment predicted:

- Under the CSIRO9 model, small increases in the modelled summer and autumn flows (~10 percent) and corresponding small decreases in winter and spring flows;
- Under the HadCM2 scenario moderate increase in spring, summer and autumn flows (~15 to 20 percent), a small increase in winter flows (~10 percent) and an overall increase in long-term average flow of approximately 15 percent; and,
- Potential changes in irrigation demand ranging from no change at Lumsden thorough to a 15 to 17 percent reduction at Invercargill.

Overall, the 2003 assessment indicated that the impacts of climate change until 2050 were likely to result in a slight reduction in agricultural drought frequency and severity in the Southland Region.

More recent analysis of potential climate change impacts include the Intergovernmental Panel on Climate Change 4th Assessment Report (IPCC, 2007) and MfE (2008) which compare data derived from a number of global climate models against a 1990 baseline (using 1980-99 average data) for a range of future emissions scenarios[13]. Downscaled results of these assessments are generally consistent with the 2003 analysis and project that over the period to 2040 in Southland:

- Average temperatures will increase between 0.6 to 1.2 °C (range 0.1 to 1.9 °C);

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[13] A useful summary of emissions scenarios as well as the modelling process and results can be found at http://www.niwa.co.nz/our-science/climate/information-and-resources/clivar/scenarios

- Annual precipitation will increase by between 2.5 to 5 percent;
- The frequency and magnitude of extreme rainfall events is likely to increase; and,
- Westerly airflows are projected in increase during winter and spring and decrease during summer and autumn with an overall increase of approximately 10 percent in the westerly airflow component.

Table 6 presents projected variations in seasonal and annual temperature and rainfall for the Southland Region calculated for a range of IPCC emissions scenarios (B1, A1T, B2, A1B, A2 and A1FI). It is noted that while projected increases in temperature of the order of 0.9 °C +/- 1 °C are relatively consistent across all seasons, model simulations project a comparatively wide range of possible changes in rainfall. **Figure 44** and **Figure 45** show the spatial distribution of projected changes in rainfall and temperature to 2040 associated with potential climate change effects.

Table 6. Average projected changes in seasonal and annual rainfall and mean temperature from 1990 to 2040 (upper and lower estimates in brackets) compared to the 1990 (1980 to 1999 baseline)[a]. From MfE (2008)

Parameter	Units	Summer	Autumn	Winter	Spring	Annual
Rainfall	% change	-2 (-44, 27)	2 (-31,19)	18 (1, 51)	13 (0, 47)	7 (-12, 29)
Mean Temperature	°C	0.9 (0, 2.4)	0.9 (0.1, 1.9)	0.9 (0.2, 2.0)	0.7 (-0.1, 1.7)	0.8 (0.2, 1.9)

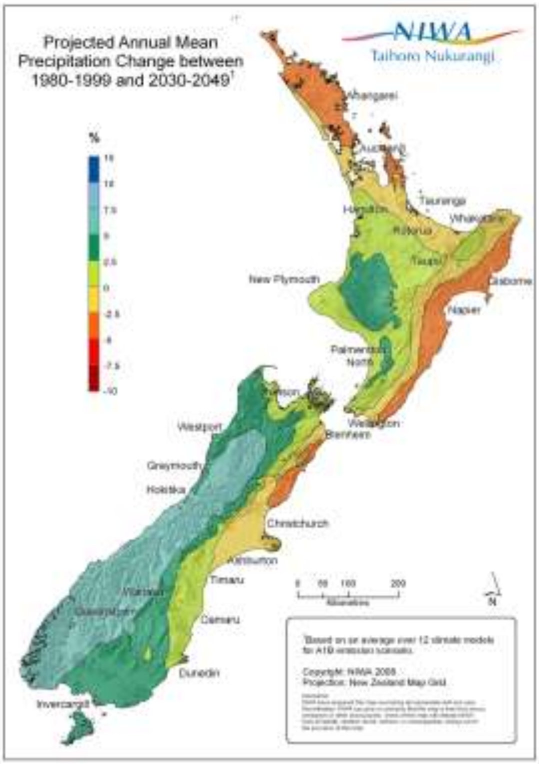

Figure 44. Projected changes in rainfall across New Zealand 1990 to 2040 (Source: http://www.niwa.co.nz/__data/assets/image/0008/74717/prann2040_hs2.png)

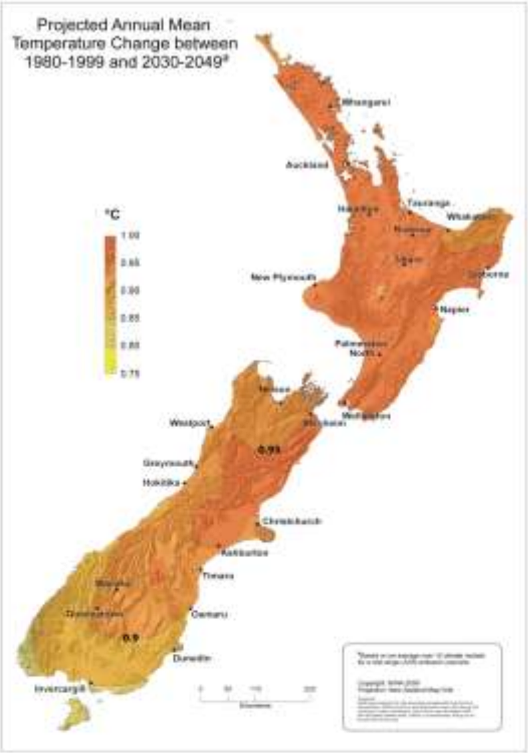

Figure 45. Projected changes in mean temperature across New Zealand 1990 to 2040 (Source:http://www.niwa.co.nz/__data/assets/image/0003/103656/Ann_temp_2040.png)

Overall, projected impacts of climate change indicate that the Southland Region will experience warmer temperatures over the next 30 years accompanied by an increase in westerly airflows and higher rainfall. Changes in temperature and wind run are also likely to result in a net increase in evapotranspiration, possibly of the order of that observed over the past 50 years.

In terms of agricultural water demand, increased water requirements for irrigation or alternative crop/land use types due to increases in temperature and evapotranspiration are likely to be at least partially offset by increased rainfall, except if changes in rainfall occur closer to lower bound projections.

However, in all except the most extreme modelled results changes in water demand and availability resulting from climate change are likely to be significantly less than natural variability resulting from ENSO effects and longer-term variation in atmospheric circulation. Potential impacts of climate change on these processes are uncertain.

4.3. Drivers for uptake of water for irrigation

Expansion of pasture irrigation has resulted in a significant increase in the volume of water allocated for consumptive use in the Mataura catchment over the past decade. Although commonly interpreted to be largely driven by financial drivers, this transition to irrigation is potentially associated with a wide range of factors which are discussed in the following section.

Overall, the uptake of irrigation is based on the costs and benefits that the farmer or potential investor perceives. This may have a number of characteristics including:

- ***Difference between productivity under dryland and irrigated land* –** the key driver of irrigation is the difference in ability to produce product under dryland farming conditions vs. irrigated conditions. Considerable attention has been paid in this study to modelling both dryland and various irrigated scenarios, because it is the additional productivity that determines the ability to fund the irrigation investment. The difference between irrigated and dryland is determined largely by local climatic conditions, particularly rainfall and evapotranspiration (ET), and to a lesser extent other factors such as temperature and sunshine hours which determine the ability to make use of additional soil moisture. This is examined further in subsequent sections.
- ***Product prices and land use returns* –** even if additional soil moisture is able to produce greater productivity, if the returns from that productivity are not sufficiently high then further capital investment in irrigation is unlikely to be supported. The majority of irrigation development in New Zealand has been driven by the high returns offered by dairying. This is true even of other land uses such as arable, because a significant part of their income is derived from dairy support activities. It is likely that continued growth in Asia and increased demand for animal protein and milk product will mean that the relative returns from dairying will at least be maintained, albeit with some fluctuations. MAF's Situation and Outlook for New Zealand Agriculture and Forestry (SONZAF, June 2010) suggests that the milk solids payout for the season ending May 2014 will be $7.20. A sustained high milk solids payout is likely to be a continuing driver for greater dairy production. Because pastoral agriculture is a water intensive system, this factor probably more than any other is likely to drive the demand for irrigation over the medium term.
- ***Capacity to undertake higher value land uses* –** in many tradition irrigation areas with extended dry periods, it is not possible to undertake high value land uses without irrigation, because the variability of production means that the necessary capital intensity cannot be supported. In these areas the introduction of irrigation tends to be associated with large scale land use change. This is not expected to occur so much in the Southland region, because dryland dairy production is a feasible and profitable, so the gains from land use change are less likely to occur with irrigation.

While much analysis is devoted to analysing the differences in production associated with irrigation, there is little attention to other reasons why landholders invest in irrigation. These other reasons are less tangible, and relate to the perceptions, skills and resources available to the enterprise manager. These other factors that may be important as drivers of irrigation demand include:

- ***Risk aversion or insurance effect*** – typically most people are risk averse. That is to say most people will pay to avoid risk, particularly if the impact of the risk is large and there is little control over the sources of risk. This is the reason why we pay for insurance, even though the cost of insurance on average is greater than the losses we would expect to incur from the insured event. This risk aversion can manifest itself in respect of irrigation, where irrigation is seen as an insurance against adverse climatic events. This risk aversion may not be based solely on the financial impacts, as studies have shown that drought events cause significant stress for farmers. The insurance effect may mean that landholders are willing to pay for irrigation even though the benefits seem marginal or even negative from a purely financial point of view.

- ***Optimisation benefits*** – in other parts of the New Zealand we typically see larger gains from system changes associated with irrigation than from the additional growth that irrigation provides. This is because the irrigation enables greater capital and system intensification than would be possible under a dryland system. In Southland, dryland dairying is undertaken even in the drier parts of the region, but it is likely that the stocking rate and management intensity is lower than optimal to allow for the impact of dry periods on farming operations. However, with the greater certainty around pasture growth associated with irrigation, farmers are able to increase their capital and system intensity closer to the theoretical optimal. Thus the reduction in variability that comes with irrigation has an impact that is greater than just the extra grass grown.
- ***Co-benefits for associated dryland areas*** – it was shown in a study of irrigation in the Opuha dam command area (Harris, 2004), that average stocking rates on dryland associated with irrigated land were greater than on other dryland operations. It is considered that this arose for similar reasons to the previous two noted benefits – that operators were more willing to adopt greater system intensity in the knowledge that there would be some feed available. Anecdotal reporting from that study suggested that the major impact was on certainty around ability to finish lambs for the works during dry periods, reducing the need to sell on a weak store market at times of limited feed. This benefit may occur in the Southland area also, although expected irrigation use for sheep and beef properties was low in this study.
- ***Management benefits*** – a reduction in variability from irrigation can simplify management of an farming enterprise. In a small operation there are typically greater demands for both management and labour than there is time to attend to all the matters required. It is difficult to reflect this type of benefit in the analysis undertaken in this report.
- ***Changing climate*** – as noted earlier it may be that undertaking an analysis over a long period of weather record may not reflect farmers' recent experience of dry periods in the catchment. It may be that the recent experience is of greater relevance for these farmers when making decisions on whether to invest in irrigation. It is noted that the period from 2000 to 2010 has seen a greater number of dry periods than the previous two decades (although possibly a lower frequency of 'drought' events than the early 1950's to late 1970's period).

This combination of factors can mean that the demand for irrigation is greater than would be predicted by a straight analysis of production changes. In the Southland situation this is most likely to be manifested in demand from the higher rainfall and deeper soils than has been predicted here. However, conversely it should also be noted that supply reliability for additional irrigation in some of the scenarios as modelled in **Section 5** is relatively low, particularly through the key December to February period. This would offset some of the perceived benefits from the risk aversion and management benefits from irrigation.

4.4. Afforestation

One specific land use activity which is often cited with regard potential effects on water availability is the replacement of tussock grassland with plantation forestry. Depending on the physical setting, such a change in land cover has the potential to appreciably reduce the volume of runoff from individual catchments.

The potential impacts of afforestation of tussock catchments has been extensively studied in a number of New Zealand catchments (notably the Glendhu catchment in upland east Otago). Results of these studies indicate that runoff in forested catchments can decrease appreciably compared to catchments retaining native tussock cover, primarily as a result of increased canopy interception[14]. In the Glendhu catchment studies, planting of 66 percent of a single catchment in *pinus radiata* resulted in a 27 percent reduction in annual water yield from the catchment compared to an adjacent catchment retaining the original tussock landcover (Fahey and Jackson, 1997).

Based on results of a range of New Zealand catchment studies, a model (WATYIELD) was developed by Landcare Research to enable prediction of potential effects of afforestation on catchment yields (Fahey et al, 2004). Application of this model to a nominal catchment in the Upper Mataura catchment (Environment Southland unpublished data) suggests that afforestation is only likely to have a significant effect on catchment yield when the proportion of the total catchment area converted to plantation forestry increases above 20 percent of the total catchment area. **Figure 46** shows results he results of the application of the WATYIELD model to Futtah Gulley in the Garston area for both young and mature forest. Overall, the data show the effect of mature forest is appreciably greater than young forest (reflecting the greater canopy area and density) and becomes relatively significant (>20 percent of catchment yield) when over 40 percent of a catchment is converted from tussock to plantation forest.

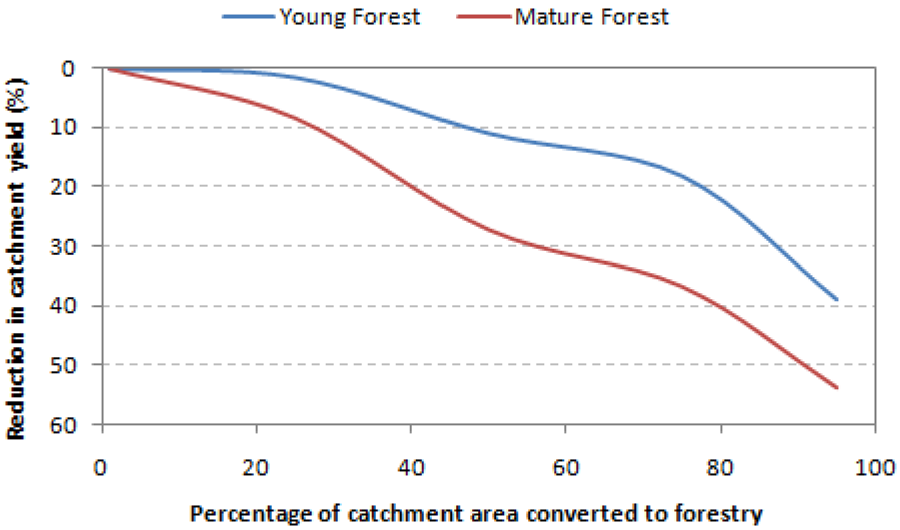

Figure 46. Modelled reduction in catchment yield for varying degree of catchment afforestation (Source: Environment Southland unpublished data)

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[14] Canopy interception refers to the process whereby a proportion of rainfall is intercepted by the foliage and subsequently re-evaporated without reaching the ground thus effectively reducing net rainfall.

5. Assessment of Future Water Demand

The following section provides an estimate of potential future water demand in the Mataura catchment including projections of irrigated demand, future unconstrained water demand and well as outcomes of supply reliability modelling of various alternative allocation scenarios.

5.1. Irrigation Demand Modelling

5.1.1. Introduction

As described in **Section 3** the growth in demand for pasture irrigation has been the single largest factor contributing to the significant increase in water allocation for consumptive use in the Mataura catchment over the past 10 years. Irrigation demand describes the volume and rate of irrigation required to maintain soil moisture in the optimal range for plant growth. Actual water use will also depend on climate, the reliability of the water supply and a range of factors associated with the management of individual irrigation operations.

A daily soil water balance model was used to calculate pasture irrigation requirements. Daily soil moisture water balance modelling is the internationally accepted method for calculating irrigation requirements (Allen *et al*., 1998). The soil water balance modelling approach has been field verified both internationally and in New Zealand, and has been shown to model well what occurs on-farm. The model requires soil, climate, and irrigation parameters. The model was run from 1 June 1972 to 31 May 2010, a total of 38 years.

The methodology utilised for irrigation demand modelling is outlined in **Appendix B**.

5.1.2. Results

Results of irrigation water demand for each of the climate and soil combinations outlined in **Appendix B** are summarised in **Table 7**. The figures show peak irrigation requirements occur in the Riversdale rainfall zone. This zone (illustrated in Appendix B, Figure B3) corresponds to the area of Mataura catchment where a majority of irrigation development has occurred over the past decade.

Table 7. Modelled irrigation water requirements

Parameter	Soil PAW (mm)			
	45	60	85	130
Riversdale rainfall				
Average annual demand (mm/y)	410	370	330	290
1 in 5 year demand (mm/y)	480	430	410	390
1 in 10 year demand (mm/y)	510	470	460	420
Athol rainfall				
Average annual demand (mm/y)	400	350	310	280
1 in 5 year demand (mm/y)	460	400	380	350
1 in 10 year demand (mm/y)	480	430	410	390
Gore rainfall				
Average annual demand (mm/y)	350	300	260	230
1 in 5 year demand (mm/y)	400	360	340	310
1 in 10 year demand (mm/y)	400	390	350	350
Wyndham rainfall				
Average annual demand (mm/y)	320	270	240	200
1 in 5 year demand (mm/y)	380	360	310	300
1 in 10 year demand (mm/y)	400	380	340	320

Figure 47 shows a plot of calculated annual irrigation requirements for a 60 mm plant available water (PAW) soil in the Riversdale rainfall zone. The figure shows annual demand varies from around 200 millimetres in wet seasons up to 500 millimetres in dry years over the 38 year period modelled. It is noted that seasonal demand over the past 10 years has generally been close to, or above the long-term average. This is interpreted to reflect the impact of climate variability on seasonal water balance with increasing seasonal water deficits occurring due to lower summer rainfall. **Figure 48** shows a plot of average monthly irrigation requirements for a similar soil type which shows demand peaks at approximately 70 mm/month during December and January reducing to between 10 to 15 mm/month at the shoulders of the season in September and April.

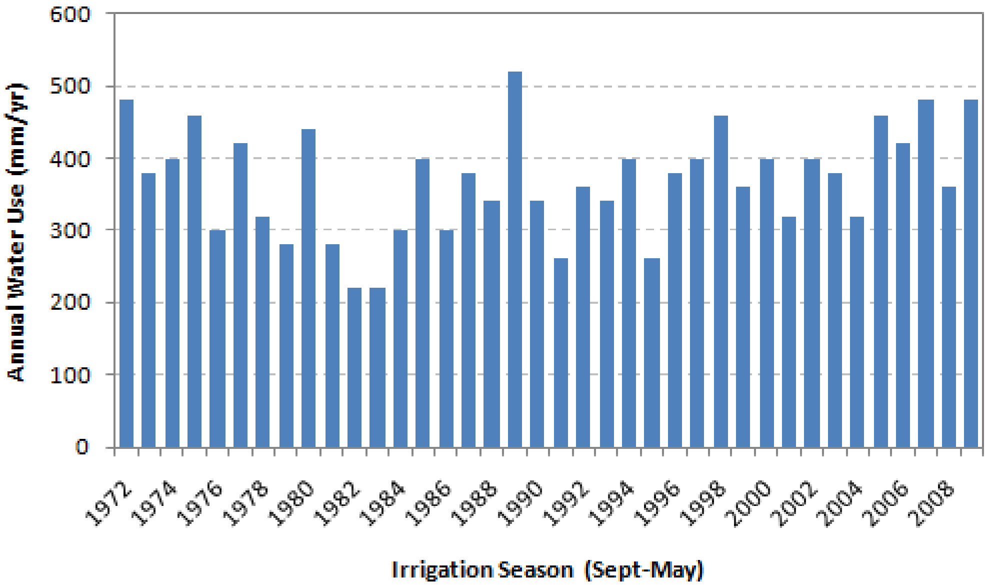

Figure 47. Calculated annual irrigation requirements - Riversdale rainfall zone, soil PAW = 60mm

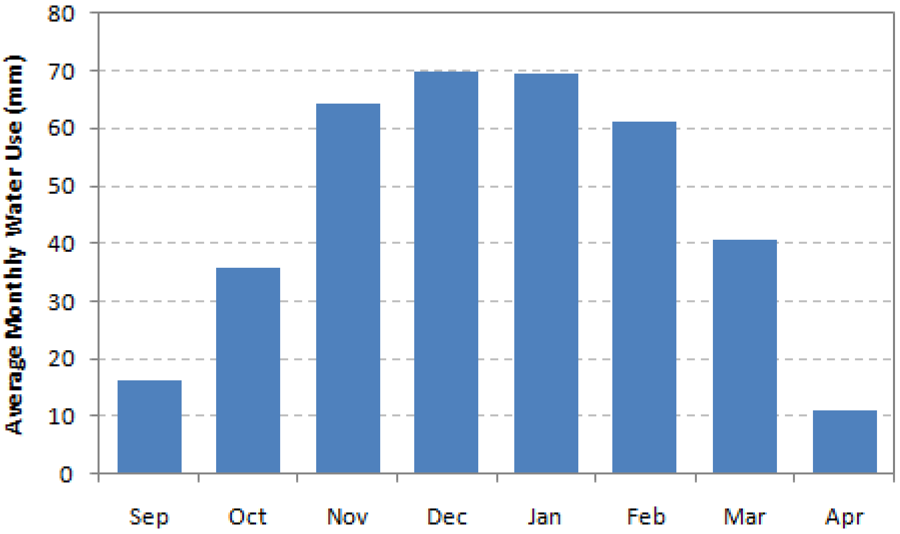

Figure 48. Average monthly irrigation requirements - Riversdale rainfall zone, soil PAW = 60 mm.

5.1.3. Comparison of Actual and Modelled Water Use

Most irrigation currently occurs within the Riversdale rainfall zone on soil plant available water (PAW) classes 45 to 85 mm (see Appendix B). Based on results outlined in **Table 7**, average irrigation water use in this area is expected to be in the range of 290 to 410 mm/year depending on soil type. However, according to Environment Southland compliance monitoring records average seasonal water use on irrigated properties in this area is generally in the range of 140 to 180 mm/year with peak recorded usage of 280 mm/year.

Some possible reasons for the discrepancy between calculated and actual water use include:

- Many farmers appear to start irrigation in late spring despite soil moisture levels being sub-optimal during September, October and November. This delay in commencement of irrigation is thought to largely reflect pasture growth in excess of feed requirements during the ‘spring flush’.

  Examination of existing irrigation water use compliance data in **Section 3.3.1** indicates that irrigation during the 2009/10 season did not commence until late November despite soil moisture levels being below requirements for optimum pasture growth for a significant period of spring. Based on the calculated demand water demand (as illustrated in **Figure 48**) this delay in the commencement of irrigation may account for up to 85 mm of calculated irrigation water demand.

  This delay in the onset of irrigation during the shoulder portions of the irrigation season (typically October-November and March-April) may reflect the nature of existing farming enterprises utilising irrigation in the Mataura catchment. For many of these enterprises, irrigation may be used as a means of maintaining pasture production to offset feed shortfalls occurring during periods of low rainfall (i.e. an ‘*insurance*’ model) rather than a means of maximising pasture production to support increased stocking rates and associated production as modelled;
- Analysis of water use records in **Section 3.3.1** suggest environmental parameters besides soil moisture may significantly influence the management decisions regarding irrigation. In particular, air temperatures, atmospheric conditions (sunshine/cloud) and frequency of rainfall appear to influence utilisation of irrigation on individual properties. Again, this may in part reflect the operation of irrigation systems to maintain feed supplies rather than as a means of maximising of pasture production through optimisation of soil moisture;
- Farmers may be irrigating smaller areas than the nominal irrigation areas recorded on resource consent applications;
- The effect of flow restrictions preventing exercise of consents with minimum flow conditions during periods of highest demand;
- Water requirements for most irrigated properties are calculated on the basis of pasture growth requirements. Irrigation requirements may be reduced if alternative crops (such as winter and autumn feed crops) are grown on a significant proportion of the irrigated area; and,
- In areas where the water table is high (i.e. <3m below ground), capillary rise will lift moisture from the water table into the root zone potentially reducing irrigation requirements.

5.2. Future Demand Projections

The following section provides estimates of potential unrestricted water demand in the Mataura catchment. These estimates are driven solely by projections of potential water demand within the catchment and do not consider physical or regulatory limitations on water availability or the multitude of factors that influence water use at a local scale. As such, they provide a means of identifying potential supply shortfalls under various regulatory options. Associated projections of future land use were also utilised as the basis of water quality modelling undertaken by NIWA to assess environmental costs associated with potential future water use (further described in **Section 7** and **Appendic C**).

Potential water demands were estimated for projected rates of demand growth over a nominal 20-year planning horizon based on ‘conservative’ and ‘accelerated’ demand growth scenarios. These scenarios are intended to provide an upper and lower bound for future growth in water demand in the absence of physical, financial or regulatory constrains. The estimates of future demand were developed by incorporating the estimates of future irrigation, municipal and industrial demand growth described in the following section.

5.2.1. Future Irrigation Demand

Three scenarios for the rate of future unconstrained irrigation growth were developed to enable estimation of potential future water demands for irrigation and for use as an input for the water quality modelling undertaken by NIWA. These were:

1. **50% of conservative growth**. Assumes an average of 375 ha of new irrigation development per year, resulting in a total area of irrigation of about 13,000 ha within the Mataura River catchment by 2030.
2. **Conservative growth**. Assumes an average of 750 ha of new irrigation development per year, resulting in a total irrigated area of approximately 20,000 ha within the Mataura River catchment by 2030.
3. **Accelerated growth.** Assumes an average of 1,000 ha of new irrigation development per year, resulting in a total area of irrigation of about 24,500 ha within the Mataura River catchment by 2030.

To place these scenarios in the context of historical irrigation development in the Mataura catchment **Figure 49** compares irrigation growth under the three future scenarios with the actual increase in irrigated area between 2000 and 2010. The figure shows the conservative growth scenario approximates the rate of increase in irrigated area during the early to mid-2000's when flow cut-offs did not have a major impact on development on supply reliability of riparian groundwater. The 50 percent of conservative growth scenario is more reflective of the longer-term (i.e over the last 10 years) rate of irrigation development in the catchment where constraints imposed by minimum flow restrictions on hydraulically connected groundwater takes and groundwater availability across the wider catchment have constrained the rate of growth. The accelerated growth scenario provides for the expansion of irrigation approximately twice as fast as the rate of growth occurring over the past 10 years.

Based on the modelled peak irrigation water demand of 4 mm/day (0.463 L/s/Ha), **Figure 50** shows the projected increase in unrestricted water demand for irrigation over the next 20 years from the current total of 168,000 m^3/day (1,940 L/s) under the three scenarios considered. This calculation indicates demand could reach 470,000 m^3/day (5,450 L/s) under the 50% conservative growth scenario by 2030, 770,000 m^3/day (8,900 L/s) under the conservative growth scenario and 970,000 m^3/day (11,200 L/s) under the accelerated growth scenario. Assuming future irrigation growth occurs primarily from groundwater, the net effect on surface water[15] required to service these projected increases would be in the order of 120,000 m^3/day (1,400 L/s) to 320,000 m^3/day (3,700 L/s).

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[15] Assuming a similar average ratio of stream depletion to groundwater abstraction to that which occurs at the current time (i.e. approximately 40%)

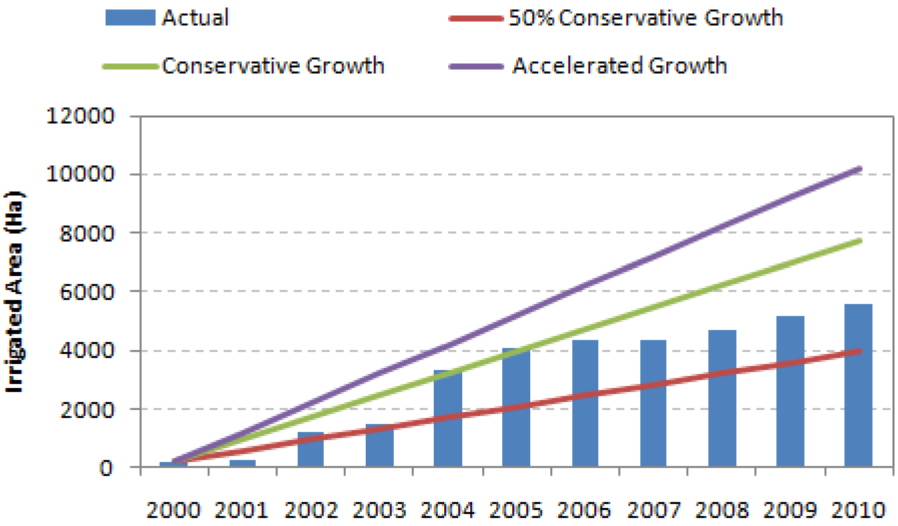

Figure 49. Comparison of future irrigation demand growth scenarios with historical irrigation development in the Mataura catchment

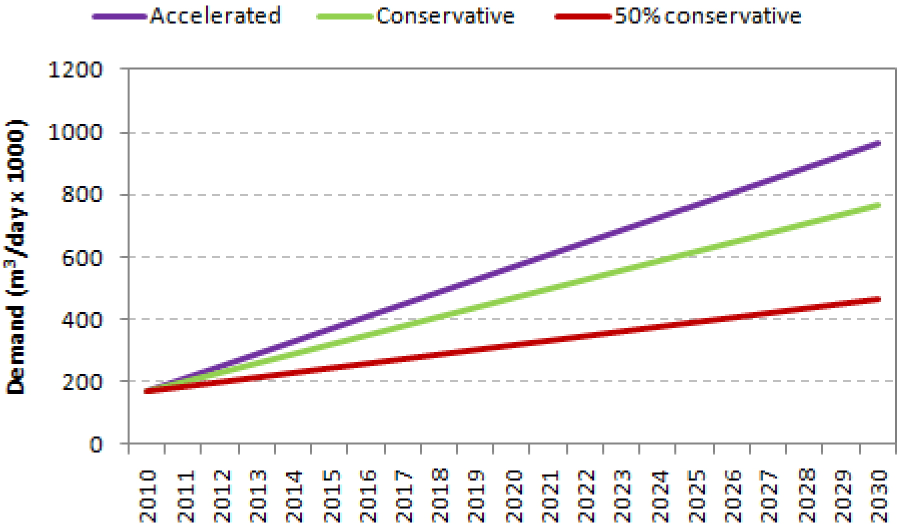

Figure 50. Future (unrestricted) irrigation demand in the Mataura catchment for the three future growth scenarios

Overall, theses estimates of future irrigation demand provide an indicative range of potential future water use for irrigation. The extent to which these demands can be met depends to a large extent on the regulatory regime in place. As further described in **Section 5.3**, given the likely reliability for future surface water or hydraulically connected groundwater allocation in the Mataura catchment these estimates effectively represent future shortfalls in supply.

Future Land Use Scenarios

In order to provide input for NIWA's Catchment Land Use for Environmental Sustainability (CLUES) model, future land use associated with the demand growth scenarios were modelled using three irrigated land use classes: (1) dairying, (2) cropping and dairy support, and (3) horticulture. Irrigated land parcels were aligned with NIWA's Regional Ecosystem Classification (REC) land units to satisfy CLUES data input requirements.

Current irrigated areas and associated land use were provided by Environment Southland, based on consented irrigated areas and local knowledge of current (2010) land use. This coverage provides the base case (status quo) scenario for the water quality modelling described in **Section 7.2.3**.

Irrigation growth was assumed to occur on land with the highest economic benefit. Economic modelling in **Section 4.5** indicates the net value of irrigation is highest in the Riversdale rainfall zone, on soils with a PAW of 85 mm or less. Analysis of the existing resource consent data indicate approximately 80 percent of existing irrigation development occurs on these lighter soils in this area. These soils were therefore assumed to be the most likely areas were irrigation development will occur in the future and modelled land use change, for the purposes of investigating potential land use effects on water quality, was restricted to this area[16].

Appendix C provides a breakdown of the area of each nominal land use type under the status quo and the three irrigation development scenarios, along with a plot of the spatial distribution of the respective land use scenarios modelled.

5.2.2. Industrial Demand

At the current time, industrial use is the second largest water use type in the Mataura catchment. A majority of current industrial use is associated with primary processing (meat, dairy and forestry) activities in the lower catchment and are derived from both groundwater and surface water sources. Projections of future industrial water use are largely based on retention of existing industry types with the addition of mining and associated secondary processing activities associated with the lignite resource in the lower catchment. In order to define future industrial water use in the Mataura catchment, the following assumptions were made with regard existing primary processing:

- Water requirements for dairy processing were assumed to increase under both the conservative and accelerated growth scenarios. Demand growth is estimated at 2000 m^3/day every five years under the conservative scenario and 5000 m^3/day every five years for the accelerated scenario.
- Meat processing is the single largest industrial water use in the Mataura catchment at the current time. Future requirements for meat processing were assumed to remain static with any increases in demand able to be accommodated within existing allocation (a majority of which is assumed to be non-consumptive associated due to the nature of current water abstraction and wastewater discharge at the Alliance Mataura plant);
- Timber processing requirements were assumed to remain static under the conservative growth scenario and increase up to 2,000 m^3/day under the accelerated growth forecast;

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[16] In reality, irrigation development (assuming water of suitable reliability is available) is likely to be spread further across the catchment (possibly reflecting the current 80/20 land area split between the Riversdale rainfall zone and the remainder of the catchment) as the decision by an individual landowner to pursue irrigation is likely to be influenced by a range of factors including, but not solely limited to, financial considerations.

- Water requirements for quarrying and gravel processing (including small-scale alluvial mining) were assumed to remain static under the conservative scenario and increase by up to 1,000 m^3/day for a period in the accelerated growth forecast associated with mining-related construction activities. For the purposes of future demand estimates water takes for gravel and quarrying activities were assumed to be non-consumptive.

Preliminary (confidential) estimates of potential water requirements for future lignite mining projects were provided by Solid Energy. These figures include order of magnitude projections for dewatering volumes and secondary processing water requirements. For the purposes of this assessment the following assumptions were made:

- In terms of mine dewatering, 20 percent of projected flows were assumed to be consumptive (i.e. used for activities such as dust suppression which result in a net loss of water) with the balance of flows returned to the catchment (i.e. non-consumptive);
- For the conservative growth scenario, secondary processing options were assumed to be effectively non-consumptive;
- For the accelerated growth scenario, upper bound estimates of mine dewatering flows and secondary processing were adopted based on the single option with the highest consumptive water requirement (rather than combining water use estimates for alternative mining/processing options).

Figure 51 provides a plot of projected future industrial water demand in the Mataura catchment. The figure clearly illustrates the potential impact of lignite mining activities on industrial water requirements which range between 20,000 m^3/day in 2030 for the conservative growth scenario to approximately 160,000 m^3/day under the accelerated scenario. These volumes represent the aggregate demand from groundwater and surface water source for industrial supply in 2030. Given the nature of potential industrial water demand (e.g. lignite mining and secondary processing), it is difficult to estimate a potential split of between groundwater and surface water abstraction given the potentially complex take and discharge arrangements that may impact on the calculation of consumptive use.

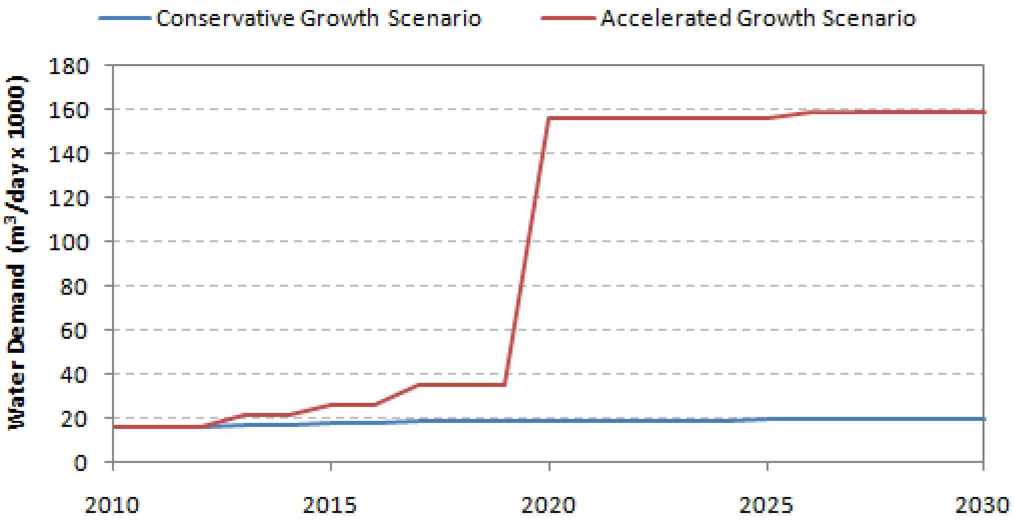

Figure 51. Estimated future industrial water demand under the conservative and accelerated growth scenarios

While it is recognised that the calculated industrial water demand is relatively speculative, it does highlight that while increases in water demand for existing industrial water uses in the catchment are likely to be relatively modest, mining and related processing activities may have a significant impact on overall future water demand in the Mataura catchment.

5.2.3. Municipal and Rural Water Supplies

At the current time, a number of reticulated water supplies exist in the Mataura catchment. These include municipal supplies servicing Gore, Mataura, Edendale and Wyndham in addition to domestic and/or stockwater schemes including the Southland District Council (SDC) Balfour-Lumsden and Edendale-Wyndham supplies, the Gore District Council (GDC) Otama rural water scheme as well as the privately run Otikerama and Kaiwera water supply schemes. Calculation of future water supply requirements for municipal and stock water supplies in the Mataura catchment include the following assumptions:

- Conservative and accelerated growth forecasts for municipal supply in Gore and Mataura were provided by the Gore District Council (GDC). These estimates range from no change in existing water demand for the conservative growth scenario (based on current Stats NZ projections of population growth) to 2 percent annual demand growth for the accelerated growth scenario.
- The recently installed Southland District Council (SDC) Edendale/Wyndham supply is assumed to have sufficient capacity to meet future demand under both the conservative and accelerated growth forecasts (the Balfour-Lumsden scheme is assumed to have similar reserve capacity and is sourced externally to the Mataura catchment);

- Rural water supply schemes were assumed to have sufficient current allocation to meet conservative growth forecasts, with demand allocation requirements increasing at 2 percent per year for the accelerated growth scenario;
- The accelerated growth forecast includes provision for development of reticulated supplies servicing the Athol, Garston and Riversdale communities (in practice a significant proportion of these communities are already serviced by individual domestic supplies to the net change in water use as a result of reticulation is likely to be relatively minor);
- Estimated workforce numbers for construction and operation of lignite mining and secondary processing operations were provided by Solid Energy. Demands for municipal supply associated with these population changes were assumed to be in addition to projected municipal supply growth. Associated demand was estimated on the basis of typical per head water requirements for municipal supplies in Southland (200 L/head/day) with an equivalent population equal to 2.8 times workforce numbers, 75 percent of whom were resident in the Mataura catchment.

Figure 52 shows a plot of projected cumulative water demand for municipal and stock water supplies under the conservative and accelerated growth scenarios. It is noted the variations in demand growth during the period 2015 to 2020 in the accelerated growth forecast reflect projected population changes resulting from construction related activities associated with potential lignite mining and processing projects.

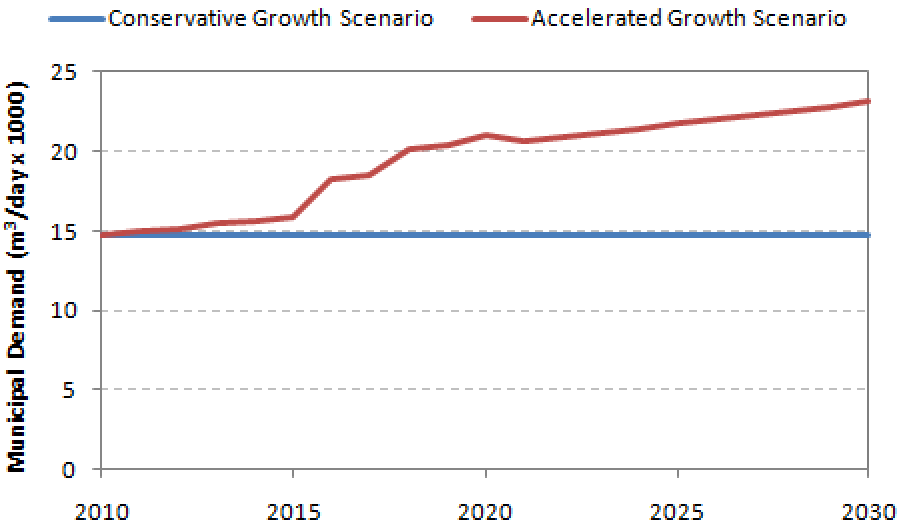

Figure 52. Estimated future water demand for municipal and rural supplies under the conservative and accelerated growth scenarios

5.2.4. Cumulative Future Water Demand

Based on the analysis outlined in the preceding section, cumulative future unrestricted peak water demand in the Mataura catchment would potentially increase from the current level of approximately 310,000 m^3/day (3.5 m^3/s) to approximately 900,000 m^3/day (10.4 m^3/s) under the conservative growth scenario and 1,200,000 m^3/day (13,900 m^3/s) under the accelerated growth scenario.

The increase in projected demand is largely driven by an assumed increase in pasture irrigation and, in the accelerated growth scenario, lignite mining and associated secondary processing. The potential growth in unrestricted water demand is shown in **Figure 53** which, for illustrative purposes also includes a third option which combines the conservative growth forecasts for municipal and industrial water supply with the 50 percent of conservative growth scenario for irrigation development.

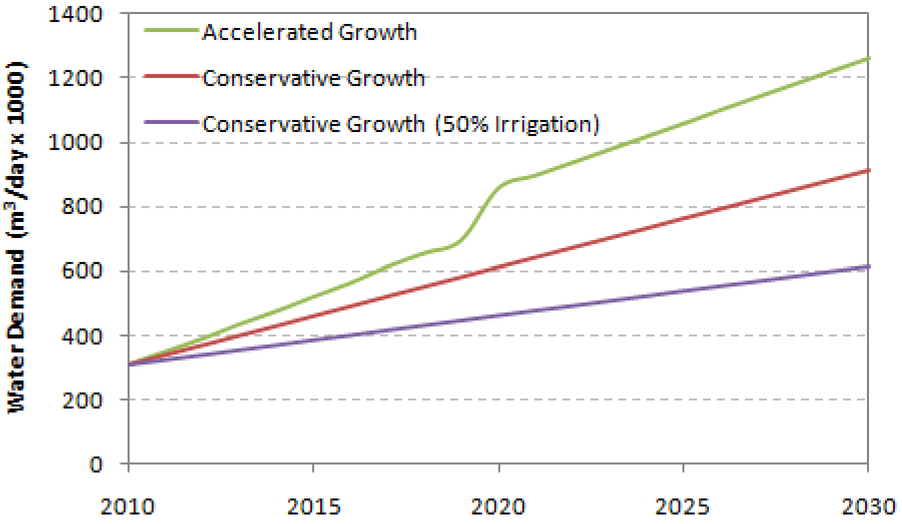

Figure 53. Cumulative water demand calculated for the conservative and accelerated growth forecasts

It is noted that these figures represent aggregate demand from surface and groundwater sources as it is difficult to predict with any accuracy the likely split in future demand growth between these sources. However, it would seem reasonable to assume that at least part of any future allocation would be derived from groundwater which, under the current allocation methodology, would reduce the calculated effect on surface water below the figures shown (by around 40 percent assuming a similar distribution of takes between surface water, hydraulically connected groundwater and groundwater takes to that occurring at the current time).

Again, it is emphasised that the unrestricted growth forecasts are presented as a relatively simplified extrapolation of historic trends and water use combined with estimates of potential water used associated with specific development options. As such, the figures do not include consideration of the range of physical, environmental, regulatory and financial constraints that are likely to significantly influence future water use. Given the current level of allocation under the MCO regime (i.e. surface water fully allocated to >MALF), these estimates are therefore best viewed in terms of potential future shortfalls in supply.

5.3. Supply Reliability Modelling

Due to the existing regulatory framework, supply reliability is likely to constrain future water resource development in the Mataura catchment. The following section analyses potential impacts of constraints under the current regulatory regime on the economics of pasture irrigation and explores the possible impact of a range of alternative management options. The analysis is undertaken in terms of pasture irrigation development for two primary reasons:

- Irrigation development is likely to be the largest future consumptive water demand in the Mataura catchment; and,
- Models to enable calculation of economic impacts of supply reliability on agricultural production are relatively well developed for irrigation compared to alternative water use options.

5.3.1. Background

Reliability of supply describes the quality of access to water for an individual water user. Reliability can be characterised by the frequency and extent of restrictions imposed on the exercise of a resource consent authorising water abstraction (referred to as a *water permit* under RMA s87). Users with a high degree of reliability of supply can typically access their full consented volume at any time, while those with a moderate or low degree of reliability may be prevented from utilising their consent for extended periods.

Temporal restrictions on access to water are typically specified by regional plans (such as minimum flows in surface waterways or minimum levels/pressures in aquifer systems) and implemented through conditions attached to individual resource consents[17]. These restrictions are typically imposed to maintain nominated environmental values, reflecting the priority given under the RMA to environmental flows over consumptive use. The frequency at which these restriction levels are reached influences the reliability of supply for individual water users. For example, in the case of a river or stream, pumping restrictions based on a low flow reached on average once every 10 years[18] will provide a much higher reliability of supply than one based on flows reached annually.

The total volume of allocation also influences reliability of supply, so the more accessible water is (i.e. the more users who can access a fixed volume), the less reliable the supply will be. For example, in a stream with a minimum flow specified but no allocation limit established, the larger the volume of water allocated, the quicker flows will reduce to the minimum with a consequent reduction in the reliability of supply. In the situation where no allocation limit is specified, continued allocation may reduce the reliability of supply to a point where a particular water use is no longer economically viable. The reduction in reliability of supply accompanying resource allocation is illustrated in **Figure 54** below. As a result, in combination with minimum flow or level restrictions, a limit (cap) on total allocation effectively establishes a lower bound for the reliability of supply for those users who obtain resource consent to access the water.

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[17] Temporal restrictions on access to water may also result from technical or engineering factors (such as an intake level or pumping lift) which limit the ability of an individual water user to access the resource.

[18] River flows are typically ‘naturalised’ to remove the effects of abstraction to determine what the natural discharge would have been with no abstraction occurring.

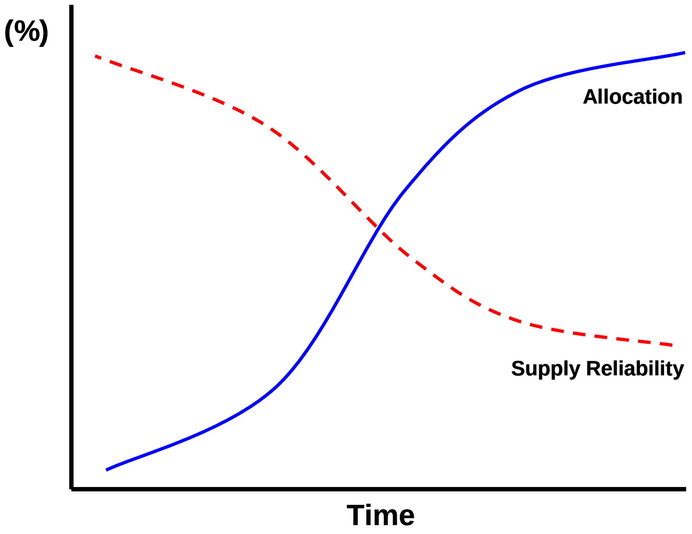

Figure 54. Schematic illustration of the decrease in supply reliability with increasing allocation

However, in terms of overall economic outcome (at a regional-scale), a trade-off exists between the overall economic benefit able to be derived from a given water resource and the reliability of supply afforded to individual resource users. This relationship, illustrated in **Figure 55** below, shows that individual users have a high level of reliability where the level of allocation is low. However, as more users access the resource, the overall economic benefits increase but the reliability of supply for individual users declines. The potential economic benefit continues to increase up to a threshold beyond which the reduced reliability of supply no longer provides positive economic outcomes overall. This illustrates the trade-off required to optimise allocative efficiency, where the level of supply reliability required to optimise overall economic benefits at a regional scale may be lower than that sought by individual users seeking to secure maximum individual benefit.

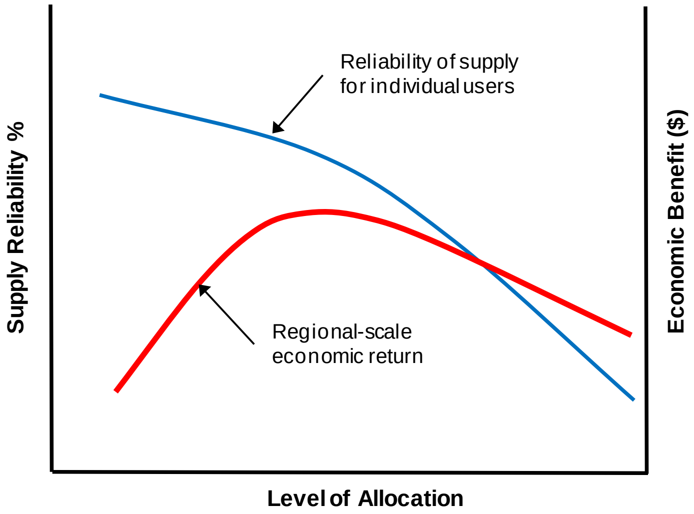

Figure 55. Impact of supply reliability on regional economic benefit.

5.3.2. Irrigation Supply Reliability in the Mataura Catchment

In general terms, as the reliability of a water source decreases, the net economic value of irrigation derived from that resource correspondingly declines. In modelling supply reliability, the following modelling assumptions were made regarding future irrigation development in the Mataura catchment:

- Virtually all new water for irrigation will be sourced either directly from the Mataura or Waikaia rivers or from hydraulically connected groundwater which is subject to similar supply restrictions. The potential for large-scale development of groundwater resources removed from the riparian margins of the main rivers was assumed to be relatively limited (due to the hydraulic characteristics of older Quaternary gravel deposits);
- Virtually all new pasture irrigation will occur upstream of the Mataura River flow monitoring site at Gore. Historically, over 95% of irrigation development (by volume) in the Mataura River catchment has been upstream of Gore. Irrigation development in the lower catchment has generally been limited to horticultural developments (particularly bulb crops) which, although having moderate short-term water requirements, are generally limited in spatial extent and have relatively low seasonal requirements per unit area.
- The peak supply requirement for pasture irrigation is assumed to be 4 mm/day (0.46 l/s/ha).

As of December 2010, calculated cumulative surface water allocation, including stream depletion effects from hydraulically connected groundwater takes, totalled approximately 900 l/s above the flow monitoring site at Gore (*Pers Comm*. K. Wilson, Environment Southland). For the purposes of reliability modelling this existing allocation was given priority over abstraction for new irrigation. In order to establish the potential impact of supply reliability on the economics of irrigation development in the Mataura catchment the following current and future supply reliability scenarios were modelled:

1. **100% supply reliability**.

   This is the reliability level for irrigation sourced from groundwater classified as having a low or moderate hydraulic connection to surface water which are not subject to minimum flow conditions under RWP Policy 29(b). The 100 percent reliability scenario provides the base case against which other water allocation options are tested.

2. **Status Quo - no change to the MCO flow allocation provisions**.

   Reliability for the last water permit issued:

(a) Given 100 ha further irrigation development (5,600 ha total catchment irrigation and total allocation above Gore of 950 l/s)

(b) Given 2,000 ha further irrigation development (7,500 ha total catchment irrigation and total allocation above Gore of 1,830 l/s)

(c) Given 4,000 ha further irrigation development (9,500 ha total catchment irrigation and total allocation above Gore of 2,750 l/s)

(d) Given 6,000 ha further irrigation development (11,500 ha total catchment irrigation and total allocation above Gore of 3,680 l/s)

(e) Given 9,500 ha further irrigation development (15,000 ha total catchment irrigation and total allocation above Gore of 5,300 l/s)

The analysis assumes reliability bands so that each new water permit does not affect the reliability of existing abstractors.

3. **Mataura River minimum flow at Gore of 13.0 m^3/s and 1:1 flow sharing**.

   Reliability for all new irrigation:

   (a) Given 100 ha further irrigation development (5,600 ha total catchment irrigation and total allocation above Gore of 950 l/s)

   (b) Given 2,000 ha further irrigation development (7,500 ha total catchment irrigation and total allocation above Gore of 1,830 l/s)

   (c) Given 4,000 ha further irrigation development (9,500 ha total catchment irrigation and total allocation above Gore of 2,750 l/s)

   (d) Given 6,000 ha further irrigation development (11,500 ha total catchment irrigation and total allocation above Gore of 3,680 l/s)

   (e) Given 9,500 ha further irrigation development (15,000 ha total catchment irrigation and total allocation above Gore of 5,300 l/s)

   Assumes the reliability of existing irrigators is not reduced and all new irrigators share the same reliability.

4. **Minimum Mataura River flow at Gore of 13.0 m^3/s, 1:1 flow sharing, and reliability bands**.

   Reliability for the last water permit issued:

   (f) Given 100 ha further irrigation development (5,600 ha total catchment irrigation and total allocation above Gore of 950 l/s)

   (a) Given 2,000 ha further irrigation development (7,500 ha total catchment irrigation and total allocation above Gore of 1,830 l/s)

   (b) Given 4,000 ha further irrigation development (9,500 ha total catchment irrigation and total allocation above Gore of 2,750 l/s)

   (c) Given 6,000 ha further irrigation development (11,500 ha total catchment irrigation and total allocation above Gore of 3,680 l/s)

   (d) Given 9,500 ha further irrigation development (15,000 ha total catchment irrigation and total allocation above Gore of 5,300 l/s)

   Assumes reliability bands so that each new water permit does not affect the reliability of existing abstractors.

5. **Minimum Mataura River flow at Gore of 17.6 m^3/s and 1:1 flow sharing**.

   Reliability for all new irrigation:

   (a) Given 100 ha further irrigation development (5,600 ha total catchment irrigation and total allocation above Gore of 950 l/s)

   (b) Given 2,000 ha further irrigation development (7,500 ha total catchment irrigation and total allocation above Gore of 1,830 l/s)

(c) Given 4,000 ha further irrigation development (9,500 ha total catchment irrigation and total allocation above Gore of 2,750 l/s)

(d) Given 6,000 ha further irrigation development (11,500 ha total catchment irrigation and total allocation above Gore of 3,680 l/s)

(e) Given 9,500 ha further irrigation development (15,000 ha total catchment irrigation and total allocation above Gore of 5,300 l/s)

Assumes the reliability of existing irrigators is not reduced and all new irrigators share the same reliability.

Scenarios 3, 4 and 5 were developed to explore the impact of alternative Mataura River flow allocation options on the financial viability of irrigation. Given the assumption that all irrigation development will occur upstream of Gore, the Environment Southland Mataura River at Gore flow recorder was utilised as the reference site for establishing supply reliability (i.e. flow allocation and minimum flows) for the scenarios modelled.

Allocation for Scenarios 3, 4 and 5 was based on the discretionary activity status threshold (30 percent of 7-day man annual low flow (MALF)) specified in Rule 18(e) of the RWP. Based on the calculated 7-day MALF of 17.6 m^3/sec at Gore, total allocation for these scenarios was established at 5.3 m^3/s. Minimum flows of 100 percent of MALF (17.6 m^3/s) and 75 percent of MALF (13 m^3/s) were utilised to illustrate a range of potential supply reliabilities.

In Scenario 4, it was assumed the reliability of each new water permit does not affect the reliability of existing water permits. This would require each successive water take consent to have a higher minimum flow than the previous consent issued, in a similar manner as occurs under the MCO allocation.

5.3.3. Model Results

Table 8 lists the average supply reliability calculated for Scenarios 2 to 5 across a nominal October to March irrigation season. As also illustrated graphically in **Figure 56**, the figures show supply reliability for any additional irrigation under Scenarios 2 and 5 is below 90 percent, due to the assumption of a minimum flow of MALF or greater. Supply reliability declines rapidly with increasing irrigated area for Scenario 2 reflecting the rapidly increasing minimum flow under the 5 percent flow allocation specified under the MCO. However, under scenarios 3, 4 and 5 reliability declines much more slowly reflecting the greater volume of allocation assumed to be available (30 percent of MALF). The relatively constant difference (~8%) in reliability between scenarios 3 and 5 reflects the effect of the 25% lower minimum flow modelled in Scenario 3 (13 m^3/s compared to 17.6 m^3/s).

Table 8. Average water availability (October-March) for modelled allocation scenarios

Scenario	Additional Irrigated Area				
	100 ha	2,000 ha	4,000 ha	6,000 ha	9,500 ha
2	87%	57%	34%	23%	11%
3	94%	93%	91%	89%	88%
4	94%	91%	88%	84%	80%
5	87%	85%	83%	81%	79%

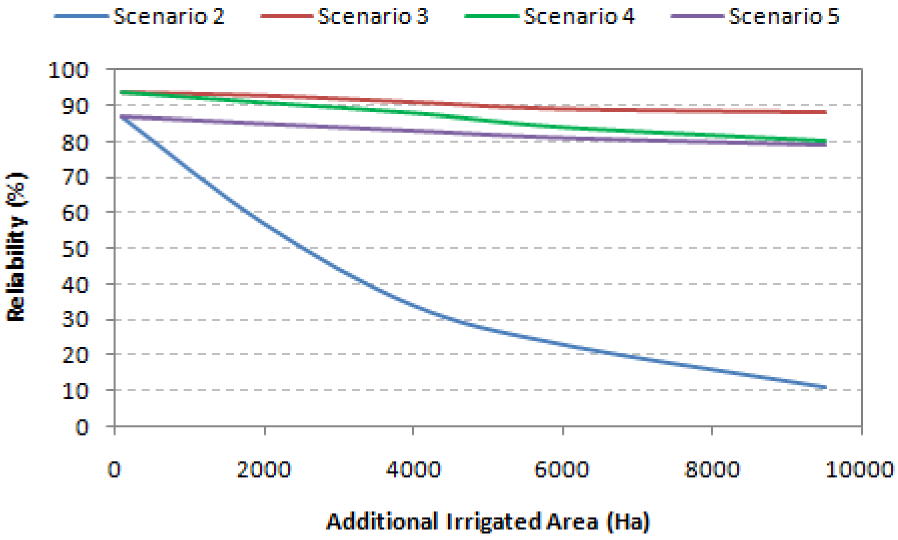

Figure 56. Average supply reliabilities calculated for modelled allocation Scenarios 2 to 5.

Figure 57 through **Figure 60** illustrate the monthly supply reliability for each allocation scenario for the range of irrigated areas modelled.

Figure 57 shows the relatively low supply reliability (~70 percent) during January and February (typically the period of highest pasture water requirements) at the current time (Scenario 2a). This reliability declines markedly with the increases in irrigated area (Scenarios 2b, c and d) due to the rapid increase in minimum flow with small increases in allocation due to the MCO 5 percent allocation criteria.

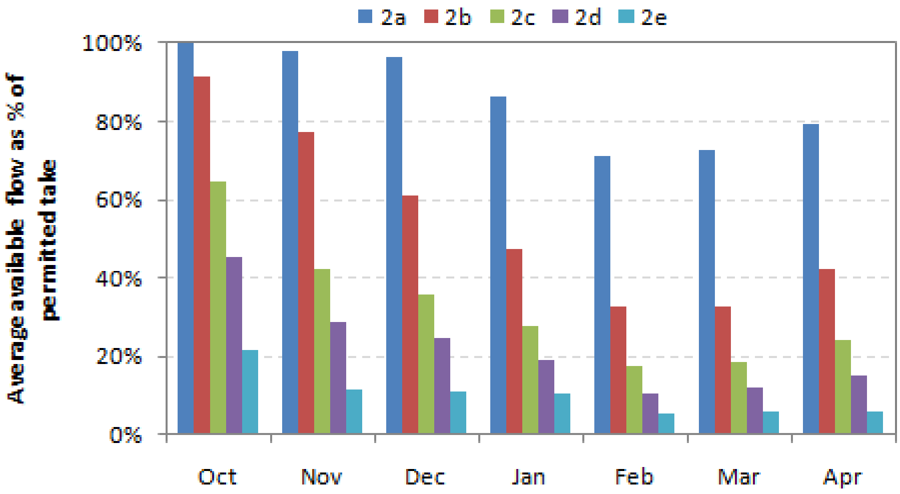

Figure 57. Scenario 2 monthly supply reliability for the last water permit issued

Figures 58 to 60 show the higher reliability resulting from the increased allocation modelled (30% of MALF) in scenarios 3, 4 and 5. All scenarios show some level of restriction occurs during the summer months (typically peaking in February) with the difference in monthly reliability between Scenario 3 and Scenario 5 reflecting the impact of the higher minimum flow utilised in the latter scenario. **Figure 59** also shows greater variation in reliability between individual monthly reliabilities in Scenario 4 as a result of the assumed stepwise reduction in supply reliability compared to Scenarios 3 and 5 which assume all new users share the same reliability (i.e. allocation bands with fixed reliability).

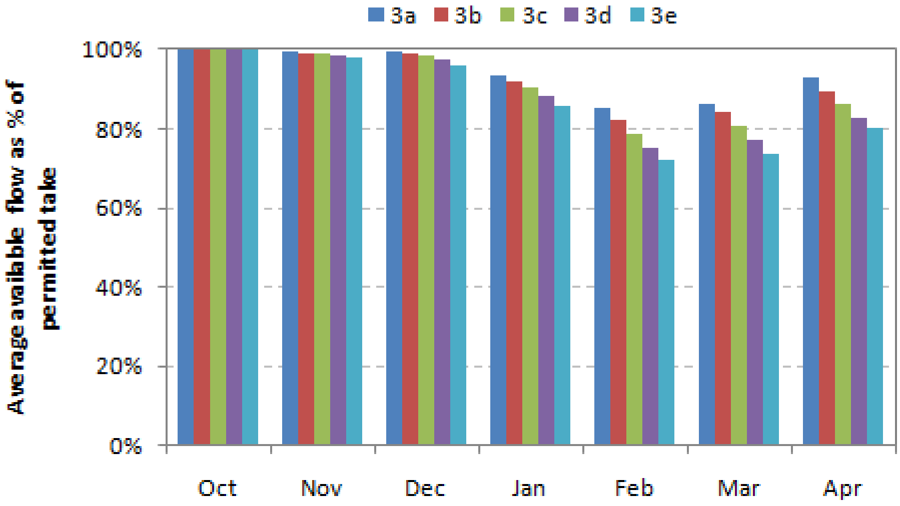

Figure 58. Scenario 3 monthly supply reliability for all new irrigation

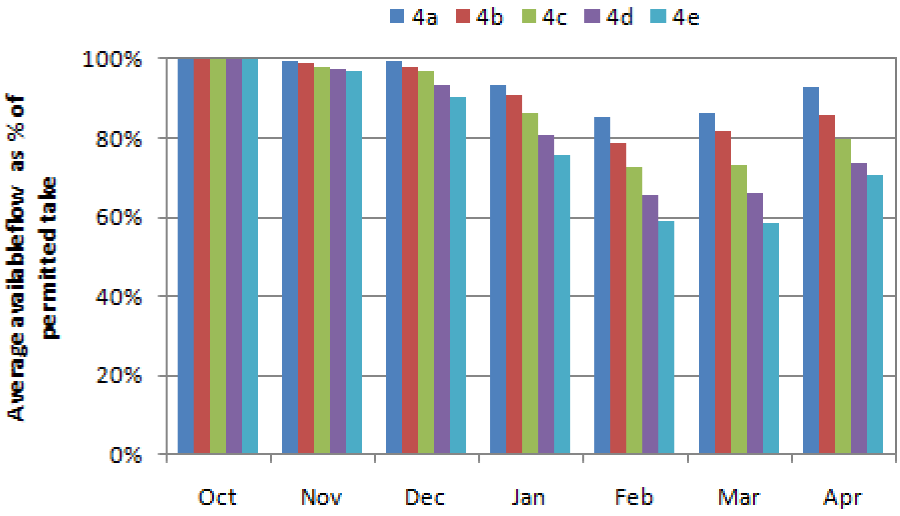

Figure 59. Scenario 4 monthly supply reliability for the last water permit issued

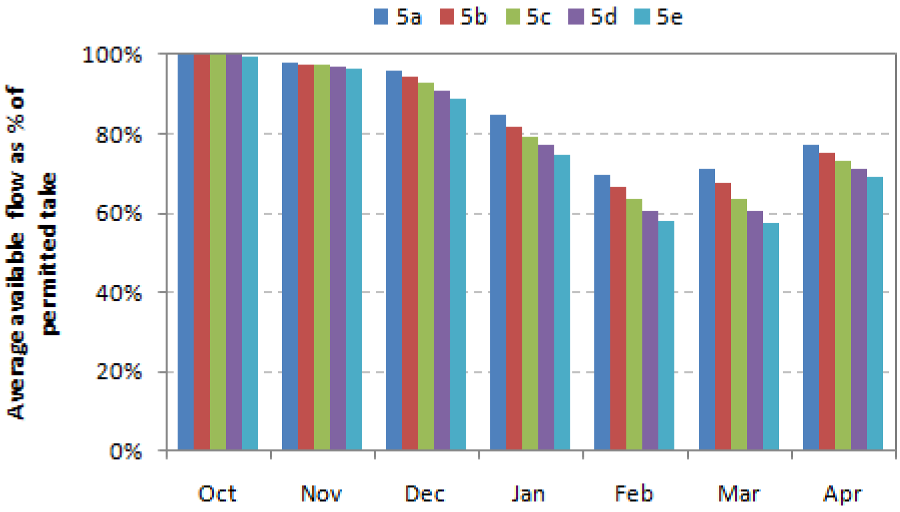

Figure 60. Scenario 5 monthly supply reliability for all new irrigation

Obviously if there is significant future demand for new water from the Mataura River for uses other than irrigation (such as large scale mining) the amount of water available for irrigation would be reduced. Supply reliability will still remain the same provided the total allocation above Gore as described in the above scenarios remains unchanged, and virtually all new abstraction is from above Gore.

6. Values Workshop

In order to obtain data to enable evaluation of potential costs and benefits associated with water resource development in the Mataura catchment a workshop was held with the project Steering Group in October 2010. The primary objective of the workshop was to identify, and if possible, compile a relative ranking of values associated with the Mataura River.

For the purposes of identifying and ranking values the Steering Group was divided into four sector interest groups representing:

- Environment
- Industry
- Local Government
- Primary Sector

Each sector group was tasked with identifying a set of values attributed to the water resources of the Mataura catchment under the broad headings (colloquially termed '*wellbeings'*) of:

- Environmental
- Social
- Economic
- Cultural

Participants were then asked to identify a score for each value based on their opinion of the current state of water resources in the Mataura catchment in terms of a simple three option ranking (poor, reasonable, good). Finally, participants were asked to provide relative weightings both between the individual values identified and the respective 'wellbeings' to reflect their perceived importance in terms of overall catchment management.

Table 9 provides a summary of the values identified across the four sector groups. While many of the values identified are inter-related, common themes emerged under each of the four 'wellbeings'. These may be summarised as:

- Environment - health ecosystems;
- Economic - a prosperous regional economy supported by diversified, viable businesses;
- Social - strong, vibrant communities providing a good quality of life; and,
- Cultural - recognition of the importance of cultural and historical perspectives in resource management

While the values workshop undertaken for this project was relatively brief, outcomes from the workshop provide a useful starting point for consideration of future management of water resources in the Mataura catchment. Useful observations drawn from the workshop exercise include:

- A wide range of values are associated with the Mataura River. These include a range of values not explicitly recognised within the existing regulatory framework ranging from environmental values such as biodiversity to economic and social values associated with out-of-stream water use;

- The relative weighting assigned both to individual values and between the four 'wellbeings' varied significantly between the sector groups, reflective of the diversity of views regarding water resource management. However, common themes emerged from each of the sector groups suggesting a common goal which may be expressed in terms of '*strong, prosperous communities within a healthy environment*'.
- Opinions regarding the current condition of the values identifies varied widely between individual sector groups (and individual participants). This observation is likely to reflect individual opinions with regard to the appropriate balance between the environmental, economic, social and cultural values identified. However, it possibly also highlights the need to disseminate information regarding the current state of the environment in a clear and concise manner to enable informed community participation in the resource management process.

Table 9. Summary of values associated with the Mataura catchment identified at the Steering Group workshop held in October 2010 (Note: average weighting between the four wellbeings shown in the last row)

Environmental	Economic	Social	Cultural
Healthy Ecosystems	***Regional Economic Prosperity***	***Strong Communities***	***Cultural and Spiritual Wellbeing***
▪ Fisheries ▪ Water Quality ▪ Habitat Diversity and Connectivity ▪ Water Quantity ▪ Flood Control ▪ Biodiversity ▪ Assimilative capacity	▪ Jobs/Employment ▪ Commercial fishing ▪ Tourism (including angling) ▪ Viable local communities ▪ Diversified viable businesses ▪ Reliability of supply ▪ Quality of supply (suitability for use) ▪ Clean green image ▪ Gravel extraction ▪ Electricity generation	▪ Angling Amenity ▪ Recreational Amenity ▪ Drinking Water Supply ▪ Community Amenities ▪ Mahinga Kai ▪ Aesthetics ▪ Education and healthcare ▪ Social Order	▪ History and tradition ▪ Food gathering ▪ Mauri ▪ Ability to participate in decision-making ▪ Access ▪ Cultural Identity
50%	***20%***	***15%***	***15%***

7. Costs and Benefits of Future Water Resource Development

7.1. Method

The major use of water in the Mataura catchment is irrigation, which accounts for approximately 80 percent of peak rate allocation. However, there are a number of other water uses in the catchment, including municipal supplies, industrial uses (dairy and meat processing), as well as potential industrial activities such as lignite mining and secondary processing. In addition, there are a number of other economic, social and environmental values associated with the Mataura River and its uses which were assessed in this study. The methods for assessing the costs and benefits for each of these are discussed below.

7.1.1. Irrigation

The economic benefit associated with irrigation development declines as supply reliability reduces. As a result, there is a point at beyond which irrigation development does not provide an economic return. The allocation scenarios and associated supply reliabilities outlined in the preceding section were used to estimate the effect of supply reliability on the economic viability of irrigation transition under a range of development scenarios.

In predicting how reliability will impact on farm economics a number of assumptions were made including:

- Virtually all new water will be sourced either directly from the Mataura or Waikaia rivers or from hydraulically connected groundwater subject to equivalent supply restrictions;
- Most irrigation will occur on farms with boundaries within 2 km of the Mataura or Waikaia rivers, and the capital cost to supply water to farm boundaries is limited to $2,000/ha.
- Most new irrigation will occur in the Riversdale rainfall zone. Historically about 80% of all irrigation development in the Mataura catchment has been within this area;
- Most new irrigation will occur on lighter soils. Historically most irrigation development in the Mataura River catchment has occurred on lighter soils (PAW<85mm). A soil PAW of 60 mm was used to represent these lighter soils.
- Most new irrigation will be for dairy or dairy support. The economic parameters utilised for modelling dairy operations are listed in **Appendix D**.

Irrigation and soil water dynamics were modelled using AusFarm[19], coupled with Aqualinc's custom irrigation component. AusFarm is a biophysical model of temperate climate pastoral systems, developed by CSIRO Australia. Details of the economic model used to estimate the economic value of irrigation are provided in **Appendix D**.

The modelled dairy farm outcomes describe the revenue and expenses associated with a dairy operation. These were adjusted for changes in capital and management costs associated with

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[19] For further information about AusFarm, see http://www.grazplan.csiro.au/.

changes in intensity or operation type, and for any storage costs. For Scenarios 2 and 4 adjustments were also made to reflect average reliability in each band[20].

In addition to dairy operations, a combined arable/support system was included in the land use mix. While there are other options, such as sheep and beef finishing and pure arable land use, the arable/dairy support was considered to most likely reflect an alternate non-dairy irrigated operation. The makeup of this arable/dairy support operation is shown in **Table 10** below. The pasture growth from the dairy results were adapted for each scenario by changing the arable/support operation EBITDA[21] to reflect the loss of pasture production in the equivalent dairy operation. This assumed that the growth reduction for the dairy operation was equivalent to the loss in dry matter (DM) or yield for the arable/support operation. For the arable/support operation the only adjustments made were capital costs associated with irrigation installation and operation.

Table 10. Land use rotation for arable/dairy support operation

Crop	Proportion of operation[22]	Returns/ha
Spring Wheat	16.7%	$510
Winter Wheat	16.7%	$540
Winter Barley	16.7%	$480
Spring Barley	16.7%	$453
Feed Crop	33%	$475
Grass	33%	$720

A small proportion of the irrigated land (1%) was considered likely to go into a horticultural operation. This was assumed to be some type of bulb growing operation, and the figures given are indicative only. This had a revenue of ~$21,000 per annum and a gross margin after capital costs of $4,900/ha. It has been assumed that the effect of reliability on these operations is minimal, since overall water requirements are relatively small compared with an irrigated pasture operation. It is likely that any reliability impacts would be ameliorated through storage or transfers.

7.1.2. Industrial and other takes

The key industrial and municipal water takes were identified and these stakeholders contacted to discuss the potential impact of different allocation scenarios on their operations. Where possible these costs were quantified.

The potential exists for other non-irrigation takes in the catchment that would be affected by the flow regime. The key potential take is associated with large-scale lignite mining in the catchment. Solid

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[20] These two scenarios had reliability banding. Aqualinc modeled the last irrigator in each band. These results were adjusted to reflect average reliability for all irrigators in that band. This adjustment assumed reliability changed in a straight line fashion for each band.

[21] Earnings before interest, tax, depreciation and amortisation

[22] Note that the total sums to more than 100 percent because of multiple uses of paddocks in one year – associated with the spring wheat crop

Energy were contacted and provided some broad indications of potential economic impact associated with a mine development. However, it should be noted that this impact is very preliminary, and the final outcome and water use would depend on the actual type and scale of operation.

7.1.3. Environmental costs and benefits

Intensification in a catchment, both from irrigation and industrial use of water, can have an impact on environmental outcomes. These outcomes can include:

- Increased concentration of nutrients in groundwater as well as the river catchment and associated estuarine area. The increased nutrient concentrations will be associated with greater risk of adverse effects on human drinking water supplies in the case of groundwater and stock drinking water supplies and aquatic ecosystems in the case of surface water;
- Increased microbial contamination and associated threats to contact recreational and food gathering activities;
- Changes in flow regimes that may be associated with the different scenarios could also pose some threat to aspects of the river ecology. However, this impact is likely to be small because the proportion of water abstracted will be a relatively minor component of the total river flow, a defined minimum flow will be maintained, and there is unlikely to be any change to the frequency of flushing flows in the river.

Two types of modelling were undertaken on the catchment nutrient outcomes under current and future scenarios of development and mitigation. These were:

- Modelling of potential water quality impacts by NIWA using the CLUES model to quantify potential catchment-scale nutrient outcomes; and,
- A simple spreadsheet model developed by Aqualinc based on likely nutrient losses from different land uses in the catchment

7.1.4. Social costs and benefits

There is clear evidence that changes to the economic activity associated with irrigation have an impact on the wider economic and social structure of the catchment and region (e.g. Harris, 2006). While some of these are difficult to measure, the major impacts are likely to be associated with increases in household incomes and with employment.

- Household income drives affordability of activities and social services such as health and education. Typically taxation also increases from increased wages and associated PAYE and GST. Higher household income also potentially increases the affordability of rates required to support district and regional council requirements[23].
- Employment drives population in a catchment, which in turn drives participation in social activities, changes in community structure, and localisation (as opposed to centralisation) of services such as health and education.

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[23] Although theoretically rates are driven by service requirements rather than affordability, in practice setting of rates is a political exercise in which affordability is a significant criterion. That is to say, services are tailored as much to affordability as to requirements.

For the purposes of this study we have estimated changes in total household income likely to be associated with the different growth scenarios, changes in employment, and changes in taxation and population. These are used as indicators of potential changes in social values, but the interpretation of the nature of these as costs and benefits is left with the decision makers.

7.2. Results

7.2.1. Costs and benefits to irrigators

Table 11 outlines the modelled annual pasture growth for the various allocation scenarios. An example farm budget utilising these figures to derive a cash operating surplus is presented in **Table 12** below. This analysis outlines the major inputs and outputs utilised to derive an overall farm budget based on advice from local farm consultants. Similar analyses were undertaken for each of the allocation scenarios.

Table 11. Modelled average annual pasture growth (t-DMha/y)

Scenario	Additional Irrigated Area				
	100 ha	2,000 ha	4,000 ha	6,000 ha	9,500 ha
2	16.9	14.3	13.1	Not modelled	
3	17.4	17.3	17.2	17.0	16.9
4	17.4	17.2	16.9	16.8	16.5
5	16.9	16.8	16.7	16.6	16.4

Table 12. Example farm budget comparing dryland and irrigated scenarios

Item	Dryland	Scenario 3e restriction	Unrestricted irrigation
General			
Average annual pasture growth (t-DM/ha/y)	10.7	16.9	17.8
Annual pasture growth range (t-DM/ha/y)	6-16	13-20	14-20
Average summer soil moisture (% PAW)	4%	45%	53%
Annual re-grassing area (% farm/y)	22%	10%	8%
Stocking rate (cows/ha)	1.8	2.9	3.1
Average baleage cut & eaten (t-DM/ha/y)	1.2	1.9	1.8
Average annual water use (m^3/ha/y)	0	2,800	3,200
Annual milk production (kg-MS/ha/y)	700	1,130	1,210
Income ($/ha/y)			
Milk @ $5.50/kg-MS	$3,898	$6,237	$6,592
Other (calves & culled cows)	$218	$349	$369
Total	*$4,116*	*$6,586*	*$6,961*
Expenses[24] ($/ha/y)			
Re-grassing	$131	$57	$48
Cutting and wrapping baleage	$296	$470	$445

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[24] Excludes interest or principle repayments, depreciation, and tax

Irrigation	0	$116	$123
All other expenses	$2,045	$3,172	$3,313
Total	*$2,471*	*$3,815*	*$3,929*
Total per cow	*$1,360*	*$1,312*	*$1,278*
Total per kg-MS	*$3,49*	*$3.36*	*$3.28*
Cash operating surplus ($/ha/y)			
Per hectare	**$1,645**	**$2,771**	**$3,032**
Per cow	**$905**	**$953**	**$987**
Per kg-MS	**$2.32**	**$2.44**	**$2.53**

Table 13 lists of the calculated net value of irrigation under the various allocation scenarios. As also illustrated graphically in **Figure 61**, modelling results indicate that the economic viability of irrigation for individuals under Scenario 2 (status quo) reduces rapidly with relatively small increases in irrigated area. This suggests that current levels of irrigation in the Mataura catchment are close to the extent viable under the current flow allocation regime with an area of approximately 1,800 ha having a net positive financial return (although the rate of return reduces relatively quickly with small increases in irrigated area). This means that under the MCO the catchment is close to the point where the water resource can be considered fully allocated with respect to future run-of-river irrigation development[25].

For the 13 m^3/s and 17.6 m^3/s minimum flow scenarios modelled the decline in returns for individuals is less steep, but nevertheless significant. The average gross margin for the 9,500 ha of additional irrigation is between 44 percent (13 m^3/s minimum flow, reliability banding) and 63 percent (13 m^3/s minimum flow, no reliability banding) of an unrestricted irrigated operation.

Table 13. Net benefit (gross margin) from irrigation ($/ha/year)

Scenario	**Additional irrigated area (ha)**				
	100	**2,000**	**4,000**	**6,000**	**9,500**
MCO	$298	$73	-$249	Not modeled	Not modeled
13 m^3/s minimum flow, no reliability banding	$415	$388	$364	$315	$298
13 m^3/s minimum flow, reliability banding[26]	$415	$392	$334	$281	$238
17m^3/s minimum flow, no reliability banding	$302	$276	$255	$230	$209

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[25] As the MCO does not establish any finite allocation limits full allocation in this sense refers to the point at which reduced supply reliability means water use for irrigation does not provide a positive financial return.

[26] Results are average for each reliability band.

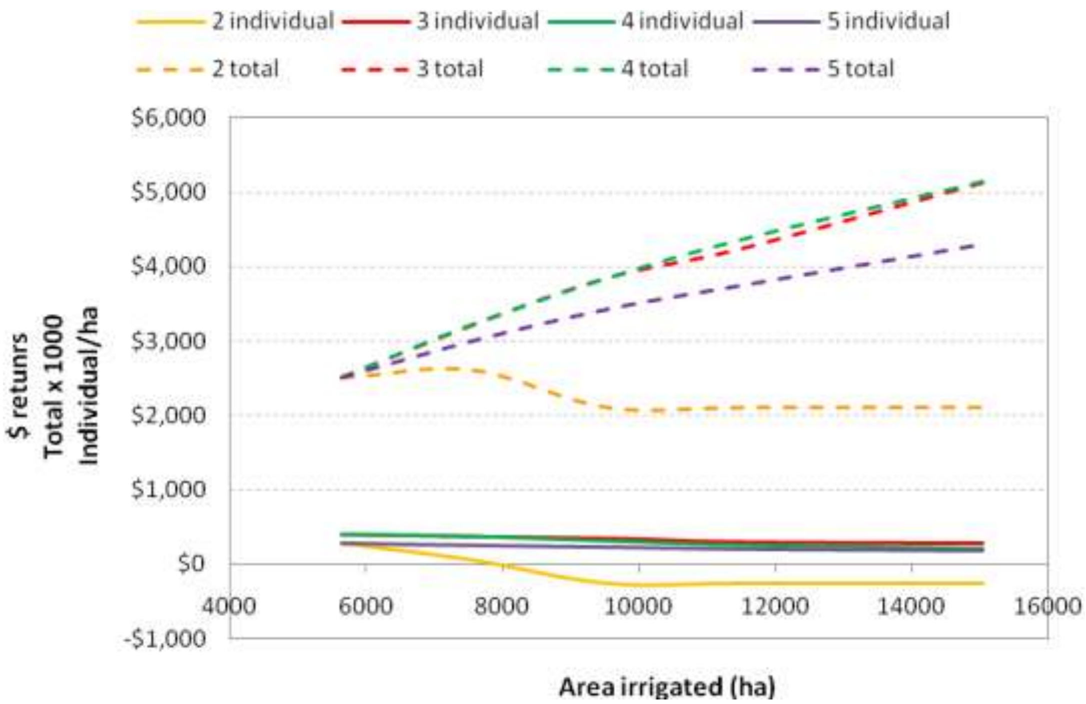

Figure 61. Estimated returns for irrigators

For the total of irrigated land area, the analysis (**Table 14**, **Figure 61**) shows that the current irrigated area under the existing MCO rules is close to the maximum that could be expected to be irrigated on an economic basis. However, under the alternate scenarios there would be an almost linear increase in net returns up to the maximum modelled. The higher minimum flow results in slightly lower returns, but there is no significant difference between the single or multiple band approach for setting allocation.

Table 14. Total net benefit (gross margin) from irrigation ($million/year)

Scenario	Additional irrigated area (ha)				
	100	2,000	4,000	6,000	9,500
MCO	$2.63	$2.77	$2.27	Not Modelled	Not Modelled
13 m^3/s minimum flow, no reliability banding	$2.64	$3.38	$4.06	$4.49	$5.43
13 m^3/s minimum flow, reliability banding[27]	$2.64	$3.39	$4.05	$4.62	$5.45
17.6 m^3/s minimum flow, no reliability banding	$2.63	$3.15	$3.62	$3.98	$4.59

This analysis strongly suggests that increasing the irrigated area will, all other things being equal, increase the regional returns but decrease the individual's returns. The position of existing irrigators can be protected through the use of reliability banding, and should the full 9,500 ha of irrigation be

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[27] Results are average for each reliability band.

implemented there would still be an increase in the overall regional returns. However, if the reliability falls to the point where new irrigation investment does not occur, the net gain to the region will not be realised. It is not clear that this point will be reached with the scenarios analysed here. Relevant points are:

- Even in the least reliable non-MCO scenario (i.e. 5e - 17.6 m^3/s minimum flow, 1:1 flow sharing, 9,500 ha additional area) pasture growth is still 94% of that achieved under full irrigation. It can be seen from **Table 15** that the pasture growth in Scenario 5e is significantly less than unrestricted irrigation in the period December to March, but is still considerably more than that achieved under a dryland regime.
- Pasture growth variability is much higher in the less reliable scenarios. The minimum pasture growth in the 5e scenario is significantly lower than in the full irrigation scenario (12.6 vs. 14.2tDM/ha/year). Furthermore pasture growth below 80% of the potential growth for that year is observed 6 times out of a 32 year record (1 in 5) in the 5e scenario. This suggests that variability of returns more than average returns are likely to be an issue with the lower reliability scenarios.
- Much of the gain associated with irrigation comes with the intensification of the farming operation. As previously described, the current dryland operation is typically below optimum stocking rates. There may be a number of reasons for this, including errors in the modelling, management skill, and adoption of a conservative farming operation to minimise downside risk. One of the benefits of irrigation is that it allows for greater certainty of returns, thus allowing greater intensification of the property. This intensification can be both capital intensification, as well as production intensification. If the irrigation does not significantly lower the variability of returns, then the gains associated with intensification may not be realised.

Table 15. Average monthly pasture growth comparisons

Month	Average monthly pasture growth: Scenario 5e compared to unrestricted[a]	Average monthly pasture growth: Dryland compared to 5e
June-August	100%	100%
September	100%	91%
October	100%	87%
November	99%	61%
December	97%	51%
January	92%	56%
February	79%	52%
March	75%	58%
April	84%	77%
May	92%	92%

[a] Unrestricted refers to takes with 100 percent reliability (i.e. no temporal pumping restrictions)

The question of the impact of supply reliability appears to be significantly different in the Southland Region to that experienced elsewhere in more traditional irrigation regions. In Southland, because dryland dairying is already viable, irrigation becomes more of a tool for generating additional feed than for enabling system change. Thus we can analyse the returns from irrigation as a cost/kgDM produced. In the case of those scenarios with an altered minimum flow, irrigation is expected to produce feed at a cost of 8 to 10c/kgDM. When reliability drops below 50%, as in the case of Scenario 2c (MCO rules plus 4000 ha of new irrigation), the cost of feed grown rises to 23c/kgDM.

For the Southland situation, where there is very low off farm costs to access water, irrigation may be worthwhile even in situations of a lower reliability than would be acceptable in other parts of the country. However, a key feature of this is the availability of low cost irrigation as, when storage and conveyance infrastructure is required, the cost of irrigation derived feed will rise rapidly to the point where it is no longer worthwhile. At $12,000/ha on and off farm costs (which is similar to that experienced at the North Otago Irrigation Company), the cost of feed is 18 to 22c/kgDM which is unlikely to be sustainable in the Southland situation.

7.2.2. Evaluation of Alternative Supply/Demand Scenarios

In order to evaluate the impact of alternative supply and demand options on the economics of irrigation in the Mataura catchment, two further scenarios were analysed:

- On-farm storage to improve irrigation reliability
- Potential impacts of long-term climate variability

On-Farm Storage

As outlined in the previous section, reliability of supply is a key factor determining the economics of water use in the Mataura catchment. One potential option to improve supply reliability within the existing regulatory framework is the use of water storage. The following section provides analysis of the economics of on-farm water storage as an option to improve supply reliability.

Economic costs and benefits of water storage for irrigation development were analysed using the methodology outlined in Section 4.4 and 4.5 to illustrate the trade-off in potential economic returns between increased reliability and increasing capital costs with increased storage volumes.

Analysis of the additional benefit/cost associated with on-farm storage was undertaken on three representative scenarios:

- Scenario 2a - essentially the reliability for the next water permit issued under status quo allocation and regulatory framework;
- Scenario 3e - the maximum irrigation scenario (9,500 ha) under a flow regime incorporating a 13 m^3/sec minimum flow at Gore, a total allocation of 30 percent of MALF and 1:1 flow sharing; and
- Scenario 5e - the maximum irrigation scenario (9,500 ha) under a flow regime incorporating a 17.6 m^3/sec minimum flow at Gore, a total allocation of 30 percent of MALF and 1:1 flow sharing.

A 250 m^3/ha storage pond would provide approximately 6 days of storage (at peak evapotranspirative demand) and a 500 m^3/ha pond would provide 12 days storage. Generally, this scale of storage would not result in a marked improvement in supply reliability as in all scenarios modelled supply restrictions would last for considerably in excess of 12 days in some years with consequent loss of pasture production.

The inclusion of storage in the modelling of the irrigation system suggests that storage can improve reliability, but only to a limited extent. The initial stage of modelling was limited to consideration of on farm storage, and analysis volumes that might be appropriate for on farm storage. The modelling results are shown in **Figure 62, Figure 63** and **Figure 64** below, and suggest that at a storage cost of $5/m^3 there is unlikely to be a net return from investing in storage, since the modelled CFS is lower with storage than without storage. This is because the capital costs of storage outweigh any benefits.

Some sensitivity testing was undertaken to assess when storage would become sufficiently beneficial to be worthwhile. At ~$3.50/m^3 cost for storage, the value of storage is close to neutral (**Figure 63**), but is unlikely to add sufficient value for it to be a worthwhile investment other than for insurance purposes. It becomes more beneficial the lower the cost, but the cost needs to be at $1/m^3 or below to show major benefits (**Figure 64**). Even then, with the current MCO flow allocation, even though storage may provide a benefit over and above no storage, there may still be a negative return overall from irrigation because reliability is so low under this flow regime.

These outcomes suggest that at least on farm storage is unlikely to be worthwhile. It may be that if there were a storage site that could be implemented relatively inexpensively, and there was likely to be a large area irrigated, then it may be worth investigating storage. However the results suggest that it is still only likely to be worthwhile if the flow regime is changed. This is because the size of the negative outcomes in the MCO regime as the area is increased mean that although storage may add value to an irrigation proposition, the overall proposition is likely to still produce a negative return.

The major caveat to storage viability is around product prices. A figure of $5.50/kgMS for dairy returns (based on a three year average) was utilised for the above analysis. However at $7.20/kgMS, which is the SONZAF prediction for 2014, storage becomes significantly more viable. **Figure 65** shows storage outcomes by scenario for a $7.20/kgMS prices and $3.50/m^3 storage cost.

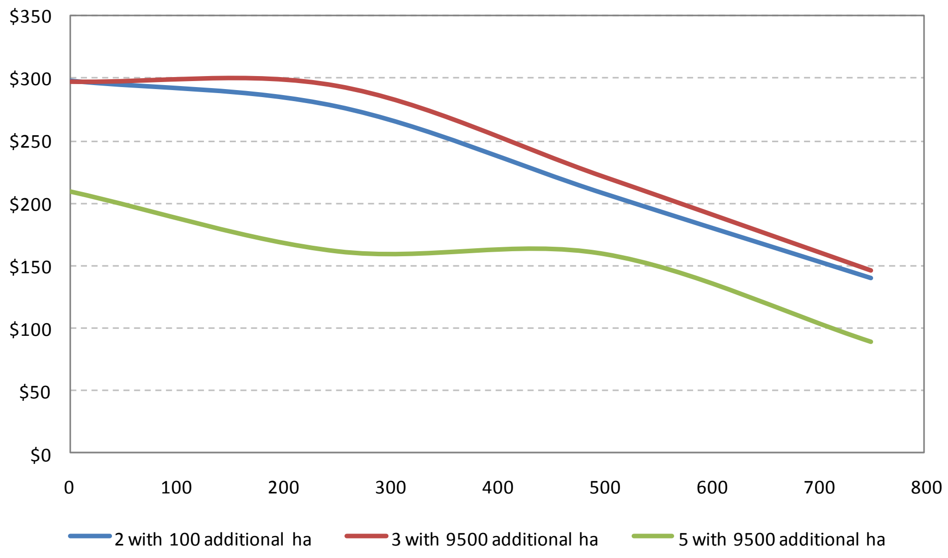

Figure 62. Per ha returns with storage (storage costs $5/m^3)

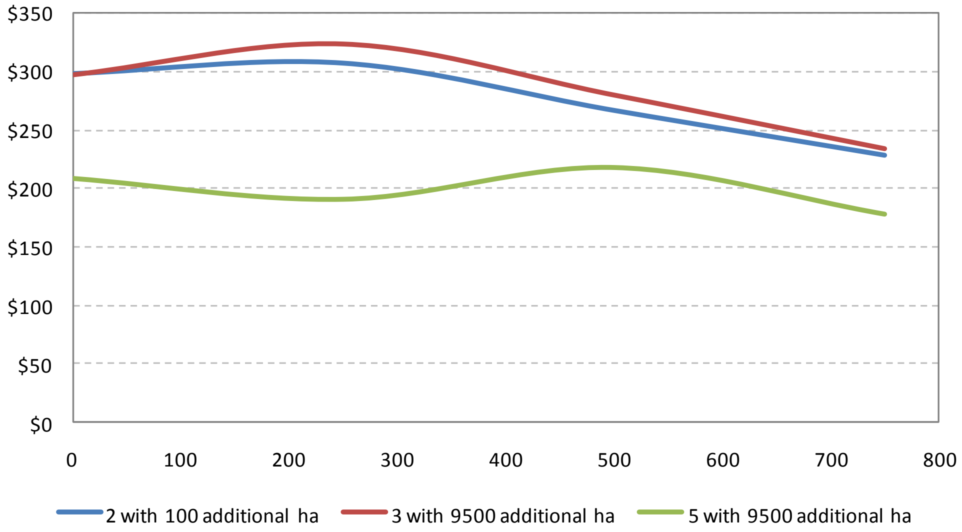

Figure 63. Per ha returns with storage (storage costs \$3.50/m^3)

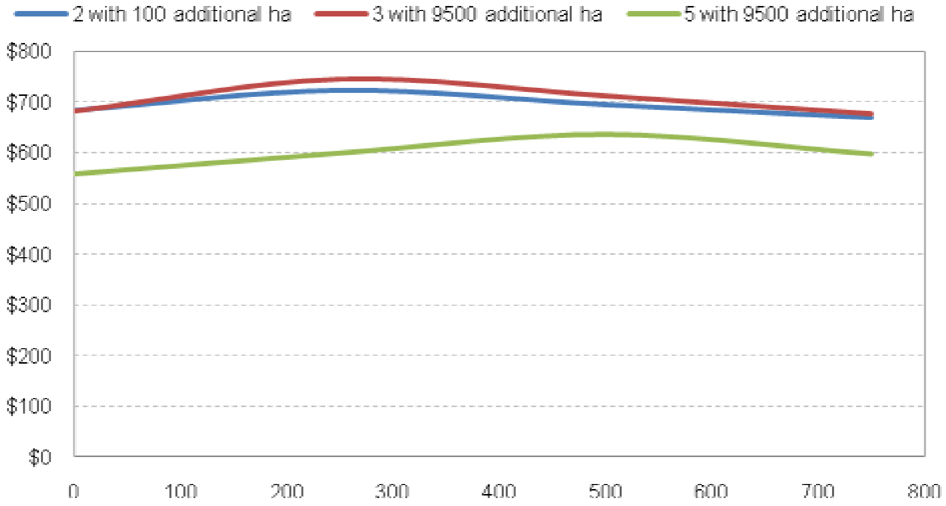

Figure 64. Per ha returns with storage (storage costs \$1/m^3)

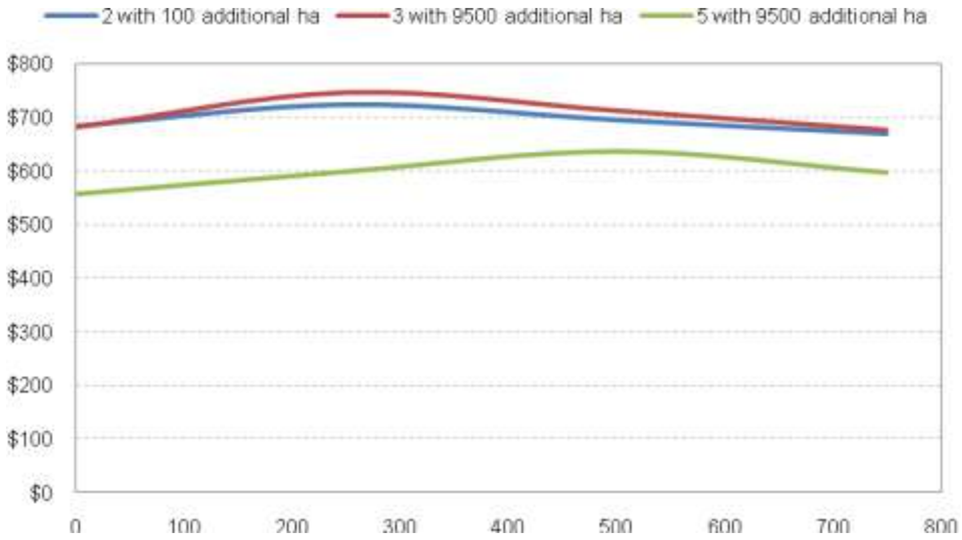

Figure 65. Per ha returns with storage at $7.20/kgMS dairy price (storage costs $3.50/m^3)

Climate Variability

As discussed in **Section 4.1**, long-term climate variability may have a significant impact on the economic viability of irrigation in the Southland Region.

A shift back to the drier climate experienced during the 1940's to late 1970's would have both a positive and negative impact on further irrigation development. Annual rainfall in the 1940's to 1970's was about 10% less than from 1978 to 2010, the period from which supply reliability and economic modelling in previous sections is based. A shift back to a drier climate would mean the economic value of unrestricted irrigation would be greater, because of the reduction in production under dryland conditions.

Without irrigation on light soils, a 10% reduction in rainfall in the Riversdale rainfall zone is expected to reduce average annual growth by about 1.1 t-DM/ha/y. However, drier conditions will also reduce flows in the Mataura and Waikaia rivers, increasing the frequency and duration of restrictions. River flow modelling, using correlation with rainfall records, suggests the number of days of restrictions would increase by 10 to 20% given a shift back to the drier 1940's to 1970's climate, with an associated cost of about $100/ha/y. Given both the reduced dryland production and the increase in restrictions, a shift to drier 1940's to 1970's type rainfall patterns is estimated to increase the estimated net value of irrigation presented in **Table 13** by about $200 to $250/ha/y.

Sensitivity Testing

The results were subjected to sensitivity analysis of key parameters. The analysis included:

- Changing the cost of capital to 6% and 10% (from the 8% used in the primary analysis)
- Feed prices from $0.14/kg to $0.22/kg
- Cost of irrigation development plus and minus 20%

- Product prices change +25%

The results of this analysis are listed in **Appendix E** and suggest that apart from changes to product prices, the results are not greatly affected by the input assumptions within the range tested. Clearly however, the viability of irrigation in the catchment will be significantly affected by product prices, and if recent trends in dairy prices continue then it is likely that there could be significantly more demand for irrigation than has been predicted here.

7.2.3. Regional Economic Impact

Any increase in irrigation in the Mataura would have a flow on impact in the wider economy. This can be represented by the changes in employment, GDP and household income. The changes associated with the scenarios assessed are shown in **Figure 66** and **Figure 67** below. The data indicate that:

- The 13m^3/s minimum flow scenarios (3 and 4) give the greatest economic impact, and this is approximately equal for both the banded and unbanded scenarios. The caveat on this, as for the irrigators returns, is that the available water is sufficiently reliable for irrigation investment to proceed.
- At the maximum level of development modelled (i.e. an additional 9,500 ha) irrigation could contribute up to $50 million in GDP and $28 million in household income. This is an additional $36 million in GDP and $20 million in household income above the current situation.
- In employment terms, the maximum irrigation development modelled (+9,500 ha) would contribute 680 full time equivalent (FTE) jobs in the region, which is an additional 480 FTEs over the current contribution.
- The net taxation impacts are calculated to be <$100,000 for the scenarios assuming small increases in irrigated area, to >$7 million/annum for the +9500 ha of irrigation scenarios. This taxation impact is nationally, and does not necessarily translate directly to additional social services in Southland, and even if it were the additional employment and population would tend to indicate greater demand for these services. However, an increase in taxation income does suggest potential for increased social services such as education and health.
- The data indicates that additional irrigation in the existing WCO rules would add to GDP, employment and household income. This is correct if the irrigation were to occur, because even if the returns to the farm owner are negative, the spending of money in the economy, and hiring of additional employees creates a wider economic impact. However, the likelihood, and sustainability of such a scenario is questionable. Long term economic impacts require profitable businesses.

The increases in economic activity, particularly regional GDP and household income, are significantly larger than the increase in the gross margin returns to irrigators, particularly when compared with the differences that might occur in other regions. This is probably because the profitability of irrigation is relatively low in the Southland region compared with other more traditional irrigation areas, and thus the CFS is much lower, while the overall impact on economic activity is similar to other regions.

It should be noted that regional economic benefit does not equate directly to impact. Not all of GDP or household income is welfare gain (i.e. it doesn't necessarily mean that people are better off). However, it does indicate the scale of potential changes in the regional economy, and to the extent that these are valued by the community they should be considered in the decision-making process.

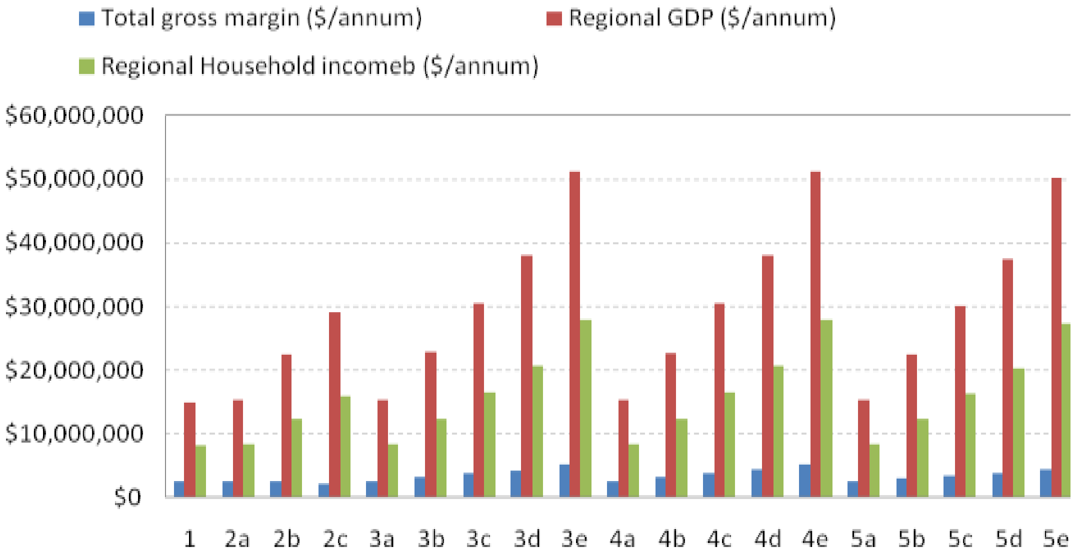

Figure 66. Regional economic impacts of different scenarios of irrigation development in the Mataura catchment ($/year)

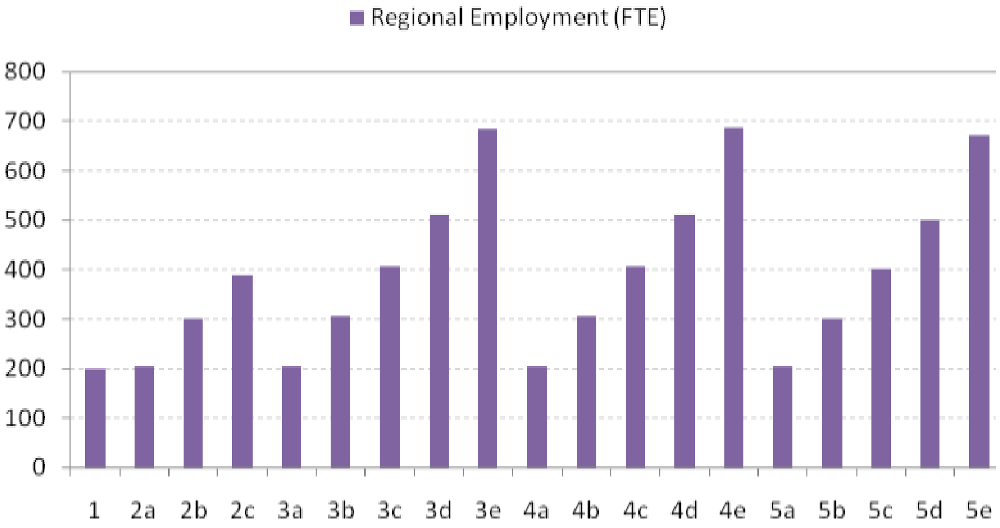

Figure 67. Regional employment impacts by irrigation scenario for the Mataura catchment (Full Time Equivalents)

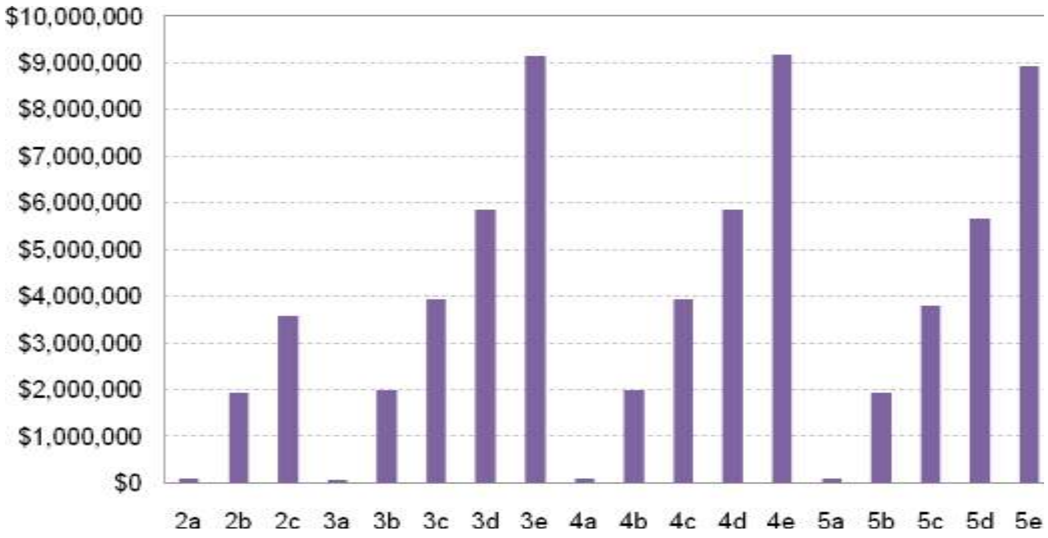

Figure 68. Regional taxation impacts by irrigation scenario for the Mataura catchment ($/year)

7.2.4. Potential impacts on municipal and industrial users

The major industrial users in the catchment are the Alliance meat works at Mataura, the Fonterra Edendale dairy processing plant, and municipal takes at Gore and Mataura.

There are no significant impacts of changes to flow regime on the two processing plants, as both have preferential takes allowing them to continue processing even at low river flows. The Edendale plant has an irrigation discharge consent to the river that is used at times when the ground is too waterlogged for land discharge. This consent requires a certain flow in the river to allow dilution of the discharge. If a new flow regime were to lower the proportion of time when this option was available, it would result in an increase in discharge to land at less favourable times. However, the Edendale plant considers that they would be able to manage this scenario through a combination of existing effluent storage, and managing discharge to land.

The Gore District Council (GDC) municipal takes also have no minimum flow limits, but water takes for the primary wellfield supplying Gore are required to implement water conservation measures below a flow of 17m^3/s at Gore. The council implements water conservation measures from this point, and implements an alternate day hosing ban at 13m^3/s, and a total hosing ban at 11m^3/s. The cost of this would be largely in time and inconvenience associated with hosing at specific times, but is not expected to extend beyond that. The additional days of some type of water conservation measures are estimated in **Table 16** below, and show that the scenarios with a 13m^3 minimum flow would cause an additional 36 days/year of water conservation measures at full irrigation (i.e. +9,500 ha). With the 17.6 m^3/s minimum flow there would be no requirement for additional water conservation measures. This is likely to overestimate the requirement for water conservation measures because it assumes full abstraction for the entire irrigation season. Therefore we can expect the actual impact to be something less than this number.

Table 16. Additional requirements for GDC municipal supply water conservation measures with increasing irrigated area (13 m^3/s minimum flow option only)

Additional irrigated area (ha)	100	2000	4000	6000	9500
Additional days/year of water conservation measures (13 m^3/s flow)	0.4	6.8	14.8	23.0	36.0

In addition to water takes, the Gore District Council sewage discharges are affected by river flows. Current consent conditions require that at $60m^3/s$ or below their dissolved reactive phosphate (DRP) levels should not exceed $1g/m^3$, and at or below $25m^3/s$ their DRP should not exceed $0.5m^3/s$. The council spends on average $140/day in chemicals and added another full time employee to accommodate this requirement. The irrigation takes will increase the requirement for sewage treatment, as shown in **Table 17** below, and would add an indicative $6,000 per annum with the full 9,500 ha of irrigation if all irrigators took their full entitlement throughout the irrigation season. However, because both the assumptions of an additional average cost of $140/day and the full take every day are significant overestimates, the true cost will be something less than this number.

Table 17. Additional requirements for GDC sewage treatment with increasing irrigated area

Additional irrigated area (ha)	100	2000	4000	6000	9500
Additional days/year of additional sewage treatment at $1gm^3$	0.1	3	7	10	15
Additional days/year of additional sewage treatment at $0.5gm^3$	6	13	19	24	29
Total cost (assuming $140/day of additional treatment)	$916	$2,215	$3,583	$4,779	$6,243

Preliminary figures provided by Solid Energy suggest that, as an example, a lignite to urea plant could add up to $370 million in GDP annually, and a further 370 jobs directly, 620 regionally and 1,470 nationally. These figures are obviously predicated on a number of assumptions regarding product prices and production size, but suggest that the impacts of a large scale industrial plant are likely to significantly outweigh any economic impacts from irrigation.

7.2.5. Environmental costs and benefits

The environmental costs and benefits will potentially arise as a result of changes to the river flow regime and from changes to nutrient loadings in the river. There are potentially some changes to biodiversity, landscape and aesthetic values with the land use changes, but because most of the impact will be intensification of existing systems, any such impacts are likely to be minimal.

Impacts to flow regimes

Any changes to flow regimes in the Mataura catchment as a result of additional abstraction would vary depending on the minimum flow (if any) adopted and with the volume of water abstracted. We can assume that if changes involve additional allocation, potentially there will be some impact, but the extent of any such effect cannot be defined because of timing and magnitude issues (particularly when abstraction occurs from hydraulically connected groundwater where there is both a temporal lag and scaling effect between abstraction and ultimate effects on surface water flows). There may also be some benefits associated with establishing a defined minimum flow as proposed in the alternative scenarios, although at the current level of allocation provided by the MCO, the environmental benefits accruing from the establishment of a minimum flow are likely to be relatively minor (given that the current level of allowable effect is within the margin of error of typical flow measurement)[28]. However, the final outcome of any changes to the flow regime cannot be definitively assessed as a cost or benefit at the current time, and further detailed investigation is likely to be required in this area before proceeding.

Impacts on nutrient loads

Land use intensification typically impacts on losses of nutrients to waterways, particularly where intensification and dairy cattle are part of the land use change mix. **Figure 69** shows that while there has been an apparent increase in Nitrate/nitrite loads, the total N load appears to have decreased. While there are some possible explanations for this associated with limiting nutrients and conversion of organic N to inorganic N[29], the lack of clarity over the direction of total N change suggests that the impact of future land use change and intensification may similarly be difficult to determine.

Similarly, increased nutrient losses resulting from land use intensification also have the potential to impact on groundwater quality in underlying aquifers, particularly in terms of nitrate-nitrogen concentrations. As discussed in **Section 2.4**, increased nitrate concentrations may have a significant influence on surface water receiving appreciable baseflow discharge. However, the relationships between land use and resulting impacts on groundwater quality can be very complex being influenced by a range of factors including current land use and land use practices, historical land use, nutrient transformation processes in the soil zone as well as the hydrogeological characteristics of the underlying aquifer.

In the Mataura catchment overall, recent assessment of groundwater quality data indicates approximately 40 percent of monitoring sites with sufficient data exhibit statistically significant increasing trends in groundwater nitrate concentrations (Liquid Earth, 2010). However, observed changes in groundwater quality do not always appear correlated with observed land use. For example, recent investigations in the Balfour area present a good example of the complex interplay of factors that influence overall groundwater nitrate concentrations (Wilson, 2009). However, it would be typically expected that groundwater nitrate concentrations will increase in response to intensification of land use[30].

Spreadsheet modelling detailed in **Appendix F** suggests that the nutrient losses from land will increase by approximately 6% in the 50% Conservative land use change scenario, with greater increases possible the more the increase in irrigated land use (see **Figure 70**).

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[28] Application of a minimum flow under the current allocation regime would also reduce the reliability of supply for existing industrial and municipal supplies from surface water and hydraulically connected groundwater

[29] Possible interpretations of the observed variations in organic/inorganic nitrogen loadings include:

1. P loadings have been decreasing, resulting in reduced conversion of inorganic N to organic N.
2. The increase in inorganic N may be due to a reduction in the conversion to inorganic N, not an increase in the loading.

[30] A Ministry of Science and Innovation funded project commencing in the Mataura catchment in the 2011/12 year will investigate factors influencing the potential impact of land use on groundwater quality.

In terms of surface water quality nutrient outcomes from the future land use scenarios associated with the assumed increases in irrigation development (**Appendix B**) were modelled by NIWA using the CLUES model (NIWA, 2011). Results of this assessment are provided in **Appendix G** and suggest if the arable/dairy support land use does not have significant numbers of animals (i.e. its nutrient losses were that of a more typical arable operation), the impact of any irrigation development on the catchment will be relatively small with current mitigation practices such as stock exclusion from streams (1 percent increase in Total-N and a 4 percent increase in P at the river mouth). This modelling further indicates that if significant new mitigation measures (including stock exclusion, nitrification inhibiters, herd shelters, improved farm dairy effluent (FDE) management and constructed wetlands) are adopted there could be an overall decrease in surface water nutrient concentrations despite an overall intensification in land use.

While there are obvious limitations to the modelling approach adopted by CLUES (e.g. the role of groundwater as a primary transport mechanism for N), the results of the analysis undertaken suggest that the environmental impact of the additional irrigation will be primarily driven by land management practice rather than land use *per se*. Thus the extent of any costs and benefits that arise will depend on the mitigations that are implemented. Based on current practice we would expect some, reasonably small increase in nutrient losses, but if more widespread mitigation were implemented in association with additional irrigation, the net impact could potentially be an overall improvement in nutrient outcomes.

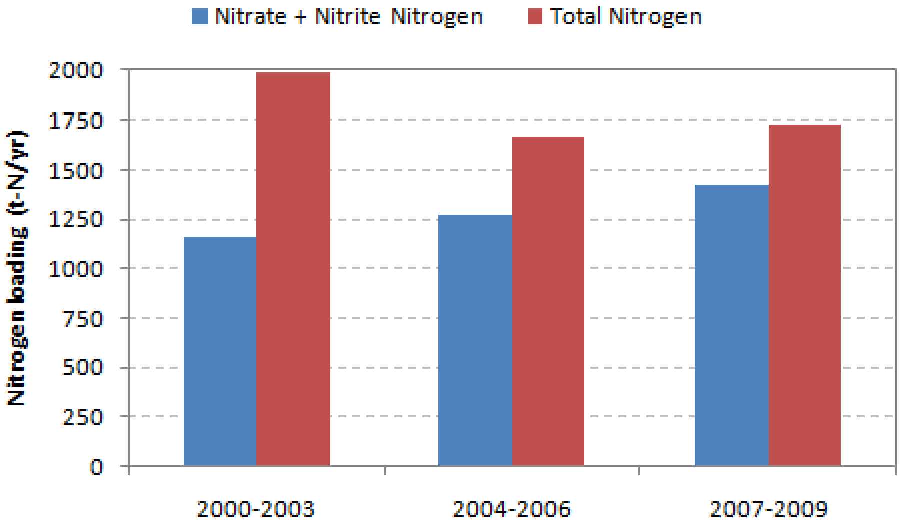

Figure 69. Changes in Nitrogen loadings over the last decade at Gore

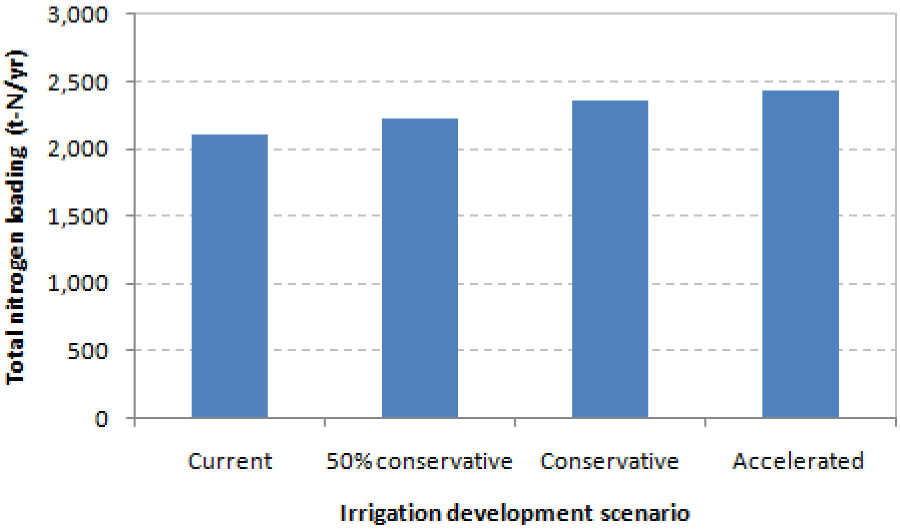

Figure 70. Predicted changes in nutrient loading in the Mataura River at Gore for each land use change scenario

Value of Environmental Impacts

As potential environmental impacts associated with increased water use in the Mataura catchment are mainly non-market impacts (i.e. they are not traded in any marketplace), they are hard to value and compare with the monetary benefits gained from irrigation. There have been a number of New Zealand studies which have attempted to place a monetary valuation on these types of non market impacts.

Yao and Kaval (2007) compiled data from 92 non market valuations from 1974 to 2005. They found an average value for consumer surplus per person per day associated with water resource improvement of $2.96, and a maximum value of $54.08. Multiplying the average figure by the number of days in the year and the number of people in New Zealand, they found a consumer surplus value for water resource improvement of $4.6 billion. They note that the non-use values in the range of studies undertaken were typically three times higher than the use values ($0.85/person/day). This valuation information is based primarily on water quality, and many of the studies were associated with groundwater and drinking water rather than quantity of water *per se*.

Kerr (2004) similarly reviewed non market valuations for water resources in a study for Meridian Energy. He found that the average value for recreational fishing was $39/user per day from four studies covering the Rakaia, Rangitata, Greenstone/Caples, and the Tongariro rivers. It should be noted that the resources studies in these situations were considered iconic, which is a similar status to that of the Mataura in terms of the value of its fishery. Kerr estimated the value of the lower Waitaki at between $1.7 and $2.1 million per annum, including recreational benefits from 36000 angler days and between 15,000 and 20,000 other user days. They concluded that the recreational benefits were likely to have little impact on the overall cost-benefit of the river because the recreational benefits were so substantially outweighed by other use benefits from the river (hydro and irrigation).

Kerr also reviewed non market valuations of existence values in New Zealand water resources. These are summarised in the report and the valuations ranged from $13/household per year[31] to $243/household/year (2009 values[32]), with a mean of $72/household per year.

A report compiled by Sharp and Kerr (2005) for the Waitaki Catchment Water Allocation Board provides a good summary of regional studies undertaken to establish non-use valuations for various environmental values associated with selected water resources in New Zealand. While not directly related to the potential environmental benefits derived from this proposal, the assessments undertaken are useful to provide context for the consideration of economic values associated with water. The summary table for non market valuations from that report are shown in **Table 18** below. Kerr and Sharp compared use values with the existence values and found that in some cases (Kawarau) the existence values may exceed the use values by a substantial margin. They concluded that:

"Even allowing for possible inaccuracy, change in TEV estimates derived for the Kawarau River indicate that people from all over New Zealand placed significant values on protection of the natural environment. For the Kawarau case, non-market values amounting to hundreds of millions of dollars per year send a clear signal that non-market impacts can be of sufficient magnitude to cause otherwise financially viable developments to fail a cost benefit test.

In the Waimakariri catchment the willingness to pay to prevent further irrigation development was positive and amounted to a NPV of $185 million for Canterbury households. Similarly reserving flows in the Ashburton River was valued at over $80 million. These types of studies are relevant to the Mataura because they indicate that maintenance of the status quo river state has a substantial and positive value.

Table 18. Summary of Non Market Existence Valuation reports ex Sharp and Kerr (2005) (Figures CPI indexed to Dec 2009).

Author(s)	Study population	Item valued	$ per house hold per year	NPV million
Kerr	NZ households	Prevent Kawarau River hydro-electricity development	$236	$2,354
Harris	Households in 4 main Waikato urban centres	Prevent Waikato River pollution returning to 1960s quality	$111	$1,110
Kerr, Sharp & Leathers	Canterbury households*	Prevent Waimakariri River irrigation development for 5 years	$44	$185
		Preserve the Waimakariri River in its existing state	$50	$504
		Improve Waimakariri River water quality from D to C standard	$41	$414
	Canterbury households* that use the Waimakariri	Prevent Waimakariri River irrigation development for 5 years	$54	$224
		Preserve the Waimakariri River in its existing state	$61	$613

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[31] Water body related valuations only.

[32] Updated using CPI index 1.19 from June 2003 to Dec 2009

Author(s)	**Study population**	**Item valued**	**$ per house hold per year**	**NPV million**
		Improve Waimakariri River water quality from D to C standard	$48	$480
	Canterbury households* that do not use the Waimakariri	Prevent Waimakariri River irrigation development for 5 years	$18	$75
		Preserve the Waimakariri River in its existing state	$14	$140
		Improve Waimakariri River water quality from D to C standard	$17	$162
Kerr, Sharp & Leathers	Canterbury households*	Prevent Rakaia River irrigation development for 5 years	$53	$218
		Preserve the Rakaia River in its existing state	$51	$515
	Canterbury households* that use the Rakaia	Prevent Rakaia River irrigation development for 5 years	$92	$384
		Preserve the Rakaia River in its existing state	$92	$917
	Canterbury households* that do not use the Rakaia	Prevent Rakaia River irrigation development for 5 years	$30	$124
		Preserve the Rakaia River in its existing state	$30	$298
Lynch	Canterbury households (excludes Ashburton)	Preserve Ashburton River flows	$84	$841
Lynch	Ashburton District households	Preserve Ashburton River flows	$141	$1,412
Sheppard et al.	Christchurch Households	Improve lower Waimakariri River water quality from D to C standard	$165	$1,650
Williamson	Auckland City households	Orakei Basin water quality	$13	$135
White, Sharp & Kerr	Waimea Plains households	20% reduction in Waimea Plains groundwater extraction	$243	$2,433
Kerr & Sharp	North Shore households	Stream channel rehabilitation	$71	$704
		Stream clarity	$80	$800
		Streamside vegetation	$25	$255
		Loss of one native fish species	$13	$134

In order to further identify the non irrigation values associated with the Mataura River it would be necessary to undertake a choice modelling study specific to that river. This involves surveying individuals for their willingness to pay for different states of the river in relation to values that they are concerned about. This modelling allows an estimation of the value to the community impact of different alterations to the state of the river, and a more direct comparison with costs of those changes to irrigators. These studies are relatively expensive and time consuming to do well, but may be worthwhile in cases where the changes considered have significant impacts on both economic and non market values.

Angler and recreational values

The NIWA angler survey was last produced in 2007/08 and showed that the Mataura River had an estimated 40,000 angler days at that time, down from 53,000 in 2001/02. Of these only approximately half were below Gore. The Mataura is nationally very highly regarded as a dry fly fishery[33].

A number of studies have estimated the value of an angler day fishing. These range from $24 to $55/day ($2003) using the travel cost method and $48/day using a contingent valuation method, with an average of $36. Kerr (2004) used a figure of $39/angler day to estimate the total recreation value of the Waitaki catchment. Applying this latter figure to the angler recreation in the Mataura main stem, and adjusting for inflation would give a figure of $1.8 million per annum.

Converting this to a NPV valuation, and allowing for the same trend increase in use of the river over the next ten years as has occurred over the last period of angler survey, gives an estimate of $21 million NPV (30 years[34]) for angler use of the Mataura River. It is important to note that this is the total value, not the change in value as a result of the different allocation and water quality outcomes. We would expect the marginal difference as a result of the different regimes to be somewhat less than this value.

7.2.6. Cultural Values

The natural resources, speciaes and taonga associated with the Mataura River have significant cultural value for Ngäi Tahu Whänui. In particular, the mauri of the resource is of particular importance for local iwi. The mauri described the life-force that flows from the wairua and is a value that can be represented by '*the qualities of health, abundance, vitality, the unpolluted and the presence of indigenous flora and fauna*'[35].

In 2007, the importance of the mahinga kai associated with the Mataura River was recognised by the granting of a mataitai on a 10 kilometre stretch of the river in the vicinity of Mataura. This mataitai provides for the management of important mahinga kai species including kanakana and tuna by, and on behalf of, local iwi.

While the cultural values associated with the Mataura River are recognised as key values in the future management of the river, it is difficult in the context of a report such as this, to quantify those values in terms directly comparable with other values associated with the river. This does not diminish the importance of cultural values but highlights the need to incorporate these into river management on an other than strictly financial basis.

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[33] http://www.nzfishing.com/FishingWaters/Southland/STHFishingWaters/STHMataura.htm

[34] Allowing for a trend increase for 10 years then static numbers.

[35] From the Mataura Mataitai Management Plan

7.3. Summary

The cost and benefits of future water resource development in the Mataura catchment can be summarised as:

- Unchanged outcomes for existing irrigators, although potentially some costs if additional mitigation were required;
- For individual farmers adopting new irrigation, there would be a decreasing return as more area is irrigated;
- For the aggregate of irrigators across the catchment, there would be an increase in benefit as more area is irrigated. The extent of this benefit will depend on the area irrigated, but with a 13 m^3/s minimum flow and an additional 9,500 ha irrigated, there would be an increase in the order of $2.8 million per annum in cash farm surplus to irrigators in the catchment.
- There would be an increase in GDP, employment, household income and taxes with increasing irrigation. These outcomes are less affected by the reliability of the irrigation, except to the extent that this prevents the full uptake of available irrigated area. In the larger irrigated areas (+9,500 ha) and a 13 m^3/s minimum flow there would be an additional $37 million in GDP, $20 million in household income, and 490 additional full time equivalent jobs. This constitutes approximately 0.1% of the regional GDP and 0.8% of regional employment. Taxation takes would be expected to increase by $9 million per annum.
- There will be a relatively minor impact on municipal and industrial takes.
- There are potentially very large impacts from the proposed lignite mining operations. This would dwarf other economic activity in the catchment, but the exact nature and size of these impacts is still to be determined. Furthermore, the interaction of these operations with any environmental and social impacts is unknown at this stage.
- There are very significant environmental values associated with the Mataura River. While it appears that the extent of any impacts would be relatively small, this needs to be confirmed by further modelling and technical work. It does appear that land management rather than land use will have the greatest impact on nutrient associated environmental values, so additional irrigation will not necessarily result in negative environmental outcomes.

The stakeholder feedback from a catchment workshop held on 15 October 2011 weighted the environmental outcomes in the Mataura River at 50 percent overall of the overall ranking with economic scoring 20 percent, and social and cultural both 15 percent. In the catchment workshop discussed above, the angler values associated with the river were considered very important in both the environmental and social categories, particularly for the environmental stakeholders. This can be taken as a strong indication that there needs to be careful consideration of any proposals that substantially alter the environment of the Mataura catchment to ensure the associated environmental costs do not outweigh economic benefits derived. Because there is only a modest gain in gross margin or welfare from irrigation because of its relatively marginal economics, the more significant trade off is likely to be between any environmental impact and the social benefits associated with increased economic activity and employment, and its associated employment and taxation impacts.

8. Options to Enhance Sustainable Water Use

The following section reviews five options for future management of water resources in the Mataura catchment including:

1. Retaining the status quo;
2. Improving technical water use efficiency;
3. Improving allocative efficiency;
4. Amending the existing regulatory framework;
5. Development of water storage

It is noted that while Options 1 and 4 are mutually exclusive, various combinations of the remaining options may potentially play a role in future management of water resources in the Mataura catchment. In particular, Options 2 and 3 relating to improvements in technical and allocative efficiency essentially represent ‘best management’ outcomes that can assist sustainable water resource management regardless of the regulatory framework under which they apply.

8.1. Option 1 - Status Quo

As described in **Section 3.1**, the MCO forms the central core of the existing regulatory framework for the management of water resources of the Mataura catchment. Since its notification in September 2000, MCO provisions have been complemented by the RWP which specifies a range of objectives, policies and rules which apply to management issues outside the immediate scope of the MCO. Together, the MCO and RWP define the current framework for managing the quantity and quality of water resources in the Mataura catchment.

While the MCO establishes the significance of nominated values in the Mataura catchment (fisheries and angling amenity), a range of potential issues exist with the current management provisions that complicate existing management of the resource and which will undoubtedly constrain the ability of Environment Southland to pro-actively address future water resource management issues in the catchment. In part, these issues reflect the origin of the MCO as a policy instrument in the early 1980’s to protect values associated with the catchment in the absence of an existing regulatory regime. Over the subsequent period, scientific understanding of the resource, issues associated with its management as well as established resource management practice all have evolved (and will likely continue to do so into the future).

As a result, there are a number of potential aspects of the current management that may hinder future sustainable management of the resource, particularly when viewed in the context of sustainable management defined in Part 2 of the RMA. These issues include:

- The current management framework was established to manage water resources in terms of the nationally significant values established by the MCO process. As discussed in **Section 6**, these values may represent only a subset of the overall values attributed to the water resources of the Mataura catchment;

- The existing system of water management is (in some aspects) administratively complex and may be subject to subjective interpretations. This can lead to uncertainty and a lack of clarity in the resource management decision-making process;
- Existing allocation provisions provide limited scope for additional allocation for consumptive water use; and,
- Water quality impacts associated with land use change and/or intensification may present a major resource management issue in the Mataura catchment. These issues are not particularly well addressed by current management provisions.

The following section explores some of the issues associated with the current water resource management framework in the Mataura catchment, in part based on experience with the application of existing provisions in the face of the increased pressure for water resource development which has occurred over recent years.

8.1.1. Flow Allocation

The current allocation regime specified in the MCO was not developed on the basis of a scientific assessment of the flow requirements to maintain the nationally significant values attributed to the catchment (in the currently accepted sense). Rather, the Planning Tribunal adopted a conservative allocation regime which, by general consensus of the parties involved, was considered as being likely to provide a high level of protection to the values associated with the river while providing for anticipated future use of the resource[36]. Overall, the Planning Tribunal concluded that *'...the 95% flow regime.......should be included for the purpose of protecting the outstanding features earlier identified. We think this can be done without adversely affecting existing users, or reasonably foreseeable future users, and consequently in the interests of conservation it should be done*'.

As a result, the current flow allocation provisions are not particularly well aligned with the values they are intended to protect other than by virtue of their relatively conservative nature. For example, one consequence of the way the flow allocation provisions were adopted (particularly in comparison with more contemporary environmental flow regimes adopted for other rivers in New Zealand[37]) is that the existing provisions do not recognise the potential for a larger proportion of water to be available for allocation at higher flows or the potential environmental benefits associated with the cessation of consumptive use during periods of low flow (e.g. by application of minimum flow cut-offs). In addition, with the benefit of hindsight, it is clear the scale of future water demand was under-estimated at the time the order was drafted and significantly higher demand has arisen, particularly over the past decade.

Implementation of proportional allocation

The MCO flow allocation provisions provide for a fixed proportion of flow to be allocated for consumptive use (5 or 10 percent depending on location). In order to maintain compliance with the

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[36] It was anticipated future use of the resource associated with thermal power generation in the lower catchment that resulted in the increased allocation (10 percent of flow) available for out of stream use in the lower catchment.

[37] Including some Water Conservation Orders that specify tiered levels of allocation subject to different minimum flows

MCO flow allocation provisions, Environment Southland has adopted a series of stepped minimum flow cut-offs that are applied to surface water takes or groundwater takes classified as having a high or direct hydraulic connection to surface water under RWP Policy 29. As illustrated in **Figure 71**, above a specified minimum of 9 m^3/s (based on the lowest recorded river flow), allocation is managed in 0.1 m^3/s blocks with each sequential block having a 2m^3/s higher minimum flow.

Minimum flows are applied to individual resource consents based on the nearest downstream flow recorder (Parawa for takes in the upper catchment, Gore or Mahers Beach for takes in the Waimea Plain and Seaward Downs or Tuturau for takes in the lower catchment), although in some cases individual takes may have more than one minimum flow to manage cumulative effects down the catchment.

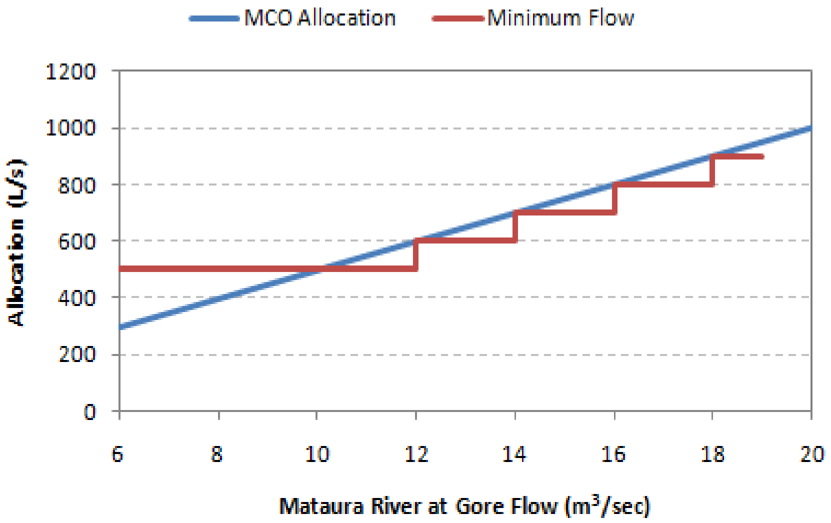

Figure 71. Example of minimum flow restrictions applied to surface and hydraulically connected groundwater takes upstream of the flow recorder at Gore

This system of stepped minimum flows at multiple sites has created some practical difficulties with regards application of current flow allocation provisions and management of future allocation. These include:

- Ensuring compliance with existing minimum flows is complicated in situations where more than one minimum flow is applied to an individual water permit (particularly when the relationship between flow at various points in the river system is not necessarily linear);
- Application of stepped minimum flows significantly alters the reliability of supply for individual users and creates issues related to equity. This situation has created tension between individual users particularly in the absence of any guidance to prioritise access to water between water use types (e.g. industrial vs municipal vs irrigation etc); and,

- Future difficulties are likely to arise with regard to managing allocation as, and when, individual resource consents expire, particularly if replacement consent is not sought for individual water takes or an application is made for altered volumes. This situation has the potential to alter the calculation on which current allocation (and therefore existing minimum flows) is based. This could result in an administratively complex situation where existing minimum flows on existing consents with higher minimum flows are adjusted downwards, or alternatively where the available allocation is granted to a new consent (with consequently higher reliability than for some existing consents) potentially creating equity issues for existing users.

Spatial Integration with RWP

Although all tributaries of the Mataura and Waikaia rivers upstream of (and including) the Otamita Stream are included in the MCO definition of ‘protected waters’, the flow allocation provisions of Section 4 only relate to *‘...rates of flow in the Mataura River and in the Waikaia River...’*. As a result, allocation of surface water in tributary streams is currently managed in accordance with Rule 18 of the RWP but must also ensure compliance with the MCO at a catchment scale. Given the difference in allocation methodology and application of minimum flows, integration of surface water allocation (including hydraulically connected groundwater takes assessed under RWP Policy 29) between tributaries and the main stems (managed in terms of the proportional MCO regime) is difficult to achieve in a practical sense[38].

Ensuring compliance with flow allocation provisions

A further difficulty with ensuring compliance with the MCO flow allocation provisions arises due to the difficulties associated with measurement of river flow at a resolution sufficient to detect changes in flow attributable to consumptive water use. This difficulty arises for three reasons:

- Measurement error can potentially comprise a significant proportion of the available allocation during periods of low flow. For example, recording equipment installed at the Environment Southland flow recorder site at Gore has a maximum rated accuracy of +/- 1mm which, based on the current rating equates to a maximum accuracy of +/- 0.1 m^3/s, notwithstanding other potential sources of error inherent in standard flow measurements. Overall, the standard error in a typical flow measurement is considered to lie in the range of +/- 5 to 8 percent of discharge;
- A majority of consumptive water use in the middle and upper reaches of the Mataura catchment occurs from groundwater with varying degree of hydraulic connection with surface water. As a result there is an appreciable lag between abstraction and potential effects on river flow; and,
- Only a proportion of water allocated for consumptive use is actually used (and historical water use compliance records have been incomplete).

It is therefore not possible to accurately quantify the actual magnitude of reductions in river flow resulting from existing consumptive water use. Examination of available flow records do not show any short-term variations in flow that can be directly attributed to consumptive water use or indicate any obvious changes in the overall rate of flow recession over time upstream of Gore. Downstream of Mataura some minor variations in water levels have been observed in the historical record due to the

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[38] It is also noted that cross boundary issues have occurred in previous instances whereby water takes have been authorised in the upper reaches of the Mokoreta River without regard to cumulative MCO flow allocation as administered by Environment Southland

operation of large-scale industrial takes. As a result, current compliance with MCO flow allocation provisions is based entirely on the theoretical effect of existing allocation rather than observed effects on actual river flow.

Management of groundwater/surface water interaction

The MCO does not contain any specific policies relating to the taking and use of groundwater. In part, this reflects knowledge of the nature of groundwater/surface water interaction when the Order was drafted, as well as the prevailing orthodoxy at the time that management of groundwater and surface water quantity were essentially separate issues. The lack of specificity regarding management of groundwater/surface water interaction in the MCO means that policies developed during the RWP process have been applied by Environment Southland to manage the effects of groundwater abstraction on surface water discharge.

However, it is noted that Section 67(4)(a) of the RMA specifies that a regional Plan must not be inconsistent with a Water Conservation Order. In the case of the MCO, while wording of the Order itself is silent with regard the management of groundwater/surface water interaction, the Planning Tribunal decision makes specific reference to groundwater by stating '*it was and still is intended that the whole of any authorised inflows that do <u>not</u> have their source in the protected waters, as for example groundwater, shall be available for abstraction*'. As a result, although the current application of Policy 29 appears to be consistent with the underlying 'intent' of the Order (in that the stream depletion effect from hydraulically connected groundwater is counted as part of the cumulative surface water allocation), current management of groundwater/surface water interaction could potentially be subject to challenge on legal grounds with regard to the literal interpretation of the Planning Tribunal decision (i.e. that all groundwater shall be available for abstraction).

This would appear to be a significant weak point in current management of water resources in the Mataura catchment. If, for example, an appeal with regard to the current management of stream depletion in the Mataura catchment were upheld by the Environment Court, this would reduce allocation from the Mataura River to around 10 percent of the current total (i.e. approximately 90 L/s) potentially allowing a significant volume of additional surface water abstraction. Alternatively, a stricter interpretation of the MCO decision[39] could potentially remove current controls on groundwater allocation through RWP Rule 23 (Abstraction and use of groundwater) and Policy 29 (Stream depletion effects).

The second point relating to current management of stream depletion regards the fact the current management provisions only manage the effects of groundwater takes classified as having a direct, high or moderate degree of hydraulic connection. In a catchment such as the Mataura all groundwater takes, including those with a low degree of hydraulic connection will result in some effect (albeit relatively minor in many cases) on surface water flows on a seasonal basis that contribute to the overall cumulative effect on baseflow discharge at a catchment scale. This issue, and a potential option for managing cumulative stream depletion effects, is further discussed in **Section 8.4** below.

Location of sites used to establish compliance with MCO flow allocation provisions

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[39] Regarding the stated intent that '*the **whole** of any authorised inflows that do <u>not</u> have their source in the protected waters.... **shall be available for abstraction***'

Section 4 of the MCO refers to maintenance of flow '*at any point......, where the flow is estimated by the Southland Regional Council from measurements undertaken at that point*'. Due to the mobility of the bed materials and problems maintain a reliable rating, flows are currently only recorded on a continuous basis at Parawa, Piano Flat, Mahers Beach, Gore, Tuturau and Seaward Downs. These sites (particularly Parawa and Gore) are the current reference sites used to establish compliance with the MCO flow allocation provisions.

As a result of the significant interaction between the Mataura River and surrounding riparian aquifer, appreciable flow loss is observed between Ardlussa and the Waikaia River confluence. Due to the magnitude of the observed flow loss (and downstream flow input from the Waikaia River), recent analysis by Hay (2010) highlighted this section of the river as a critical reach for maintaining habitat to support the nationally significant values attributed to the trout fishery. Due to the mobility of bed material and problems maintaining a reliable rating flows are only recorded by manual gauging in this reach on an irregular basis. As a result, the potential exists for abstraction (as currently managed) to result in an alteration to flow in excess of the MCO allocation provisions over this reach, while remaining compliant at the downstream Gore site as a result of surface water inflows and baseflow discharge over the intervening reach.

Consumptive vs non-consumptive water use

One of the issues which has emerged with the practical application of the MCO in recent years is the potential for subjective interpretation as to the manner in which individual provisions should be applied.

Section 4 of the MCO refers to the allocation from the river as including '*water taken in accordance with the Act from the protected waters upstream of that point and not returned to the protected waters*' This infers that takes which return some or all water to the river will be considered as non-consumptive and excluded from the cumulative allocation. However, the provisions do not specify a spatial or temporal scale over which they apply, resulting in a requirement for subjective interpretation to differentiate between consumptive and non-consumptive takes.

For example, at the current time water abstraction for the Alliance meat works at Mataura is managed by Environment Southland as a non-consumptive take as water taken from the river and utilised for cooling and other industrial processing is treated and returned to the river within a short distance downstream of the point of abstraction. However, in the case of the Gore District Council municipal supplies for Gore, the calculated stream depletion effects of water abstracted from the existing supply bores is counted as part of the existing allocation from the Mataura River despite being returned to the river via the Gore oxidation ponds (return flows to the river are significantly in excess of the calculated effect on the river). The primary reason for this take being classified as consumptive despite apparently complying with the MCO exclusion for non-consumptive use is the intervening distance between the point of abstraction and the point of discharge (up to 7 kilometres in the case of Coopers Wells) and the location of the Gore flow site in the intervening reach, although this classification is totally subjective.

A similar example applying to the classification of consumptive/non-consumptive use occurs in the case of net water use for irrigation. In this case only a portion of water applied to land via irrigation is actually lost from the catchment (associated with evapotranspiration), with the balance contributing to higher soil moisture levels, increased recharge and ultimately increased baseflow to surface water. Calculations by Lincoln Environmental and MWH (2003) suggest that actual consumptive use irrigation is typically less than 40 percent of total water use. However, due to the time delay (potentially of the order of several months) between abstraction and contribution to increased baseflow, irrigation net-use is currently not accounted for in determining consumptive allocation.

8.1.2. Water Quality

Current water quality provisions of the MCO (also established in the RWP water quality classifications) establish water quality standards that have to be met in receiving waters after reasonable mixing. Both monitoring and anecdotal information suggest these standards have contributed to improvements in water quality parameters (particularly BOD, ammonia and colour) associated with point source discharges in the lower catchment. However, although the RWP establishes a number of rules and policies related to water quality, it is uncertain if these are in themselves sufficient to deal with potential future water quality issues in the Mataura catchment in terms of:

- Changes in water quality associated with changes in land use and land use intensification (particularly those associated with non-point source discharges); and,
- Recognition of the influence of groundwater quality and associated baseflow discharge on surface water quality at a catchment scale.

8.1.3. Summary

The MCO has played an important role in water resource management by establishing a set of nationally significant values (fisheries and angling amenity) associated with the Mataura catchment. Provisions of the MCO established to protect these values include:

- A prohibition on damming in the main stem of the Mataura and Waikaia rivers and restrictions on damming in tributary streams;
- A basic flow allocation regime; and,
- A set of water quality standards applying to the management of discharges.

Since becoming operational in 2010, the management framework has effectively been extended by the RWP which established a range of objectives, policies and rules addressing issues not covered by the MCO provisions.

Future water resource management in the Mataura catchment is likely to see increased requirements for a comprehensive, effective and integrated policy framework to ensure sustainable management of the quantity and quality of the water resource. The ability of the current management framework to provide an effective means of dealing with increasingly complex (and evolving) management issues is constrained by both the scope and nature of existing provisions as well as the subjective and somewhat uncertain nature of their application.

8.2. Option 2 - Improved Technical Water Use Efficiency

A range of definitions are available to describe technical water use efficiency. In general, these definitions refer to a range of performance indicators which can be used to characterise volumetric water use within a productive system in terms of units of production per unit of water used (Purcell and Curry, 2003). Technical water use efficiency is reduced by losses associated with the storage (e.g. evaporation, leakage), conveyance (e.g. leaking pipes and valves) and use (e.g. water not utilised for intended end use) of water for a specific activity.

8.2.1. Irrigation Water Use

A large amount of literature is available to describe technical water use efficiency for irrigation (e.g. ASCE (1978), Burt *et al* (1997), Bright *et al* (2000), Edkins (2006)). Although there are many definitions of irrigation efficiency, they can be grouped into three main categories of irrigation efficiency, application efficiency and distribution efficiency (McIndoe, 2002).

Irrigation efficiency describes the volume of water applied to an irrigated area that is used beneficially to support crop growth. Irrigation efficiency can be calculated in a range of alternative ways such as water use efficiency (WUE) which is defined as:

$$WUE = \frac{Production\left(\frac{kg}{ha}\right)}{Irrigation\ water\ use\left(\frac{m^3}{ha}\right)}$$

Application efficiency is a similar concept to irrigation efficiency but relates to system performance during a single irrigation event and can be characterised in terms of concepts such as water application efficiency (WAE) where:

$$WAE = \frac{Volume\ of\ water\ required\ to\ replace\ crop\ evapotranspiration}{Volume\ of\ water\ applied\ to\ irrigated\ area}$$

Distribution efficiency is a measure of the evenness of irrigation whereby uneven application of water contributes to lower application efficiency. Distribution efficiency is typically quantified in terms distribution uniformity (DU) which describes the evenness of water application to a crop over a specified area or Christiansen's uniformity coefficient (CU) which describes the performance of sprinkler systems.

Key factors influencing overall irrigation efficiency include the overall design of the irrigation system and its operation on a day-to-day basis. McIndoe (2002) tabulated typical water losses from irrigation systems from a range of field trials. These figures showed that the main losses from irrigation systems result from uneven application or excessive application depths. Excessive application is typically due to sub-optimal system design or management of the irrigation system. Uneven application usually results from poor distribution uniformity (windy conditions or sub-standard sprinkler distribution patterns) or by excessive application rates causing surface redistribution (McIndoe, 2002). Interestingly, the figures quoted showed that direct evaporation typically accounts for overall losses of less than 3 percent, event during hot, low humidity conditions.

A large number of resources are available to provide guidance on good design and management practice for irrigation systems. Many of these resources are available through Irrigation New Zealand[40] who have produced a range of material relating to good management practice including the New Zealand Irrigation Manual as well as codes of practice for irrigation system design and evaluation. Many of these resources are available through the Irrigation New Zealand knowledge centre (http://irrigationefficiency.co.nz/) which contains links to a wide range of reference material both from New Zealand and overseas.

It is recommended that Environment Southland, through its land management functions and partnerships with sector groups such as Irrigation Southland, continue to actively promote such materials to irrigation water users in the Southland Region to ensure the design and management of irrigation systems supports technical water use efficiency.

8.2.2. Other Water Uses

For water uses other than irrigation, criteria to establish technical water use efficiency are less well defined.

For some industrial uses, comparison of water use per unit of production is a useful benchmark. For example, as part of internal environmental management undertaken by Fonterra, water use per litre of milk processed has been utilised to compare water use between individual processing sites and identify potential areas for reductions in water use through initiatives such a process improvements and re-use. However, in many cases there are no established industry guidelines or standards for water use so it can be difficult to identify ‘reasonable’ volumetric usage through the resource consent process for individual industrial water users.

Similarly, water use for municipal supplies is highly dependent on the water use by individual residential, industrial and commercial consumers, as well as the condition of storage and reticulation infrastructure. One common measure of water use efficiency for reticulated supplies is average and/or peak water use per head of population. NZS 4410:2010 provides guidance for calculation of supply requirements for new reticulated supplies, although it is noted that actual use can vary significantly between existing supplies. For example, MWH (2009) reported peak water usage in the Tuatapere township to be greater than 1,600 L/head/day which is significantly in excess of typical design flows[41].

Most local authorities manage actual water use through asset management programmes to main infrastructure as well as promotion of water conservation measures during periods of high demand/restricted availability. In the Mataura catchment, it is noted that existing consents for the Gore water supply require instigation of water conservation measures when flows in the Mataura River drop below 17 m^3/s.

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[40] It is also noted that Irrigation New Zealand are also an active participant in the Primary Sector Water Partnership which is a relatively recent industry-lead initiative to promote sustainable freshwater management through the establishment of targets for nutrient management and water use efficiency.

[41] For example, the maximum design flow for the recently completed Edendale-Wyndham water supply was 1,000 L/head/day, with an average design flow of 300 L/head/day

8.2.3. Summary

To ensure optimal utilisation of the available resource, technical water use efficiency should form part of good management practice for all water use advocated by Environment Southland.

However, while technical water use efficiency is commonly cited[42] as an example where potential reductions in consumptive water use can be achieved, the reality is that increases in water availability achieved through improved efficiency will be modest and certainly not of the order required to have any significant influence on potential future supply shortfalls in the Mataura catchment.

It is also noted that improved technical water use efficiency does not always result in corresponding environmental benefits. In many cases poor technical water use efficiency results in losses of water back to the environment (except in the case of increased evaporation), which act to partially offset effects arising from water abstraction.

8.3. Option 3 - Improved Allocative Efficiency

Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources. The relative value of water in terms of potential alternative uses is an important consideration for the rational allocation of water as a scarce resource, whether by regulatory or economic means (SKM, 2006).

Economic efficiency is an important element of water resource management to ensure that water available for consumptive use is utilised in a sustainable manner, in keeping with Part II of the Resource Management Act (which seeks to balance environmental, social, cultural and economic values). An activity can be described as economically efficient if there are no other uses that could yield a higher value or net benefit. More commonly however, an activity is described as economically inefficient if its costs exceed the resulting benefits, or it can be demonstrated that the resource could be used to produce something with a higher net benefit (Australian Productivity Commission, 2006). The standard definition of economic efficiency, as it applies to water resources, has three main components: technical, allocative and dynamic efficiency (Counsell, 2003).

In economic terms the broad objective of water allocation policy is to ensure that water made available for consumptive use is utilised in a manner which maximises its contribution to the economy as a whole. While it might be a broad generalisation (possibly somewhat generous) to assume that all methods of water use represent *physical efficiency*, it can generally be accepted that water will only be utilised in a manner consistent with positive economic outcomes (i.e. water will not be used in loss-making enterprises for any extended period), and therefore the condition of economic efficiency can be expected to persist over time (although not necessarily at an optimum level).

As described in **Section 3.3**, available compliance records indicate that a significant proportion of water allocated for consumptive use in the Mataura catchment is never actually utilised. Given the finite volume of water available for consumptive use on an economically viable basis under the existing management framework, this situation results in sub-optimal allocative efficiency whereby additional water users are effectively prevented from accessing the resource due to resource consents held by existing users which are never fully exercised.

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[42] For example, feedback from the project Steering Group at the October 2010 ‘Values’ workshop clearly identified technical water use efficiency as a water management issue

The following section considers three options that could be considered as part of initiatives to improve allocative efficiency and ensure maximum benefit is derived from the available water resource. These include:

- Optimisation of volumetric and peak rate allocation to individual users;
- Methods for calculating actual allocation; and,
- Options for facilitating transfer of allocation between individual users.

8.3.1. Optimisation of seasonal and peak rate allocation

Analysis of available water meter records indicate a significant difference between consented water allocation in the Mataura catchment and actual water use. This results in a situation whereby a significant proportion of available seasonal allocation (between 50 to 80 percent depending on the season) is never actually used[43]. Figures for cumulative peak rate abstraction are more difficult to determine from existing water use records as a significant number of consents (at least historically[44]) only report cumulative season water use. However, based on seasonal usage and duration of abstraction figures, it would appear that the actual peak rate of abstraction is similarly well below that authorised by existing resource consents.

The non-utilisation of a significant proportion of existing allocation has the potential to significantly reduce allocative efficiency, effectively preventing additional users from accessing the resource available under the current allocation regime thereby reducing the cumulative economic benefit able to be derived from the available allocation.

In terms of irrigation water use, the primary reason for the discrepancy between allocated rates and volumes and actual water use appears related to the mode in which irrigation systems are typically operated in the Southland Region. Whereas modelled water use (which is largely consistent with current seasonal allocation of between 300 to 350 mm/year) calculates volumetric water requirements to maintain soil moisture in the optimal range for pasture growth, actual use appears to reflect operation of systems in an ‘insurance’-type mode. Under this mode of operation, irrigation is utilised to mitigate shortfalls in feed supplies due to moisture stress under existing management regimes (e.g. stocking rates similar to, or marginally above, those use on dryland properties) rather than to maximise production under more intensive operations (with correspondingly higher stocking rates).

One option to improve overall allocative efficiency is therefore to better align consented rate and volumes with actual water use thereby potentially ‘freeing up’ allocation for additional users. This could be achieved by establishment of formalised criteria (through the RWP) for establishing peak rate and seasonal allocation for irrigation water users, possibly based on water requirements to meet

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[43] Although seasonal usage by individual consents may be higher than average figures (see **Section 3.3**)

[44] Implementation of electronic metering resulting from implementation of the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010 will significantly improve the quality of available water use records

crop demand under certain climate conditions[45]. However, while this may be a desirable outcome to enable efficient utilisation of the available water resource, there are a range of potential issues that would need to be addressed before any such measure could be successfully introduced. These include:

- Practical difficulties in justifying (on technical grounds at least) volumetric or peak rate allocations based on sub-optimal operation of irrigation systems. This would effectively require Environment Southland to restrict the manner in which irrigation can be used based on grounds other than technical water use efficiency;
- Potential reluctance on the part of existing users to accept any reduction in seasonal and/or peak rate allocations. This is likely to reflect the desire for individual users to maximise their own security of supply so, in the case of an extreme low rainfall event, the ability to exercise their consent is not restricted in terms of the cumulative volume and rate of take, other than by existing minimum flow (and /or minimum groundwater level) restrictions;
- The current under-utilisation of existing allocation provides an additional degree of conservatism with regard potential environmental effects associated with current levels of abstraction. Increased allocative efficiency would (by definition) increase the overall rate and volume of water use. While this would increase allocative efficiency (and thereby the overall net benefit able to be derived from the available water resource), it would place greater emphasis on ensuring the adequacy of environmental limits;
- Measures to better align allocation and use may encourage higher levels of water use as a means to justify/maintain levels of allocation higher than would be utilised otherwise; and,
- Allowance for potential changes in water demand associated with long-term changes in rainfall which can potentially occur over the term of an individual consent. For example, **Figure 72** plots long-term annual rainfall departure at Mandeville (I68081) over the period 1950 to 2010 and clearly illustrates the abrupt change in rainfall occurring pre/post 1977 (described in **Section 4.1**). Obviously any assessment of potential irrigation water requirements has to be cognisant not only of the reliability of supply resulting from inter-annual variations in rainfall but also changes in potential water demands resulting from potential future ‘shifts’ in rainfall patterns.

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[45] An example of this is the WQN9 Policy included in the Environment Canterbury *Natural Resources Regional Plan* which limits seasonal allocation on the basis of water requirements to provide for optimal irrigation 4 out of 5 years (i.e. 80 percent reliability)

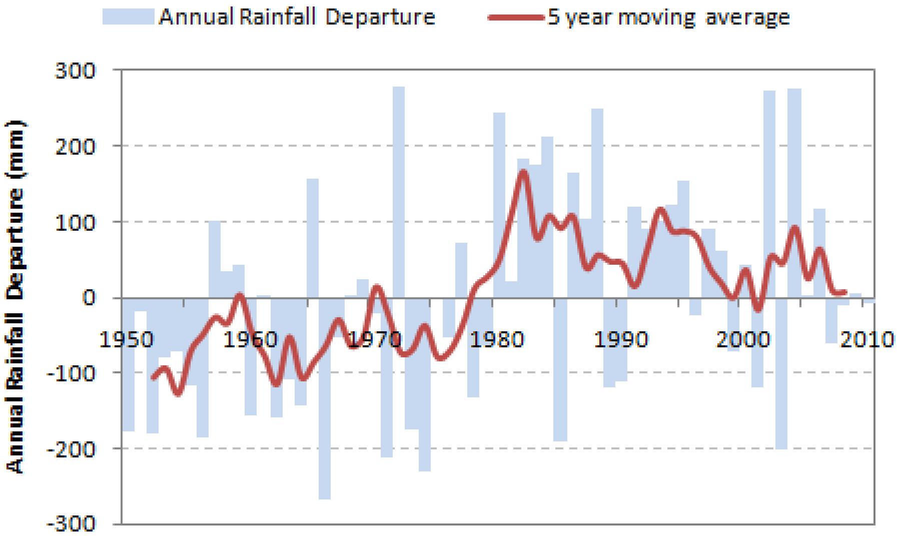

Figure 72. Long term departure in annual rainfall at Mandeville (I68081), 1950-2010.

Overall, increased allocative efficiency through improved alignment of water allocation and actual use is a 'best practice' objective for overall water management. However, in terms of irrigation water use, changes to a formalised method for establishing allocation rates and volumes requires improved understanding of the application of irrigation within farming systems in the Southland Region. This understanding is needed to establish defendable criteria for '*reasonable use*' which take into account both the role of irrigation within farming systems in the Southland context as well as potential effects of climate variability on water demand.

In addition, due to the limited mix of water use in the Mataura catchment, requirements for peak rate abstraction generally coincide for individual users. As a result, the volume of water able to be 'freed-up' by revision of existing seasonal and peak rate allocation is likely to be limited by requirement to manage the short-term (instantaneous or daily) rate of surface water and hydraulically connected groundwater abstraction to ensure cumulative effects on surface water remain within the prescribed limits. Optimum utilisation of available seasonal and peak rate allocation would therefore likely require a wider mix of water use in the catchment (so peak rate requirements can be spread over a longer time period) or the use of storage to retain allocation available at times when demand is low.

8.3.2. Methods for calculating stream depletion effects

At the current time, a majority (>90 percent) of allocation from the mid and upper reaches of the Mataura River is associated with the calculated stream depletion effects from groundwater takes classified as having a direct, high or moderate degree of hydraulic connection with surface water under Policy 29 of the RWP. Notwithstanding uncertainty associated with legal interpretation of the current management approach discussed in **Section 8.1**, this calculation is based on a series of assumptions regarding the actual nature of consumptive water use. For example, Policy 29 specifies that potential stream depletion effects will be calculated in the following manner:

- *Where there is a direct hydraulic connection, the stream depletion effect will be managed as an equivalent surface water take;*

- *Where there is a high degree of hydraulic connection, the stream depletion effect will be determined as the greater of:*

  a. The effect of <u>150 days</u> pumping at the rate required to deliver the seasonal volume (i.e. the magnitude of stream depletion calculated assuming the pumping rate = seasonal volume/150 days); or,

  b. The effect of <u>continuous pumping at the maximum permitted rate</u> over the period required to deliver the seasonal volume (i.e. stream depletion calculated assuming continuous pumping for a duration equal to the seasonal volume/maximum daily pumping rate)

- *Where there is a moderate degree of hydraulic connection, the stream depletion rate will be calculated as the effect of <u>150 days</u> pumping at the rate required to deliver the seasonal volume.*

While this methodology essentially establishes potential stream depletion effects assuming the maximum pumping scenario provided for by the resource consent conditions, few (if any) consents are exercised at the assumed rates, volumes and durations specified in Policy 29. For example, analysis of existing irrigation water take compliance data in **Section 3.3** indicates:

- The typical duration of pumping in any given irrigation season is between 70 to 90 days, with the longest recorded duration slightly over 120 days;
- Seasonal volumes are virtually never fully exercised. More commonly, seasonal use for irrigation consents lies in the range of 30 to 50 percent of allocated volumes;
- Abstraction rarely occurs on a continuous basis across the irrigation season. More typically, periods of irrigation are interspersed between irregular intervals of little or no abstraction; and,
- Abstraction rarely occurs at, or close to, the maximum permitted rate for extended periods.

As a result, the current method of calculating cumulative allocation from the Mataura River is likely to significantly over-estimate the magnitude of effect resulting from actual water use (particularly as a majority of current impacts are associated with irrigation takes). This situation arises for two reasons:

- Rates of take and duration of abstraction assumed in RWP Policy 29 significantly exceed those occurring in practice; and,
- Application of assumed rates and duration of abstraction result in takes being classified as having a different hydraulic connection that would be the case based on actual use (or criteria more reflective of actual use). For example, a particular take maybe classified as having a moderate degree of hydraulic connection under current Policy 29 criteria (and thereby the calculated stream depletion included in the cumulative surface water allocation), whereas over a pumping duration closer to that utilised in practice (e.g. 70 to 90 days), the corresponding calculation may indicate the take would be classified as having a low degree of hydraulic connection and therefore managed in terms of groundwater allocation only.

While it may be argued that a degree of conservatism in the calculation of cumulative allocation is warranted, it is clear that the current method of calculating allocation results in levels of supply reliability (resulting from application of minimum flow controls) potentially lower than warranted to actually match the actual level of effect occurring[46]. The net effect of this is to reduce allocative efficiency by:

- Constraining supply reliability for existing users
- Constraining access to water with a supply reliability sufficient to provide economic return for additional users.

Potential options to improve allocative efficiency associated with the current method of calculating allocation include:

- Ensuring better alignment between allocated the rate and volume of water allocated to individual users and actual use;
- Modifying criteria for the assessment of stream depletion effects to ensure assessment criteria are more reflective of patterns of actual water use.

Such measures will be assisted by collection of more comprehensive and better quality water use compliance data. In particular, application of electronic data loggers and/or telemetry to water measurement will significantly improve characterisation of actual water use under a range of climate and operational conditions.

8.3.3. Options for enhancing transfer of allocation

A further option to improve allocative efficiency is to enhance the ability for allocation to be transferred between individual water users[47]. By this means allocation not being utilised by an individual resource consent holder can be accessed by another existing (or potential) water user thereby increasing the net benefit able to be derived from the available allocation.

Section 136 of the RMA currently provides for water permits (in part or wholly) to be transferred between different locations and individuals, provided regulatory approval is obtained from the Regional Council. However, in practice this process takes time and may incur transactional costs associated with administration of the transfer process and assessment of environmental effects and has not been widely utilised in New Zealand (although use is increasing).

A range of potential options exist to enhance water transfer between individual users to improve overall economic efficiency. Many established systems for transfer of allocation in overseas jurisdictions involve financial transactions operating under a range of market settings. At the current time, although some water transfer does occur on a financial basis in New Zealand[48], there are a range of regulatory and attitudinal impediments to utilisation of market-based instruments (MBI's) as a mechanism to enhance overall economic efficiency[49].

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[46] It is noted that it is virtually impossible to discern an impact from existing abstraction on flows in the Mataura River in terms of short-term variations in river flow or the rate of flow recession.

[47] Thereby contributing to 'dynamic efficiency'

[48] For example see https://www.hydrotrader.co.nz/auction/index.jsp

[49] It is noted various work streams under the New Start for Fresh Water programme include consideration of the potential application of MBI's

However, alternatives exist to purely financial mechanisms to enhance optimal water management such as the development of collaborative water user groups. This concept involves a group of water users who collaboratively manage a given volume and rate of allocation subject to access restrictions (e.g. minimum flows and flow sharing arrangements) and compliance requirements established by the Regional Council. Users within the group then determine for themselves how access to the available resource is managed on an operational basis.

In order to manage such a system, governance arrangements are required which allow allocation to be transferred between nominated abstraction points subject to a set of rules designed to ensure cumulative effects (particularly in terms of effects on surface water or groundwater resources) are managed in accordance with the established access rules. As a result, implementation of such systems requires application of technology to enable management of allocation and use on a real-time basis.

Collaborative water user groups can potentially operate across a range of scales from sub-catchment or aquifer to catchment scale. In the Southland Region, given the nature of existing (and potential future) water use development of collaborative user groups at a groundwater zone scale would provide a means to enable improved utilisation of existing allocation while managing overall cumulative effects at a local scale. However, there are a range of potential impediments to the development and implementation of arrangements to enhance the dynamic management of water allocation. These may include:

- The need for water use to be recorded and managed on a real-time basis by the application of electronic recording and telemetry (although this may be partially achieved through implementation of the Resource Management (Measurement and Reporting of Water Takes) Regulations 2010);
- The need to develop a potentially complex set of rules governing transfer to ensure environmental effects remains within specified limits;
- Requirements to develop and implement administrative and governance systems capable of managing a transfer system on an operation basis;
- There may be limited incentives for existing users to participate in water transfer thereby potentially relinquishing the security provides by existing regulatory allocations;
- The uncertainty associated with access to water may preclude investment by additional users; and,
- The limited mix of potential water users means water use requirements for individual users typically coincide limiting the potential for transfer to occur on a temporal basis.

8.3.4. Summary

Overall allocative efficiency is a ‘best practice’ objective for water resource management to ensure that consumptive water use occurs in a manner that enables the greatest net benefit to be derived from the available resource[50]. At the current time allocative efficiency in the Mataura catchment can

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[50] It is noted that allocative efficiency is independent of the volume or rate of water available for consumptive use.

be characterised as sub-optimal with a significant proportion of water available for consumptive use never actually being utilised. This situation effectively reduces the reliability of supply for existing water users under the MCO regime and prevents additional users from accessing the available resource.

Improving alignment between consented volumes and actual water use has the potential to ‘free up’ allocation that is currently not utilised thereby enabling additional users to access the resource. However, establishment of ‘reasonable use’ criteria for peak rate and seasonal allocation requires improved understanding of the application of irrigation within farming systems in the Southland Region as well as consideration of the potential influence of long-term climate variability of water requirements. Also, due to the hydraulic connection between groundwater and surface water resources throughout much of the Mataura catchment, it is likely that the requirement to manage cumulative effects on surface water (in terms of instantaneous or short-term abstraction rates) rather than seasonal allocation would ultimately limit the volume of water able to be made available for re-allocation by improved alignment of allocated volumes and actual use.

Current surface water allocation in the Mataura catchment is calculated as the total of direct surface water takes combined with stream depletion effects for hydraulically connected groundwater takes calculated following the methodology established in RWP Policy 29. Examination of actual water use data suggest criteria for the rate and duration of abstraction utilised in Policy 29 significantly exceed those occurring in practice. As a result stream depletion effects calculated using the current Policy 29 methodology are likely to significantly over-estimate actual effects on surface water. While a degree of conservatism may be warranted in terms of managing cumulative effects on surface water, the current methodology results in a reduction in the reliability of supply for individual users and is likely to prevent additional users accessing the resource at a reliability sufficient to provide an economic return. Review of the Policy 29 criteria would provide an opportunity to ensure calculated effects are more closely aligned with actual water use practice and may enable a modest amount of additional allocation to occur in the existing MCO allocation regime[51].

Allocative efficiency in the Mataura catchment could also be improved by enhanced transfer of allocation between individual water users. This would enable allocation not being utilised by resource consent holders to be utilised by other existing (or potential) water users thereby increasing the net benefit able to be derived from the available allocation. Options that could potentially be utilised to improve allocative efficiency through enhanced water transfer range from market-based instruments to more collaborative user group mechanisms. However, potential application of such mechanisms in the Mataura catchment may be limited by the complex monitoring and governance arrangements required to manage abstraction on a real-time basis to ensure cumulative effects remain within specified limits, the limited number of water users in the catchment as well as barriers related to the security of supply for individual users.

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[51] However, effective management of cumulative stream depletion effects may also require incorporation of effects on river baseflow resulting from groundwater takes currently classified as having a low degree of hydraulic connection under RWP Policy 29 (further discussed in **Section 8.4.3.2**)

8.4. Option 4 - Alternative Regulatory Framework

Development of an alternative water resource management framework in the Mataura catchment has the potential to address some of the shortcomings of the existing regulatory regime discussed in **Section 8.1** in a manner that enhances the overall sustainable management of the resource. Important considerations in the development of any such alternative management framework include incorporation of improved scientific understanding of the key values associated with the resource and how these are influenced by water quantity and quality, sufficient flexibility to proactively respond to changing resource management issues and specification of management provisions in a manner that enables clear and transparent resource management decision-making. Development of an alternative management framework therefore has the potential to:

- Include consideration of a wider range of values in the overall management of the water resources of the Mataura catchment;
- Simplify practical application of water allocation provisions and ensure consistency in management across the catchment;
- Implement a flow allocation regime that is scientifically-based and directly related to the values being managed in the catchment (including tributary and main stems);
- Increase water availability to meet at least some of the potential future demand in the catchment.
- Clarify existing provisions relating to consumptive/non-consumptive use and the management of groundwater/surface water interaction; and,
- Extend the scope of existing provisions to better address current (and potential future) issues associated with the impact of non-point source discharges on water quality and integrated management of groundwater and surface water allocation.

8.4.1. Process for amending existing regulatory framework

Section 65 of the RMA establishes a process which allows for the preparation and change of Regional Plans. Under these provisions any person (including the Council itself) can initiate a process to change the provisions of an existing Regional Plan with any such application proceeding through a similar consultation and hearing process to that utilised during the preparation of the original plan. This process provides an opportunity for Regional Plans to adapt to new or altered resource management issues and incorporate new or improved information and/or methods related to overall resource management. In terms of the RWP, this type of process was followed during the initial plan development phase to incorporate variations related to management of groundwater, surface water quality and quantity as well as stock access. Since the RWP became operative in January 2010, RMA Section 65 has been utilised to initiate a series of proposed changes to the RWP related to issues such as community water supplies (Plan Change 3), refuse disposal facilities (Plan Change 4), hazardous wastes (Plan Change 9) and contaminated land (Plan Change 10).

Section 216 of the RMA outlines a similar process for the revocation or variation of a Water Conservation Order. However, while this process has been utilised to extend the scope of existing WCO’s (e.g. the Water Conservation (Buller River) Amendment Order, 2008), it is largely untested with regard the revocation or significant alteration of a WCO.

The single case where an application was made to significantly amend an existing WCO under RMA Section 216 (in this case to enable hydropower development) was referred to the Environment Court which declined the application (Environment Court C102/07) on the grounds that any variation to a WCO must be consistent with the overall purpose of the Order. In this case the Environment Court decision noted that "*the conservation purpose remains predominant and is not to be undermined by reference to countervailing criteria under part II RMA*" effectively meaning factors such as the economic or social benefits resulting from the proposed development could not be taken into account in determining the outcome of the application. The only other process for altering provisions of a WCO is an application to the minister where both the original applicant and regional council agree on the scope and details of changes proposed.

Therefore, while an established process exists for amending provisions of Regional Plans, the equivalent process for Water Conservation Orders is largely untested and establishes a high threshold[52] that must be met for any such application to be successful. As described in submissions by counsel for Environment Southland at the Oreti River WCO hearing:

'……..Sec 216 which allows for revocation or amendment of an order after two years. However there is a world of difference between what the legislation seems to allow and the pain and expense of setting out to achieve it. For all but technical non-controversial matters, a revocation or amendment application is a re-run of an application for an order (Sec 216 (4)) with the added onus on the applicant to argue against the status quo and to show why the order should be varied[53]*.'*

As a result, consideration of the development of an alternative regulatory framework for water management in the Mataura Catchment needs to be cognisant of the potential challenges associated with amending the provisions of a WCO, which would be required to change the status quo.

Notwithstanding the practicalities of any such an exercise, the following section considers two options for development of an alternative resource management framework in the Mataura catchment. The first option considers management of the water resource under existing provisions of the RWP (i.e. essentially the situation if the MCO were not in place), while the second considers the potential attributes that may be considered in a regulatory framework developed independently of the MCO or RWP.

8.4.2. Regional Water Plan

As previously discussed, Section 67 of the RMA requires a regional plan to be not inconsistent with a Water Conservation Order. As a result, many of the features of the MCO are essentially matched by equivalent rules or policies in the RWP. **Table 19** below provides a comparison of the sections of the MCO relating to management of water quality and water quantity against the equivalent RWP provisions which shows that, with the exception of water allocation, provisions are essentially equivalent, albeit expressed in slightly different terms in the RWP reflecting activity status as defined in RMA Section 87A.

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[52] Essentially that any alteration to a WCO must be consistent with its conservation purpose

[53] Evidence of Barry Slowley to the Oreti Water Conservation Order hearing panel

Table 19. Comparison of MCO and RWP provisions relating to management of water quality and quantity

Existing MCO Provisions	Equivalent RWP provisions
Section 4: *Rates of flow in the Mataura River and Waikaia River* ▪ Restriction on consumptive water use to no more than 95 percent of the naturalised flow upstream of the Mataura Island Bridge and 90 percent of naturalised flow downstream	Rule 18: *Abstraction, diversion and use of surface water* ▪ Restricted discretionary activity: allocation <10 percent of MALF ▪ Discretionary activity: allocation 10 to 30 percent of MALF ▪ Non-complying activity: allocation greater than 30 percent of MALF ▪ Methods for determining minimum flows and levels specified in Appendix I
Section 5: *General provisions relating to water permits, discharge permits and regional plans* ▪ Provides for exceptions to WCO provisions in relation to specific activities including: - Fisheries/wildlife research or enhancement - Construction of infrastructure - Soil conservation and river protection - Stock water and stock-water reservoirs	Rules 24 to 38*: Structures in river and lake beds* ▪ Rules relating to a construction, maintenance and removal of a wide range of structures in river and lake beds including bridges and other infrastructure, erosion control structures, boat ramps, navigational aids etc Rules 39 to 48: *Bed disturbance activities in river and lake beds* ▪ Rules relating to a activities in river and lake beds including channel deepening/realignment, gravel extraction, weed/sediment/debris removal and vehicles and machinery
Section 6: *Water permit to dam not to be granted* ▪ Prohibition on damming on the main stems of the Mataura and Waikaia Rivers ▪ Restriction on damming tributaries of the Mataura and Waikaia Rivers if it would be harmful to the spawning or passage of salmonid fish	Rule 29: *Dams and weirs* ▪ Prohibited activity - damming on the main stems of the Mataura and Waikaia Rivers ▪ Prohibited activity - damming tributaries of the Mataura and Waikaia Rivers if it would be harmful to the spawning or passage of salmonid fish
Section 7: *Provisions relating to discharges to protected waters* ▪ Specification of water quality standards to be met by discharges after reasonable mixing	Policy 1: *Surface water body classes* ▪ Establishment of water quality classes equivalent to MCO classifications to be met by discharges after reasonable mixing

In terms of allocation the MCO adopts a relatively simple proportional allocation system based on a percentage of naturalised river flow, while the RWP adopts a staged allocation approach based on an approach developed by NIWA (2004). This methodology establishes a default allocation and minimum flow and specifies methods for undertaking instream habitat analysis for critical value species to determine an appropriate minimum flow when levels of allocation exceed the default threshold. The RWP framework also specifies requirements for flow sharing to help maintain flow variability during extended periods of flow recession and provides for supplementary allocation (e.g. for water storage) at higher flows.

Overall, the main points of difference between the MCO and RWP flow allocation provisions can be summarised as:

- The MCO establishes a proportional allocation based on a relatively small percentage of naturalised river flow while the RWP potentially allows higher levels of flow allocation (depending on the outcomes of technical assessment);
- The MCO does not specify minimum flows, while the RWP requires abstraction to cease a prescribed minimum flows (a default of MALF where allocation is less than 10 percent of MALF and flows determined by instream habitat analysis for higher levels of allocation) and establishes a flow sharing mechanism whereby abstraction is required to progressively reduce between a defined trigger point and the minimum flow;
- The RWP provides for supplementary allocation at high flows while the MCO allows only a fixed proportion of flow to be available at all times.

The remaining MCO provisions are essentially replicated in the RWP (in the case of restrictions on damming) and are complimented by additional rules and/or policies which provide additional guidance for resource management (in the case of structures and activities in the beds of rivers or lakes and surface water quality).

One major point of difference between the MCO and RWP is that the MCO identifies specific values (fisheries and angling amenity) as nationally outstanding in the ‘protected waters’ whereas objectives, policies and rules in the RWP refer to a wider range of values (as defined in Part 2 of the RMA) and do not specifically identify the values associated with particular waterbodies. The RWP does identify trout and habitats for trout and salmon in terms of objectives for water quality and quantity management (Objectives 3 and 5) but only in general terms rather than their nationally significant character in the Mataura catchment. Similarly, Appendix I of the RWP (which describes *Methods for Determining Minimum Flows and Levels)* outlines the concept of ‘critical values’ to be utilised for determining minimum flows which, in the case of the Mataura river is the retention of appropriate levels of adult brown trout habitat available at the 7-day MALF.

Hay (2010) recently undertook instream flow assessment surveys on two reaches of the Mataura River as an exercise to determine what minimum flows be required to maintain appropriate levels of habitat for chosen critical species as per the RWP flow allocation provisions. The assessment noted that:

The prospective minimum flows are intended to retain 90% of feeding habitat (WUA) for adult brown trout at the mean annual low flow (MALF) or at the flow at which habitat is optimal, whichever flow is least (again in accordance with Appendix I to the Regional Water Plan for Southland). The choice of habitat retention level is somewhat arbitrary and is based more on risk management than ecological science. The risk of ecological impact increases as available habitat is reduced. The greater the value *of an instream resource, the less risk is likely to be considered acceptable by conservation stakeholders. The 90% habitat retention level suggested in this case is based on the assumption that a 10% reduction in habitat availability is unlikely to cause a detectable decline in fish populations. This level of habitat retention for adult trout in these reaches is arguably appropriate given the nationally outstanding status of the brown trout fishery in the Mataura River, as prescribed by the Water Conservation Order.*

However, practical application of the RWP allocation methodology to management of water allocation in the Mataura catchment would likely require further technical analysis to ensure levels of allocation and minimum flow were appropriate to ensure the outstanding values in the catchment would be protected at an appropriate level. Limited information is currently available to quantify how angling amenity may be affected by alternative allocation options.

It is also noted that practical application of the current RWP surface water allocation methodology in other catchments in Southland has identified some operational issues such as:

- The staged methodology is not particularly transparent and provides limited surely of outcomes at levels of allocation exceeding the default limits;
- Depending on outcomes of technical assessment, discretionary or non-complying water take applications may be assigned a lower minimum flow (and hence higher reliability of supply) than initial consents granted under the default allocation regime;
- The lack of established flow bands may mean the reliability of supply for existing users is potentially reduced by subsequent allocation; and,
- As with any proportional allocation system, achieving practical compliance with the 1:1 flow sharing provisions may be difficult.

Overall, the RWP presents a relatively pragmatic alternative to the existing MCO given that it has been through an extensive public consultation process in relatively recent times. With the exception of flow allocation, provisions of the RWP essentially encompass existing MCO provisions relating to damming, activities, structures and water quality with associated objectives, policies and rules providing additional context for resource management. With regard flow allocation, the RWP establishes a science-based approach to the establishment of flow allocation and minimum flows. One additional feature of a Regional Plan is that it is subject to plan change processes initiated under Section 65. This can provide an opportunity to enable resource management to adapt to changing resource management issues and improved technical knowledge.

Section 8.6 provides an overall summary to enable comparison of the advantages and disadvantages of the MCO and RWP approaches to management of water resources in the Mataura catchment.

8.4.3. Alternative regulatory options

The following section considers a range of management considerations that may be included in any alternative water resource management framework developed for the Mataura catchment. Some or all of these options could potentially be utilised to modify or extend existing MCO or RWP provisions to develop a ‘hybrid’ management framework, or alternatively, used to develop an entirely separate management regime.

Flow allocation

The natural flow regime of a river or stream has a number of components that influence the overall hydrological and ecological character of the individual waterbody. These characteristics include:

- The median discharge;
- The timing, frequency, magnitude and duration of low flow events;
- The frequency and magnitude of high flow events.

Together these characteristics combine to produce a temporal flow pattern which supports the environmental, cultural, economic and social values attributed to a particular waterbody. Consumptive water use has the potential to adversely impact on these values if the resulting changes to the flow regime exceed particular thresholds. A framework for managing consumptive water use may contain a range of provisions designed to maintain particular aspects of the flow regime. This *environmental flow* to ensures values associated with the water resource are not adversely impacted to a level in excess of nominated thresholds.

The three most basic attributes of a typical environmental flow include provisions that specify:

- A minimum flow at which consumptive use (aside from that utilised for reasonable domestic or stock water use under section 14(3)(b) of the RMA or by permitted activity rules specified in a Regional Plan) must cease;
- A flow allocation which establishes the cumulative volume of water available for allocation; and,
- Rules for maintaining overall flow variability and to retain larger flushing flows for habitat quality and channel forming purposes (see **Figure 73** below).

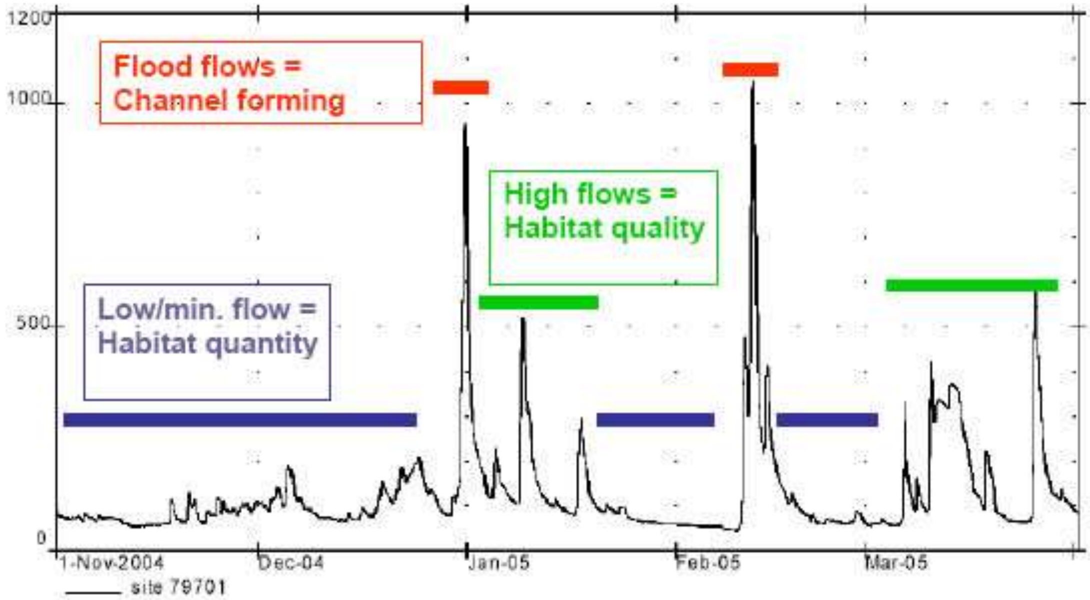

Figure 73. Different flow regime components in the Waiau River *(Figure taken from Beca (2008))*

Allocation Bands

Environmental flows are typically established to maintain a set of values (including environmental, cultural, economic and social values) associated with a particular waterbody above nominated thresholds. Many environmental flows comprise a multiple allocation bands each of which has a defined set of minimum flow, flow allocation and flow sharing rules.

Figure 74 illustrates a slightly more complicated set of flow allocation bands in this case established on the basis of supply reliability with each allocation band having a fixed volume of allocation with a defined reliability of supply above the minimum flow.

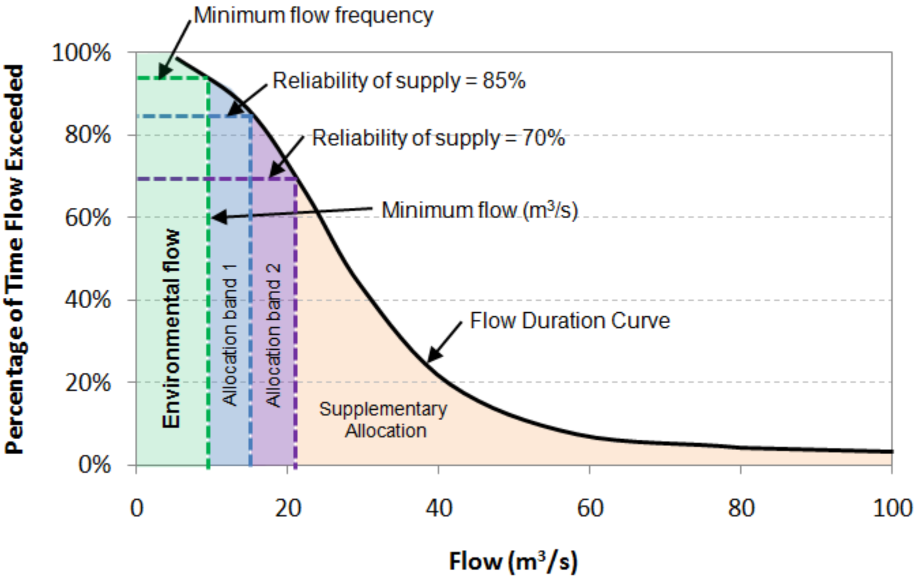

Figure 74. Allocation bands defined on the basis of supply reliability

A range of other options exist to define allocation bands such as resource share or proportional allocation. The key point being that various methods for defining allocation bands can be combined to develop a relatively sophisticated environmental flow that is tailored to the specific characteristics of an individual catchment. Potential benefits of an environmental flow incorporating the attributes described in the previous section in a catchment such as the Mataura (compared to the status quo) include:

- A minimum flow at which point all consented abstraction must cease can be established on the basis of scientific assessment of the flows required to maintain specific instream values;
- Specification of a flow allocation band (or bands) with a fixed allocation and minimum flow criteria would potentially simplify management of current (and potential future) allocation which at the current time is administered in terms of relatively complicated series of stepped minimum flows (with some consents linked to minimum flows a more that one monitoring point);
- Flow allocation bands could be established to ensure groupings of users share equivalent supply reliability. This would go some way to addressing current concerns held by some stakeholders regarding equity between users whereby existing ‘first-in’ consents enjoy a significantly higher reliability of supply than more recent consents, regardless of the nature of water use;

- Flow allocation bands where users share equivalent reliability of supply would increase the potential for utilisation of transfer mechanisms to increase allocative efficiency. At the current time the potential to transfer allocation between individual users is constrained by the different reliability characteristics of individual resource consents;
- Flow allocation and minimum flows could be established on a sub-catchment basis to avoid the current situation whereby individual consents may be linked to minimum flows measured at different points within the catchment;
- Specification of allocation bands may enable the provision of increased volumes of water at high flows to facilitate water storage which at the current time is constrained by the proportional allocation which applies at all times;
- Allocation bands provide a fixed supply reliability for individual water users which is not diminished by subsequent allocation for consumptive use; and,
- Increased transparency and improved certainty of outcomes for the resource consent process as a result of clear specification of the volume of water available for allocation and associated minimum flow and/or flow sharing restrictions.

Management of groundwater/surface water interaction

As discussed in **Section 8.1**, there remains a degree of uncertainty regarding application of the existing RWP stream depletion policies in the Mataura catchment due to a lack of specificity in the wording of the MCO. Any alternative regulatory framework should therefore look to clearly establish a framework for integrated management of groundwater and surface water quantity.

Section 8.2.2 identified potential improvements that could be made to existing stream depletion policies in the Regional Water Plan associated with the current method for calculation of the potential magnitude of effects on surface water resulting from hydraulically connected groundwater takes.

However, to more fully integrate management of groundwater and surface water resources any review of the methodology for managing groundwater/surface water interaction should also include provisions aimed at managing the cumulative effects of groundwater abstraction on streamflow.

While current stream depletion policies (RWP policy 29) primarily relate to the management of groundwater takes with a high degree of hydraulic connection to surface water, it is increasingly recognised that all groundwater takes to some degree contribute to a cumulative reduction in baseflow at a catchment scale. This effect is particularly relevant in the Upper Mataura catchment and across the Waimea Plains, both of which effectively function as closed basin systems whereby, due to the underlying geological structure, all water in the hydrological system (whether in the form of groundwater or surface water) eventually exits the basin via the river at the downstream basin margin (Parawa in the case of the Upper Mataura Valley, Gore for the Waimea Plains).

Liquid Earth (2009) proposed a methodology to manage cumulative effects of groundwater abstraction on surface water flows in the Southland Region. This proposal essentially involved modification of the existing RWP stream depletion policies to include two components:

1. Management of those groundwater abstractions that have a direct or immediate effect on the surface water environment through application of pumping controls based on minimum flows

established for hydraulically connected surface water (essentially equivalent to the existing RWP Policy 29 criteria for groundwater takes with a direct or high degree of hydraulic connection); and

2. Establishment of a 'baseflow allocation' to cap the total cumulative effect of unrestricted groundwater abstraction (i.e. groundwater takes classified as having a moderate or low degree of hydraulic connection under RWP Policy 29) on surface water discharge at a catchment scale.

Further development and application of the proposed methodology to account for the cumulative effects of unrestricted groundwater abstraction could provide for improved integration in the management of groundwater and surface water quantity. However, issues regarding the management of groundwater/surface water interaction will remain until alterations are amendments are made to clarify existing management provisions.

Consumptive vs non-consumptive use

Current MCO flow allocation provisions make allowance for the exclusion of non-consumptive water use from total allocation. However, as detailed in **Section 8.1**, the wording of these provisions is ambiguous and therefore potentially subject to differing interpretations. Any alternative management framework developed for the Mataura catchment should look to establish clearly defined criteria for classification and management of non-consumptive use. This is likely to be particularly important with regard potential large-scale mining development within the catchment which may result in relatively complex water management issues including:

- Management of dewatering flows which are essentially returned to the catchment;
- Discharge of dewatering and process water flows at locations removed from the point of take;
- Storage and subsequent discharge of mine and process water flows; and,
- Situations where dewatering operations induce in cross-catchment groundwater throughflow.

The concept of net use could also be applied to modify criteria for allocation to irrigation or municipal water takes which effectively return a significant proportion of water back to the catchment[54].

Management of water quality

Existing water quality provisions of the MCO (which are also adopted in terms of the RWP water quality classifications for the Mataura catchment) provide a relatively basic of water quality standards that primarily relate to physical, chemical and microbial contaminants associated with point-source discharges (e.g. temperature, pH, colour, clarity, dissolved oxygen and 'toxic substances')[55].

However, while the quality of point source discharges generally improved over recent years, new water quality issues have emerged in relation to non-point source contamination associated with land use and land use intensification. Current water quality issues in the Mataura catchment are typically associated with nutrients (primarily nitrogen and phosphorus) and microbial contamination in the main stems, along with habitat quality in many tributary streams. These factors can adversely impact on ecosystem health and exceed standards for contact recreation.

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[54] Although any such measures would have to account for temporal and/or spatial effects.

[55] The nature of these provisions generally reflects the nature of water quality issues at the time the Order was drafted which were primarily concerned with point source discharges, particularly in the lower catchment.

In addition, as discussed in **Section 2.4**, it is also now recognised that groundwater quality may exert a significant influence on the quality of hydraulically connected surface waters, particularly during low flow periods in areas where appreciable baseflow discharge occurs. As groundwater quality in many areas is significantly influenced by overlying land use, this increases the potential for direct linkages between land management and catchment-scale water quality impacts, particularly as standards for management of groundwater quality (Drinking Water Standards for New Zealand, 2005) set appreciably different limits for nitrogen than guidelines for management of surface water quality. Impacts on aquatic ecosystem health and biodiversity in the Fortrose Estuary and the nearshore coastal environment area may also emerge as issues for future water quality management in the Mataura catchment (e.g. Stevens and Robertson, 2010).

Environment Southland is currently undertaking a range of initiatives associated with management of land use and associated impacts on water quality. This work could potentially form the basis for a more comprehensive framework for managing water quality in any amended regulatory framework which could potentially include:

- Clearly defined water quality targets including water quality standards and management objectives for biodiversity and ecosystem health;
- Definition of sub-catchment limits for nitrate and other contaminants to enable management of water quality in a manner consistent with established resource management standards and objectives. This could involve allocation and management of assimilative capacity at a local scale;
- Improved linkages between the management of groundwater quality and relevant water quality standards for hydraulically connected surface water;
- Improved linkages between water use and associated land management practices;
- Specific management provisions to address water quality issues associated with artificial land drainage
- Specific controls on land use based on the physical characteristics of land units and the sensitivity of receiving environments.

8.5. Option 5 - Water Storage

Water storage can be utilised for a variety of purposes to yield economic and environmental benefits through hydropower generation, supply for irrigation and other consumptive water uses as well as augmentation of low flows. Storage can also provide attenuation of flood peaks to assist mitigation of downstream flooding risk and provide a valuable recreational resource. However, depending on location, design and operation water storage also has the potential to have a significant impact on rivers and streams through changes to natural flow regimes, effects on aquatic ecosystems, changes to natural character and loss of productive land.

In terms of consumptive use, water storage provides a mechanism that enables the reliability of supply to be maintained during periods of reduced supply availability due to hydrological conditions and/or regulatory constraints (minimum flows, flow allocation restrictions, minimum groundwater levels).

Storage construction to support irrigation may be pursued at a range of scales, each of which has different technical, regulatory and economic considerations. The following section provides an overview of options available for storage to provide for projected increases in future water demand in the Mataura catchment including:

- On-farm storage
- Regional storage
- Managed aquifer recharge (MAR)

8.5.1. On-Farm Storage

Analysis of on-farm storage as an option to improve supply reliability in **Section 5.5.1** and **Section 6.2.2** indicates that under the current (MCO) flow allocation regime, storage is likely to provide a small positive economic benefit for a relatively small additional irrigated area. At the assumed storage cost of \$3.50/m^3, modelling indicates that storage of between 250 to 500 m^3/ha would provide a slight positive economic benefit but would not significantly increase reliability of supply. Larger storages capable of securing significant increases in reliability were considered uneconomic due to the high capital cost compared to the modest increase in net benefit resulting. The potential benefits able to be derived from storage were larger under the alternative flow allocation scenarios modelled, but the analysis in Section 6.2.2 suggests that on-farm storage is likely to provide only a marginal return where capital costs are low[56]. Storage has a greater benefit at higher product prices, and sustained milk solids payout above \$7 would make it considerably more attractive in conjunction with an alternate flow regime.

For the purposes of this report much of the area identified as deriving the greatest productive benefit from irrigation is located on the Waimea Plain between Gore and Balfour. In general, this area is covered by thin alluvial soils with limited topographic relief overlying permeable alluvial gravel deposits. As a result, the potential to develop on-farm storage in this area is constrained by:

- The limited opportunities to utilise existing topography for storage construction;
- Thin, highly permeable soils that would require artificial lining of storage to prevent significant leakage;
- Limited availability of on-site or local materials (e.g. clay) suitable for use as low permeability liner material;
- Shallow depth to groundwater that may interfere with construction of below-ground storage particularly where lining is required.

Combined, these factors mean that on-farm storage development is likely to be at least partially above ground and require lining of ponds. These factors are considered likely to increase storage costs above the level that would make on-farm storage economic to pursue. The exception to this would be in situations where conditions were near optimum (i.e. suitable topography, minimal requirements for lining, limited infrastructure requirements).

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[56] Typical costs for on-farm storage vary significantly between individual operations. For example, Scott (2010) indicated unit costs for on-farm storages less than 100,000 m^3 are typically in the range of \$4 to \$12/m^3 so the figures used for the analysis are at the lower end of the likely range of costs.

8.5.2. Regional Storage

Regional storage is subject to similar financial constraints as on-farm storage but has the potential to deliver higher net benefit if lower unit storage costs can be obtained through economies of scale. However, due to regulatory and technical constraints is would appear difficult for any regional storage option to achieve the <\$1/m^3 unit cost considered in **Section 6.3.3** as likely to provide economic benefits sufficient to justify the large capital expenditure involved.

Storage Locations

Due the nature of the topography in Southland, potential large-scale storage sites in the Mataura catchment are generally limited to the headwaters of the Mataura and Waikaia Rivers. However, as a result of the prohibition on damming the main stems of the Mataura and Waikaia Rivers, any large-scale storage in the headwater areas would have to be located either on tributary streams or off-river. Development of storage on tributary streams is also likely to be constrained by MCO and RWP requirements to avoid adverse effects on the spawning and passage of salmonid fish as well as the flows available for storage away from the main stems. Even if a suitable site could be located, development of off-river storage would likely incur higher unit costs than on-river storage due to requirements for infrastructure to divert and recover water from storage.

Sites in the mid to lower section of the catchment (e.g. Otamita Stream or catchments draining the western Catlins) are removed from the assumed areas of irrigation demand and would require some form of pumping to transfer water to the middle reaches of the catchment significantly increasing capital and operating costs for any such storage (at least in terms of irrigation development).

Conveyance

Headwater storage in the Mataura catchment would be removed from the main area of anticipated demand growth in the Waimea Plains/Riversdale area. This would necessitate conveyance of water from storage sites to downstream section of the catchment. The most cost-effective means of achieving this would be through augmentation of natural flows in the Mataura River with the corresponding withdrawal of equivalent volumes of water near areas of demand in the middle catchment. Water could then be abstracted directly from river intakes and conveyed to individual properties via pipe or open channel or utilised to augment flows to compensate for stream depletion effects due to increased abstraction from hydraulically connected aquifer systems. Requirements for pumping from surface or groundwater sources to supply elevated terrace areas along the margins of the valley (e.g. the Wendonside Terrace and western sections of the Waimea Plain), would significantly increase unit costs.

The governance arrangements required to enable flow augmentation as a primary conveyance method may be problematic particularly with regards to management of overall environmental effects (to ensure cumulative effects remain within designated parameters) and equity issues surrounding the potential benefits for existing users in terms of increased reliability. Some modification and/or clarification of MCO flow allocation provisions would also likely be required to enable utilisation of flow augmentation as the primary conveyance method.

Storage Volumes

A further constraint on the potential to develop regional-scale storage in the Mataura catchment is the volume of water available for storage under the MCO flow allocation regime. **Table 20** provides an indicative assessment of the total volume of water available for allocation at various points in the catchment and the corresponding area of irrigation that could be supported by a theoretical water storage able to capture the maximum volume of water available. These figures show that the resulting storage volumes are relatively modest and only sufficient to support relatively modest increases in irrigated area which would likely to be insufficient to achieve the economies of scale required to achieve a unit cost sufficiently low to achieve a financial return on investment.

Table 20. Available allocation and corresponding irrigated area based on median flows at three sites in the mid and upper section of the Mataura catchment

Site	Median Flow (m^3/s)	Annual Discharge ($m^3 \times 10^6$)	Available Allocation ($m^3 \times 10^6$)	Approximate Irrigated Area (ha)[a]
Parawa	12.9	410	20	4,600
Piano Flat	8.6	270	14	3,200
Gore	49	1,550	77	17,600

[a] Calculation assumes 20% losses for evaporation and conveyance and a seasonal water requirement of 3,500 m^3/ha

The storage volumes outlined in **Table 20** are based on the calculated annual average irrigation demand of approximately 350 mm/year calculated for a 60 mm PAW soil in the Riversdale and Athol climate zones (see **Section 5.1.2**). In the examples shown, deceasing volumetric water requirements closer to actual use (typically <240 mm/year) would increase the area able to be irrigated from the available storage volume by around 50 percent. However, the practicalities of capturing the entire allocation available in off-river or tributary storage are likely to present a significant technical challenge. Therefore, notwithstanding economic feasibility, development of regional-scale headwater storage would likely require an amendment to the existing MCO flow allocation provisions to enable increased capture of high river flows.

Overall, in addition to other constraints, it is therefore unlikely sufficient volumes of water would be available under the MCO allocation regime to make large-scale water storage in the Mataura headwaters economically viable. Under the RWP, Policy 15 provides for a supplementary allocation to enable water harvesting above the natural mean. This policy does not establish a fixed volume of supplementary allocation but indicates consent conditions on any such proposal would address matters such as flow variability and flood flows.

Summary

Opportunities for the development of medium to large-scale storage in Southland are generally limited to areas in the headwaters of the major catchments and around the margin of inland valleys. However, development of such regional storage is significantly constrained by water availability as well as restrictions on damming under the current regulatory framework. However, even under an alternative regulatory regime, storage costs would have to be at the low end of typical costs ($1 to $2/$m^3$) to provide sufficient economic incentive to pursue such an option, particularly given the overall economic returns from irrigation development in Southland. Bulk storage could however be an option for alternative water uses providing a higher net benefit (such as industrial or mining water use) or returns from irrigation were sustained at high levels.

8.5.3. Managed Aquifer Recharge

Managed aquifer recharge (MAR) describes the active management of water to recharge aquifers for subsequent recovery and use, or to provide environmental benefit. MAR is a well proven technology in many overseas applications and presents potential opportunities for conjunctive and sustainable management of surface and groundwater resources.

The one significant advantage of MAR over other storage options is that it seeks to utilise the natural storage capacity within existing aquifer systems rather than requiring construction of above-ground storage infrastructure. This presents obvious advantages in terms of costs and environmental effects such as loss of productive land and alteration to natural flow regimes. However, there are a range of factors that potentially restrict the realistic application of MAR to certain environmental settings. The flowing sections provide an overview of the MAR concept and assess its potential application in the Mataura catchment

Overview

MAR involves supplementation of natural recharge to an aquifer system under controlled conditions by diversion of water into natural or artificial structures such as recharge wells, infiltration basins, galleries or river-beds. The resulting increase in the volume of water stored in the underlying aquifer can then be utilised for consumptive purposes or to enhance environmental values associated with the resource such as stream baseflow or groundwater dependant ecosystems (SKM, 2010).

The source of water utilised for MAR can vary according to the nature of a particular environmental setting. Successful examples of MAR operation include diversions from water sources such as:

- Local rainfall and stormwater runoff;
- Rivers, streams and lakes;
- Recycled water from wastewater treatment plants; and,
- Groundwater diverted from other aquifers or remotely within the same aquifer system

Particularly in arid climates MAR presents an opportunity to recycle treated wastewater for subsequent re-use.

The application of MAR and resulting increases in groundwater storage can assist overall water resource management in a variety of ways including:

- Providing a means of retaining seasonal water surpluses, particularly in terms of surface water flows;
- Increasing the volume and/or rate of water available for consumptive use;
- Improving the reliability of supply for existing water users;
- Reduced infrastructure requirements compared to alternative water storage options;

- Potential environmental benefits including increased baseflow to rivers and streams and enhancement of groundwater dependent ecosystems such as wetlands and phreatophytic vegetation;
- Improvements in groundwater quality due to increased throughflow within the target aquifer system; and,
- Mitigating situations where existing groundwater abstraction exceeds the sustainable limit.

However the potential feasibility of MAR as a water management option is dependent on a range of factors including:

- Water availability to supplement aquifer recharge;
- The quality of the recharge water source, particularly in terms of suspended sediment (which may significantly reduce potential infiltration/recharge rates) and contaminants (particularly where the aquifer system is utilised for potable supply or discharges to sensitive aquatic environments).
- The physical and hydraulic characteristics of the target aquifer system. The aquifer system has to have the capacity to accept additional recharge at a reasonable rate and retain water in storage for a sufficient period until required for consumptive use;
- The ability to develop and apply the often complex governance arrangements required to manage what can be a relatively complex resource management proposition particularly in terms of allocation of resulting costs and benefits.

Types of MAR schemes

MAR schemes have been developed in a range of configurations to suit local geological and hydrogeological conditions.

Figure 75. Types of MAR schemes (from NRMMC (2009))

provides a schematic illustration of some of the most common MAR techniques.

Aquifer storage and recovery (ASR)

Aquifer storage and recovery is the process of injecting water into an aquifer system via a recharge well for subsequent recovery from the same well. Figure 1 shows a schematic illustration of the operation of an ASR scheme with seasonal injection and recovery of water from a confined aquifer system.

Aquifer storage transport and recovery (ASTR)

Aquifer storage, transport and recovery (ASTR) is similar to ASR but water is recovered from a well located some distance from the injection well. In many applications ASTR is utilised to provide additional water treatment via the natural processes of filtration and adsorption occurring as water flows through an aquifer system.

Percolation tanks and recharge weirs

Percolation tanks and recharge weirs are dams built in ephemeral streams (i.e. stream channels that contain water only after rainfall or snowmelt) to detain water that infiltrates through the bed, increasing storage in hydraulically connected unconfined aquifers. Additional recharge to the aquifer system is generally abstracted form the aquifer system down-valley and may act to increase the duration and extent of surface flow in the stream channel.

Bank filtration

In bank filtration, groundwater is extracted from a well or caisson near or under a river or lake to induce infiltration from the surface water body. In effect bank filtration represents abstraction of groundwater from hydraulically connected riparian aquifers generally with the overall objective of improving water quality. It can also be used as a pre-treatment mechanism for ASR. An example of a successfully operating bank filtration scheme in New Zealand is the Kawakawa municipal water supply scheme in the Bay of Islands.

Dune filtration

In dune filtration, water is infiltrated from basins constructed in dunes, and extracted from wells or basins at lower elevation. The filtration improves water quality and helps to balance supply and demand.

Infiltration basins

Infiltration basins and channels are typically constructed off-stream. Surface water is diverted into these structures and allowed to infiltrate (generally through the unsaturated zone) to the underlying water table. This recharge method is extensively used in alluvial aquifer systems which have requisite scale and hydraulic properties.

Underground dams

In construction of underground dams, a trench is constructed across the stream bed in ephemeral streams where flows are constructed by basement highs. The trench is keyed into the basement and backfilled with low permeability materials, helping to retain flood flows in the alluvial materials surrounding the stream.

Sand dams

Sand dams are built in ephemeral streams in arid areas with low permeability materials underlying the stream bed. Over time sediment accumulates in front of the dam creating an ‘aquifer’ that can be tapped by wells in dry seasons.

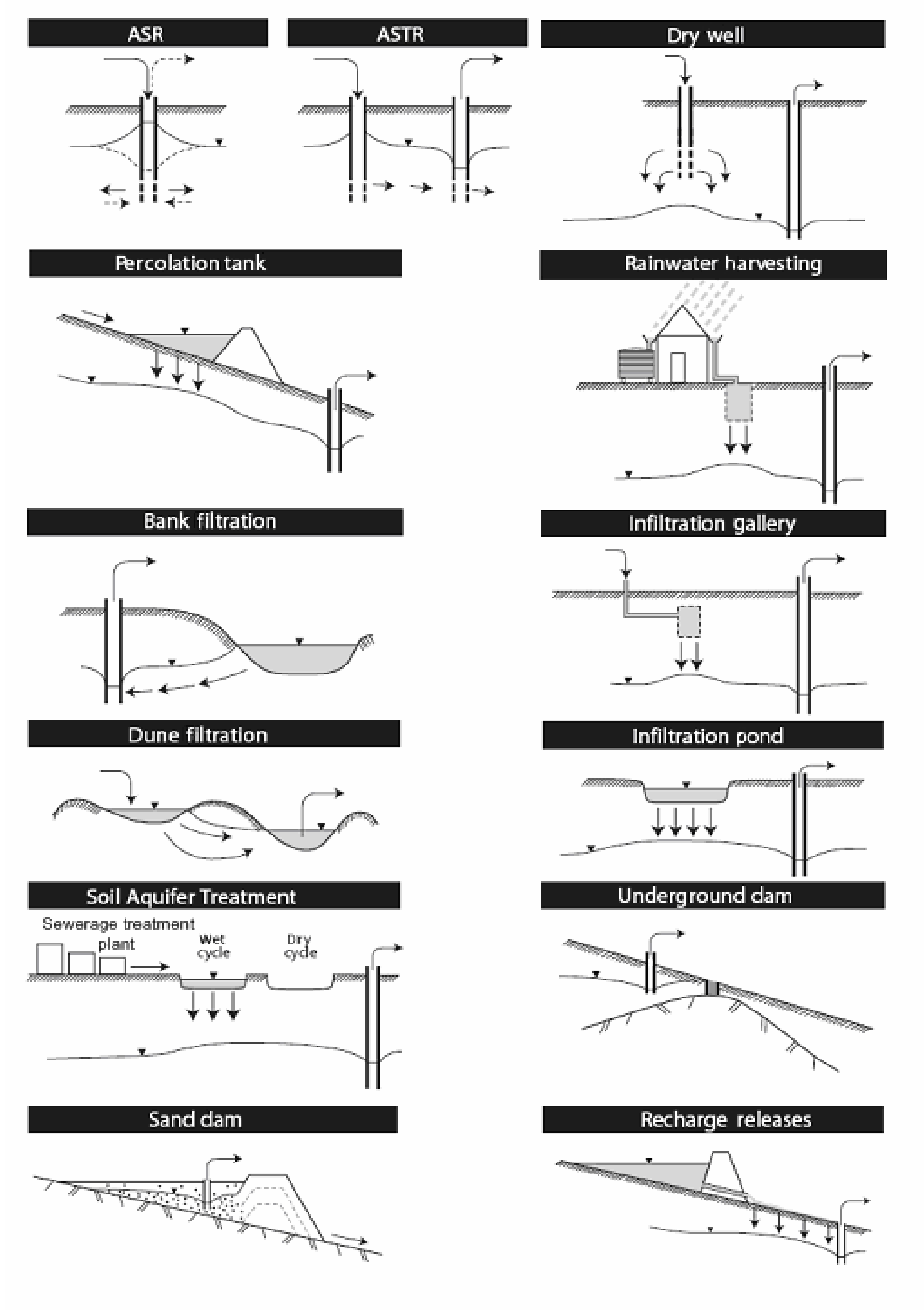

Figure 75. Types of MAR schemes (from NRMMC (2009))

Successful Application of MAR

Successful application of MAR as an option to enhance sustainable water management depends on a number of factors related to the physical and hydrogeological environment and the overall management of the scheme. Assessment of these factors is a major component of feasibility investigations for any MAP scheme. Key factors determining the potential for successful application of MAR include:

- ***Clogging*** - clogging refers to a reduction in the infiltration capacity of the geological materials at, or near, the point of recharge resulting from the deposition of suspended sediment in water being recharged or biological growths occurring in response to increased nutrient loadings. Clogging can have a major impact on the volume of water able to be recharge into an aquifer system and maintenance required to address clogging can contribute significantly to overall operational costs for MAR schemes (particularly where physical works are required to address clogging in recharge wells or infiltration basins.
- ***Aquifer characteristics*** - both the physical and hydraulic characteristics of the host geological materials are critical to the successful application of MAR.

  The aquifer system has to have sufficient storage capacity to accommodate sufficient quantities of water to make any MAR scheme viable. Storage capacity may be difficult to accurately define in many aquifer systems where there is appreciable geological heterogeneity or where complex confined or semi-confined conditions exist.

  Aquifer hydraulic properties also have to be suitable to ensure the aquifer is sufficiently permeable to accept the additional recharge flux without resulting in appreciable mounding of the water table. However, if aquifer permeability is too high the recharge flux may be rapidly dispersed over a relatively wide area, thereby reducing the ability to effectively recover the stored water, or discharged from the aquifer system to hydraulically connected surface water resulting in a significant loss of storage. The ability of a MAR scheme to recover a reasonable proportion of the additional recharge is a key factor in the technical and economic feasibility of any MAR scheme.
- ***Environmental issues*** - if not properly designed and managed MAR schemes can result in adverse environmental effects associated with increased water tables (flooding/inundation of low-lying land), increased baseflow discharges (affects on aquatic ecology, reduction in flood capacity) or changes in water quality (contaminants introduced in recharge water, reactions between recharge water and aquifer materials or native groundwater).
- ***Governance Issues*** - development and operation of MAR schemes may result in relatively complex governance issues regarding access to water and attribution of costs associated with construction and operation.

Potential application of MAR in the Mataura catchment

The shallow unconfined riparian aquifers which flank the Mataura River upstream of Gore are the most widely utilised groundwater resource in the Southland Region. These aquifer systems are hosted in highly heterogeneous alluvial gravel deposits formed as a result of reworking of the older Quaternary outwash terrace surfaces during entrenchment of the major river systems over the post glacial period. The aquifers are typically elongate and laterally confined within the relatively narrow extent of recent floodplain deposits and exhibit a limited saturated thickness (typically less than 25 metres), high permeability (typically >2,000 m^2/day) and a high degree of hydraulic connection to surface water.

As illustrated in **Figure 76**, one common characteristic of these riparian aquifer systems is a limited retention time for groundwater storage resulting from periods of high recharge (high rainfall and/or river flow). The figure shows the transitory nature of groundwater storage with much, if not all storage resulting from significant recharge discharged from the aquifer system within one to two months. This is attributed to the combination of the restricted lateral dimensions, high aquifer permeability and hydraulic connection to surface water. As a result, riparian aquifer systems are unlikely to provide a realistic option for MAR schemes seeking to utilise seasonal water availability to address supply shortfalls in summer and autumn.

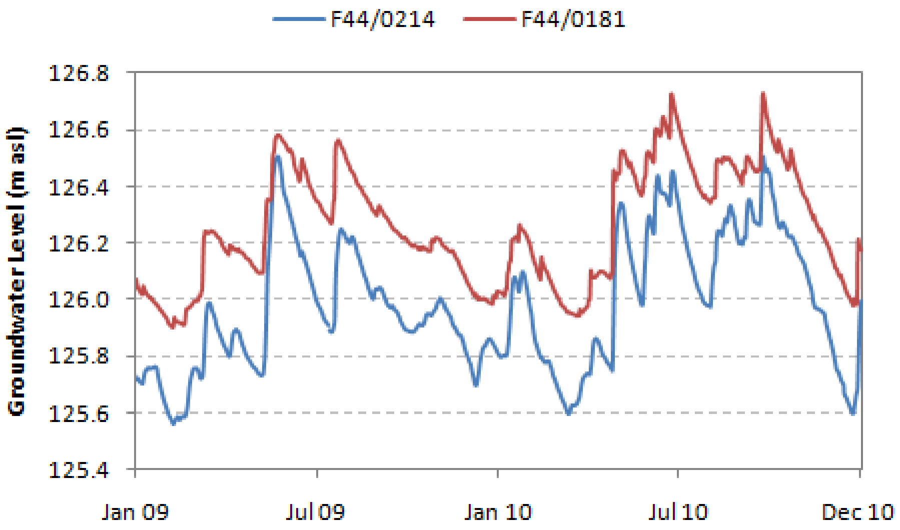

Figure 76. Typical hydrographs from riparian aquifers in the Mataura catchment

One example of direct relevance to the potential application of MAR in riparian aquifers in the Mataura catchment is a trial undertaken in the Eyre River, to the north-west of Christchurch. This trail involved the release of water from the Waimakariri Irrigation Scheme into the dry bed of the Eyre River over a three week period in 2005 to artificially recharge groundwater levels in the surrounding aquifer system. Results of monitoring showed an increase in groundwater levels (i.e. increased water storage in the aquifer) as a result of the trial over a relatively wide area (approximately 4,000 ha). However, within one to two a months of trial completion groundwater levels had returned to background levels reflecting a combination of increased baseflow to the lower reaches of the Eyre River and dissipation of the recharge flux due to the relatively permeable nature of the aquifer system

Other aquifer systems in the Mataura catchment would also appear relatively unsuited to application of MAR. For example, Lowland aquifer systems such as the Knapdale and Waimea Plains groundwater zones typically have a water table less than 3 metres below the ground surface (limiting volumetric storage potential), low to moderate permeability (increasing the potential for issues associated with groundwater mounding and water recovery) and are typically drained by a relatively dense network of first and second-order streams (increasing the potential for loss of storage resulting from increased baseflow discharge).

Due to uncertainty regarding subsurface geology and hydrogeological characteristics, the potential for MAR in deeper, confined aquifer in the Mataura catchment is difficult to quantify. Confined aquifer within the alluvial deposits (for example the Garvie Aquifer) appear to exhibit suitable hydraulic characteristics, however the physical dimensions of this aquifer system and potential hydraulic connection to other aquifers is uncertain. In addition, its location underlying the Wendonside Terrace would present technical and economic challenges associated with conveyance so the most prospective options associated with augmentation of recharge to this aquifer system may be associated with infiltration of runoff from the foothills to the north. Based on the limited geological data available, the potential for MAR utilising storage in the Tertiary lignite measure deposits underlying the Quaternary gravels would appear low due to the predominance of mudstone and other fine-grained sediments.

It is also noted that potential utilisation of MAR in deeper confined aquifers may be potentially constrained by suspended sediment loadings likely to occur in water sources from moderate to high surface water flows. **Figure 77** illustrates the relationship observed between suspended solids measured at the Otamita Bridge and discharge at Gore. The data indicate suspended sediment loadings are relatively low at flows less than 80 m^3/s but potentially increase sufficiently above this threshold to present a major challenge associated with clogging.

Even assuming a MAR scheme utilised flows less than 80 m^3/s, a seasonal recharge volume of 1 million m^3/year would result in the annual accumulation of 10 tonnes of suspended sediment (assuming a suspended sediment concentration of 10 g/m^3). While sediment accumulation of this order could be managed within a recharge/infiltration basin, such loadings are likely to present a challenge for the efficient operation of recharge wells such as would be required for MAR schemes utilising confined aquifers. This would necessitate pre-treatment of water prior to recharge which may have a significant effect on the economic viability of any such scheme

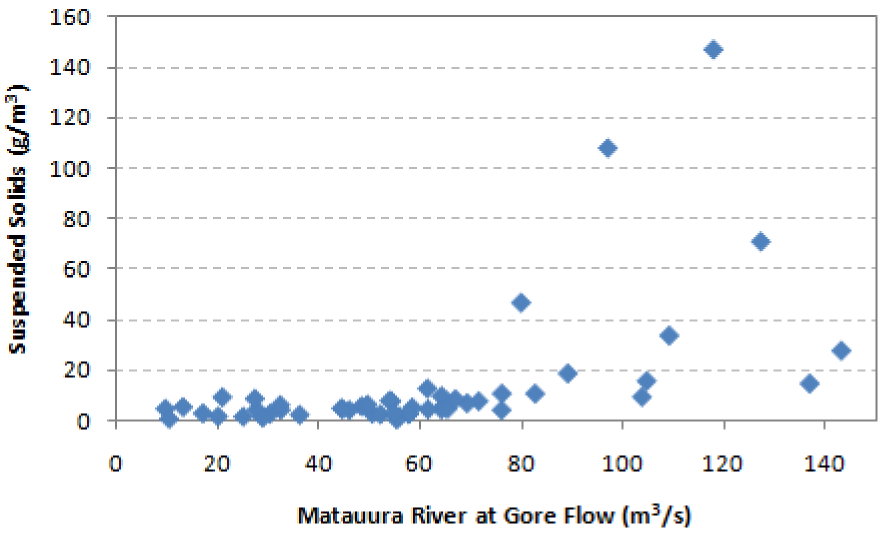

Figure 77. Observed relationship between suspended sediment concentrations in the Mataura River at Otamita Bridge and river flow at Gore

Overall, while MAR schemes present opportunities to enhance sustainable management of surface water and groundwater resource in many environmental settings, their potential application in the Mataura catchment is likely to be significantly constrained by the hydrogeological characteristics of the groundwater resource.

8.6. Summary

Table 21 provides a summary of the potential advantages and disadvantages of the options for future water resource management in the Mataura catchment considered in the preceding section.

Table 21. Potential advantages and disadvantages associated with options considered for future water resource management in the Mataura catchment

Management Option	Advantages	Disadvantages
1. Retention of the Status Quo ***(MCO + RWP)***	▪ Provides explicit recognition for significance of angling and angling amenity values ▪ Provides a conservative approach to water allocation ▪ Prohibits damming on Main stem of Mataura and Waikaia rivers ▪ Well established having been in place for ~15 years	▪ Does not explicitly recognise the range of values associated with the Mataura catchment ▪ Flow allocation provisions difficult and complex to implement and may be subject to uncertainty and subjective interpretation creating potential ‘weak points’ ▪ Flow allocation methodology not well linked to environmental values ▪ Overlap between coverage of MCO and RWP provisions ▪ Difficult to amend to take account of

		changing management issues or improved information
2. Technical Water Use Efficiency	▪ Ensures water is utilised in most efficient manner for end purpose ▪ Forms part of '*best practice*' water use ▪ Provides benefits to water users	▪ Unlikely to provide any significant increase in water availability ▪ Improved technical water use efficiency does not always result in environmental benefit (e.g. poor efficiency can act to partially offset effects of water abstraction)
3. Improved Allocative Efficiency	▪ Allows for improved alignment between water allocation and use ▪ Increases the cumulative benefit able to be derived from available allocation ▪ A component of '*best practice*' water management	▪ Potentially increases overall water use
a. Revised peak and seasonal allocation	▪ Possible to 'free up' modest quantities of water for re-allocation	▪ On-farm practice appears to significantly influence water use ▪ May be difficult to specify rates/volumes for irrigation other than based on maintenance of optimum soil moisture ▪ Likely to encounter reluctance from existing/new users regarding allocation of rates/volumes lower than optimal ▪ On-farm Irrigation practices may change over time and in response to long-term variations in rainfall ▪ The potential to re-allocate water on a seasonal basis may be limited by the need to manage effects associated with peak rate abstraction.
b. Modification of methods for calculating stream depletion	▪ Ensure calculated stream depletion effects reflect actual water use practices ▪ Refinement of calculated allocation volumes may enable further allocation under MCO provisions	▪ Requires better data to characterise actual water use patterns ▪ If not matched by allocated rates and volumes then potential exists for consents to be exercised in a manner that would result in greater effects than calculated
c. Improved options for transfer of allocation	▪ Provides a means of achieving allocative efficiency by enabling water to be shared between multiple users within established	▪ Requires real-time recording of water use ▪ Requires development of rules to manage and administrative system to record and

	environmental parameters ▪ Allows redistribution of water based on user requirements rather than regulatory means	track usage ▪ Implementation may require development of complex governance arrangements ▪ May be difficult to convince existing users to alter terms of existing water permits ▪ Uncertainty of securing allocation may preclude new investment. Would need to be implemented in conjunction with other, less reliable, consent allocations ▪ Limited 'pool' of users and mix of water uses ▪ Transfer involving market-based systems may encounter community resistance
4. Alternative Regulatory Framework	▪ Provides opportunity to address shortcomings in existing management framework ▪ Potentially allows future resource management to be approached in a more strategic manner than current reactive approach	▪ Requires changing existing management framework which has provided for recognition of nationally significant values associated with Mataura catchment
a. Regional Water Plan	▪ Provisions for Mataura catchment essentially equivalent to MCO in all respects except water allocation and outlines objectives, policies and rules which provide improved context for resource consent decision-making ▪ Through RMA Section 65 process has ability to change to address new issues or improved information ▪ Provides a process for science-based decision making ▪ Potentially increases water availability ▪ Addresses some of the inconsistencies/ambiguity in existing framework ▪ Has been through a extensive community consultation process	▪ Does not provide explicit recognition of the nationally significant values associated with the Mataura catchment ▪ Does not establish fixed allocation quantities or minimum flows outside default limit and may result in erosion of security of supply with increasing allocation ▪ Flow-sharing provisions difficult to implement ▪ Flow allocation may result in perverse outcomes e.g. later users can potentially obtain higher reliability of supply than 'first-in users' ▪ May not address wider groundwater quality/quantity issues associated with groundwater/surface interaction and land use intensification

	■ Under court interpretation of RMA Section 216 any changes to existing management framework would have to be consistent with the 'conservation purpose' of the MCO	
b. Alternative Regulatory Framework	■ Provides opportunity to address issues such as: - Cumulative groundwater/surface water allocation - Definition of consumptive / non-consumptive water use - Intensification of land use ■ Can be utilised as a process to develop variations to existing RWP provisions	■ Requires significant inputs (both time and financial) to support policy development ■ Likely to require extensive consultation process, particularly if involves significant change to existing management framework
5. Water Storage	■ Provides opportunity to utilise seasonal water surplus to meet future water demand	■ Have to overcome significant economic, regulatory and technical challenges to provide a viable option
a. On-farm storage	■ Enables water users to increase reliability of supply	■ Evan assuming low cost storage additional capital costs make on-farm storage marginally economic ■ In areas of likely demand, storage likely to be required to be above ground and lined increasing construction costs
b. Regional storage	■ Enables water users to increase reliability of supply ■ May provide additional benefits associated with recreational amenity and flow augmentation	■ Potential storage sites constrained by MCO/RWP provisions, off-river storage likely to increase unit cost ■ Need economy of scale to minimise unit costs, limited by existing MCO allocation and potential volumetric use ■ Conveyance likely to primarily involve flow augmentation. This could provide additional environmental benefit but may require complex governance arrangements and infrastructure to convey water from river.
c. Alternative Storage (MAR)	■ Relatively minor infrastructure requirements ■ Potential environmental benefits through	■ Shallow aquifers in Mataura catchment have limited volumetric storage capacity and are hydraulically connected to surface water resulting in short 'residence

	augmentation of baseflow	time' for additional recharge ▪ Deeper aquifers in the Mataura catchment are relatively unexplored and may have limited storage potential due to geological characteristics ▪ Suspended solids content of mid to high flow river water may limit recharge options and/or increase treatment and maintenance costs ▪ MAR schemes may require complex governance with regard attribution of costs and potential benefits

8.7. Feedback on Management Options

A summary of work undertaken for the Mataura Catchment Strategic Water Study was presented to the project Steering Group at a meeting held at the Mataura Community Centre on Wednesday 18th May 2011.

Following the presentation, feedback on the alternative management options canvassed was sought from the Steering Group using a similar process to that utilised in the earlier Values Workshop (see **Section 6**). Steering Group Members were divided into the four sector groups representing Local Government, Primary Sector, Environment and Industry and each group asked to rank the management options against the key values identified at the earlier workshop (essentially a summary of the values listed in **Table 9**). The ranking was made in terms of a simple three tier system reflecting whether the group considered each management option as likely to result in positive, negative or neutral (or insufficient information) outcomes against key values grouped under the headings of environmental, economic, social and cultural 'wellbeings'. A summary of this ranking exercise is presented in **Table 22** below.

Table 22. Summary of Steering Group feedback on possible future water resource management options in the Mataura catchment (Note: Red shading = negative outcome, Green = positive outcome and Blue = neutral outcome or insifficient information).

Value / Sector Group	Status Quo	Improved Allocative Efficiency	Alternative Regulatory Framework	Water Storage
Environmental				
Local Government	🟥	🟥	🟩	🟩
Primary Sector	🟦	🟥	🟩	🟩

Environmental	🟥	🟦	🟦	🟦
Industrial	🟩	🟩	🟩	🟩
Economic				
Local Government	🟥	🟥🟩	🟩	🟩
Primary Sector	🟦	🟩	🟥🟩	🟩
Environmental	🟦	🟩	🟦	🟥
Industrial	🟥	🟩	🟩	🟥🟩
Social				
Local Government	🟥	🟦	🟦	🟩
Primary Sector	🟦	🟩	🟥🟩	🟩
Environmental	🟥	🟦	🟦	🟦
Industrial	🟩	🟩	🟦	🟩
Cultural				
Local Government	🟥	🟥	🟦	🟦
Primary Sector	🟦	🟦	🟥🟩	🟩
Environmental	🟥	🟦	🟦	🟦
Industrial	🟩	🟩	🟦	🟩
Summary				
Positive	3	7.5	6.5	10.5
Neutral / Insufficient Information	5	5	8	4
Negative	8	3.5	1.5	1.5

The rankings indicate that a continuation of status quo management was viewed as the most likely option to result in negative management outcomes while the alternative options were generally viewed more favourably.

The negative ranking attributed to status quo management primarily reflected two major considerations:

- Observed declines in values associated with the Mataura River under status quo management (and the potential for this situation to continue); and
- The limited efficacy of the existing regulatory framework as a means of managing the range of pressures and issues associated with management of water resources in the Mataura catchment.

The alternative options considered were generally considered as being likely to result in more favourable management outcomes than the status quo. However, with regard the alternative options the two major comments from the Steering Group were:

- Consideration of any alternatives management options must be informed by sufficiently detailed information and analysis to identify how alternative management options are likely to impact/affect specific values; and
- Any alternative management framework needs to provide certainty with regard limits and outcomes. This point was identified in terms of the current RWP which, although identifying a methodology for management of water quality and quantity does not always provide certainty of outcomes (e.g. the RWP flow allocation methodology does not provide fixed allocations, minimum flows etc)

Overall, the general consensus of the meeting was that the existing management framework is unlikely to provide for effective future management of key values in the Mataura catchment and the potential for development of alternative management options was viewed favourably provided adequate provision is made for the protection of key values.

9. Summary

9.1. Existing allocation and water use

The volume of water allocated for consumptive use in the Mataura catchment has increased significantly over the past 10 years from approximately 100,000 m^3/day in 2000 to around 300,000 m^3/day in late 2010. A significant proportion of this increase is associated with the expansion of pasture irrigation from approximately 200 ha to 5,400 ha over the same period. Allocation for other uses including industrial and municipal supplies also increased in recent years, but to a lesser degree than irrigation.

The increase in water allocation from 2000 to 2010 has been almost exclusively from groundwater which currently comprises approximately 85 percent of all allocation. However, when potential effects of groundwater abstraction on surface water are taken into account, approximately 40 percent of the total allocation is attributed to surface water. Based on this calculation, the Mataura River is currently considered to be fully allocated under the MCO provisions (in terms of direct surface water and hydraulically connected groundwater takes) at flows below mean annual low flow (MALF) across a majority of the catchment. This means that further run-of-river allocation for consumptive use is only available at moderate to high river flows.

Water use compliance information indicates that current water use is significantly lower than allocated rates and volumes. On a seasonal basis, few consents utilise anywhere near their full allocated volumes, with typical use in the range of 30 to 50 percent of seasonal allocation. The available data also suggest that short term (i.e. instantaneous and/or daily) abstraction, although proportionally higher than seasonal use, is again appreciably below allocated rates and volumes.

9.2. Factors influencing demand and availability

Analysis of historical climate data suggests natural climate variability, particularly in terms of rainfall variability, has a significant influence of water demand and availability in the Mataura catchment. This variability occurs on an inter-annual scale with variations in seasonal rainfall exhibiting a relatively good correlation with NNSO phase. During El Niño conditions westerly airflows typically increase and rainfall is above average over southern New Zealand whereas during La Niña conditions westerly airflows decrease and rainfall is generally below average. The occurrence of historical drought events indicates a significantly increased potential for significant dry periods to occur in the Mataura catchment during La Niña conditions.

Possibly of greater significance in terms of potential future water demand and availability than individual El Niño/La Niña events are decadal-scale climate variations which are observed in historical climate (particularly rainfall) data from the Southland Region. These changes have been associated with a phenomenon termed the Interdecadal Pacific Oscillation (IPO) which influences seas surface temperatures and atmospheric circulation patterns across a significant portion of the Pacific region. Shifts in the IPO between the warm (positive) and cool (negative) phases essentially modulate the ENSO cycle and tend to occur every 20 to 30 years. Warm (positive) phases of the IPO tend to associated with an increase in the frequency of El Niño events, while cool phases typically result in more frequent La Niña conditions.

Projected impacts of climate change indicate that the Southland Region will experience warmer temperatures over the next 30 years accompanied by an increase in westerly airflows and higher rainfall. However, in all except the most extreme modelled scenarios, changes in water demand and availability resulting from climate change are likely to be significantly less than natural variability resulting from short to medium-term variations in atmospheric circulation

9.3. Future water demand

Potential future water demands were estimated over a nominal 20-year planning horizon based on ‘conservative’ and ‘accelerated’ estimates of future irrigation, municipal and industrial demand growth. These scenarios are intended to provide upper and lower bound estimates of potential growth in water demand in the absence of regulatory constraints on water use. In reality, the extent to which these demands can be met largely depends on the regulatory regime in place. Given the current level of allocation under the MCO regime, these estimates are best viewed in terms of potential future shortfalls in supply.

Results of the assessment suggest irrigation is likely to be the primary driver of future water demand in the Mataura catchment. However, lignite mining and secondary processing may also make a significant contribution to future water demand. Based on estimates of future irrigation, industrial and municipal demand growth, potential supply shortfalls to 2030 are estimated to range between 400,000 and 800,000 m^3/day.

9.4. Economics of irrigation

A number of scenarios were modelled to investigate the effect of supply reliability (essentially an outcome of access restrictions (i.e. minimum flows) and total allocation) on the economics of irrigation under different allocation scenarios. Results of this assessment suggest that under the current MCO flow regime the economic viability of irrigation reduces rapidly with relatively small increases in irrigated area. Therefore, while the MCO does not prescribe a maximum allocation limit, this analysis suggests that the catchment is close to the point where the water resource can be considered fully allocated with respect to future run-of-river irrigation development.

Further modelling water undertaken to evaluate the viability of water storage as an option to improve supply reliability. This analysis indicated that, due to the relatively modest increase in net benefit derived from irrigation, storage is only likely to provide an economic return where it can be established on a very low unit cost basis.

9.5. Costs and benefits of future water use

The total net benefit from existing irrigation in the Mataura catchment is calculated as being of the order of $2.6 million in direct benefit, which equates to approximately $15.4 million in GDP. Under the alternative management scenarios considered (roughly approximating potential allocation under the RWP methodology) net benefit would potentially increase to approximately $5.5 million resulting in an additional $37 million in GDP, $20 million in household income and 490 equivalent full-time jobs. Lignite mining and processing operations could potentially have an effect that dwarfs other economic activity in the catchment, however the exact size and nature of any such operations is yet to be determined.

There are very significant environmental values associated with the Mataura River. While it appears that the extent of any impacts associated with potential future water resource development would be relatively small, this needs to be confirmed by further modelling and technical work. It does appear that land management rather than land use will have the greatest impact on nutrient associated environmental values, so additional irrigation will not necessarily result in negative environmental outcomes.

In the values workshop undertaken with the Project Steering Group, the angler values associated with the river were considered very important in both the environmental and social categories, particularly for the environmental stakeholders. This can be taken as a strong indication that there needs to be careful consideration of any proposals that substantially alter the environment of the Mataura catchment to ensure the associated environmental costs do not outweigh economic benefits derived.

9.6. Options for future resource management

A range of options for future water resource management in the Mataura catchment were considered including:

1. Retaining the status quo;
2. Improving technical water use efficiency;
3. Improving allocative efficiency;
4. Amending the existing regulatory framework;
5. Development of water storage

The MCO and RWP currently form a framework for water resource management in the Mataura catchment. While providing a basic framework for managing the quality and quantity of water resources in the catchment to maintain the nationally significant fisheries and angling amenity values established by the MCO, the analysis highlights some potential shortcomings associated with the current management provisions. Overall, it is suggested that future water resource management in the Mataura catchment is likely to see increased requirements for a comprehensive, effective and integrated policy framework to ensure sustainable management of the quantity and quality of the water resource. The ability of the current management framework to provide an effective means of dealing with increasingly complex (and evolving) management issues is constrained by both the scope and nature of existing provisions as well as the subjective and somewhat uncertain nature of their application.

Improved technical and allocative efficiency are suggested as options that should form part of best practice regardless of the regulatory framework under which they apply. Economic efficiency is an important element of water resource management to enable efficient and equitable use, and of encouraging conservation and sustainable management of water resources.

Improved technical water use efficiency is a means to ensure that water available for allocation is used in a manner which results in optimum benefit per volumetric unit for a range of end uses. While incentives exist for individual water users to improve technical water use efficiency, it is unlikely to enable additional water to be made available for consumptive use under the current management framework.

Options to improve allocative efficiency have the potential to enable modest increases in water availability under the current management framework by ensuring a greater portion of allocation available for consumptive use it utilised for productive benefit. However, development and implementation of to enhance allocative efficiency may require considerable effort which may not be commensurate with the overall benefits arising.

Water storage provides an option to increase both water availability and supply reliability in the Mataura catchment. However, on the basis of economics alone, modelling suggests that storage only provides significant net benefits to irrigation when per unit costs are low. The potential for development of water storage to improve supply reliability is further complicated by a range of regulatory and technical constraints that are likely to serve to increase overall storage costs. Due to the nature of the hydrogeological setting in the Mataura catchment alternative storage options such as managed aquifer recharge (MAR) are unlikely to present practical water storage options.

Amendment of the existing regulatory framework would provide an opportunity to increase water availability in the Mataura catchment and provide an opportunity to address some of the shortcomings inherent in the existing management regime. Adoption of the RWP as the primary regulatory instrument would essentially maintain existing MCO provisions with the exception of flow allocation which would be managed utilising a science-based methodology. This approach would also enable a degree of flexibility to allow future management to adapt to changing issues and improved scientific information and management methodologies through the RMA Section 65 plan change process. However, the water allocation provisions of the RWP are not without their own limitations and a range of options are identified that could be utilised to develop a more transparent and effective regulatory framework.

However, any consideration of changes to the existing regulatory framework needs to be cognisant of the provisions of RMA Section 216 which relates to the amendment or revocation of Water Conservation Orders. It is noted that this process is largely untested and, based on the limited existing case law, would likely have to meet a high threshold in terms of maintaining the overall conservation values of the existing MCO in order to successfully proceed.

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Appendix A. Water Conservation (Mataura River) Order 1997

Water Conservation (Mataura River) Order 1997

SR 1997/126

PURSUANT to sections 214 and 423 of the Resource Management Act 1991, His Excellency the Governor-General, acting by and with the advice and consent of the Executive Council, and on the recommendation of the Minister for the Environment made in accordance with the report of the Environment Court following an inquiry by that Court, makes the following order.

ANALYSIS
(List of Sections)

1. Title and commencement
2. Interpretation
3. Outstanding features
4. Rates of flow in Mataura River and Waikaia River
5. General provisions relating to water permits, discharge permits, and regional plans
6. Water permit to dam not to be granted, etc
7. Provisions relating to discharges
8. Scope of this order

ORDERS
1. Title and commencement—

(1) This order may be cited as the Water Conservation (Mataura River) Order 1997.
(2) This order comes into force on the 28th day after the date of its notification in the Gazette.

2. Interpretation—

In this order, unless the context otherwise requires,—
``Act'' means the Resource Management Act 1991:
``Authorised inflows'' means discharges of water or water containing waste into protected waters pursuant to a discharge permit:
``Protected waters'' means—

(a) The Mataura River from its source (approximate map reference NZMS 260 E42:502333) to its confluence with the sea (approximate map reference NZMS 260 F47:877946); and

(b) The Waikaia River and its tributaries, the Ōtamita Stream, and all other tributaries of the Mataura River upstream of its confluence with the Ōtamita Stream (approximate map reference NZMS 260 F45:881582); and

(c) The Mimihau Stream and the Mokoreta River and each of their tributaries.

3. Outstanding features—

It is declared that the protected waters include outstanding fisheries and angling amenity features.

4. Rates of flow in Mataura River and Waikaia River—

(1) Because of the outstanding features specified in clause 3, the rates of flow in the Mataura River and in the Waikaia River must not be reduced, by the grant or exercise of water permits, below the minimum rate of flow specified in subclauses (2) and (3).

(2) The minimum rate of flow at any point in the Mataura River and the Waikaia River above the Mataura Island Road Bridge (approximate map reference NZMS 260 F46:850158), where the flow is estimated by the Southland Regional Council from measurements taken at that point, must be 95% of—

(a) The flow so estimated by the Southland Regional Council at that point; plus

(b) Water taken in accordance with the Act from the protected waters upstream of that point and not returned to the protected waters—

less authorised inflows upstream of that point which did not have their source in the protected waters.

(3) The minimum rate of flow at any point in the Mataura River below the Mataura Island Road Bridge (approximate map reference NZMS 260 F46:850158), where the flow is estimated by the Southland Regional Council from measurements taken at that point, must be 90% of—

(a) The flow so estimated by the Southland Regional Council at that point; plus

(b) Water taken in accordance with the Act from the protected waters upstream of that point and not returned to the protected waters—

less authorised inflows upstream of that point which did not have their source in the protected waters.

5. General provisions relating to water permits, discharge permits, and regional plans—

(1) A water permit or a discharge permit must not be granted under Part 6 of the Act and a regional plan must not be made under Part 5 of the Act in respect of any part of the protected waters if such a permit or plan would contravene the provisions of this order.

(2) The prohibitions in subclause (1) do not apply to water permits or discharge permits granted or regional plans made in respect of any part of the protected waters for all or any of the following purposes:

(a) Research into, and enhancement of, fisheries and wildlife habitats:

(b) The construction, maintenance, or protection of roads, bridges, pylons, and other necessary public utilities:

(c) Soil conservation and river protection and other activities undertaken pursuant to the Soil Conservation and Rivers Control Act 1941:

(d) Stock water and stock-water reservoirs.

6. Water permit to dam not to be granted, etc—

(1) A permit to dam the Mataura River from its source to the sea and the Waikaia River from its source to its confluence with the Mataura River must not be granted under Part 6 of the Act.

(2) A permit to dam any tributary of the Waikaia River or the Mataura River which forms part of the protected waters must not be granted under Part 6 of the Act if the dam would harm salmonid fish-spawning or prevent the passage of salmonid fish.

(3) The prohibition in subclause (1) does not apply to water permits in respect of the weir at approximate map reference NZMS 260 F46:912385 if the water permits are granted or renewed subject to similar terms and conditions to which the former permits were subject.

7. Provisions relating to discharges—

(1) A discharge permit must not be granted and a regional plan must not be made for any discharge into the protected waters if the effect of the discharge would be to breach the following provisions and standards:

(a) Any discharge is to be substantially free from suspended solids, grease, and oil:

(b) After allowing for reasonable mixing of the discharge with the receiving water in that part of the protected waters between map references NZMS 260 F45:967503 to F45:963508 (Mataura River),—

(i) The natural water temperature must not be changed by more than 3 degrees Celsius:

(ii) The acidity or alkalinity of the waters as measured by the pH must be within the range of 6.0 to 8.5, except when due to natural causes:

(iii) The waters must not be tainted so as to make them unpalatable, nor must they contain toxic substances to the extent that they are unsafe for consumption by humans or farm animals, nor must they emit objectionable odours:

(iv) There must not be any destruction of natural aquatic life by reason of a concentration of toxic substances:

(v) The natural colour and clarity of the waters must not be changed to a conspicuous extent:

(vi) The oxygen content in solution in the waters must not be reduced below 6 milligrams per litre:

(vii) Based on not fewer than 5 samples taken over not more than a 30-day period, the median value of the faecal coliform bacteria content of the water must not exceed 2000 per 100 millilitres and the median value of the total coliform bacteria content of the water must not exceed 10000 per 100 millilitres:

(c) After allowing for reasonable mixing of the discharge with the receiving ater in that part of the protected waters between map references—

(i) NZMS 260 F45:894581 to F45:885584 (Mataura River); and

(ii) NZMS 260 F46:917391 to F46:924396 (Mataura River),—

(A) The natural water temperature must not be changed by more than 3 degrees Celsius:

(B) The acidity or alkalinity of the waters as measured by the pH must be within the range of 6.5 to 8.3, except when due to natural causes:

(C) The waters must not be tainted so as to make them unpalatable, nor must they contain toxic substances to the extent that they are unsafe for consumption by humans or farm animals, nor must they emit objectionable odours:

(D) There must not be any destruction of natural aquatic life by reason of a concentration of toxic substances:

(E) The natural colour and clarity of the waters must not be changed to a conspicuous extent:

(F) The oxygen content in solution in the waters must not be reduced below 6 milligrams per litre:

(G) Based on not fewer than 5 samples taken over not more than a 30-day period, the median value of the faecal coliform bacteria content of the waters must not exceed 200 per 100 millilitres:

(d) After allowing for a reasonable mixing of the discharge with the receiving waters in those parts of the protected waters other than the parts specified in paragraphs (b) and (c),—

(i) The natural water temperature must not be changed by more than 3 degrees Celsius:

(ii) The acidity or alkalinity of the waters as measured by the pH must be within the range of 6.0 or 9.0, except when due to natural causes:

(iii) The waters must not be tainted so as to make them unpalatable, nor must they contain toxic substances to the extent that they are unsafe for consumption by humans or farm animals, nor must they emit objectionable odours:

(iv) There must not be any destruction of natural aquatic life by reason of a concentration of toxic substances:

(v) The natural colour and clarity of the waters must not be changed to a conspicuous extent:

(vi) The oxygen content in solution in the waters must not be reduced below 5 milligrams per litre.

(2) Where it is impracticable, because of emergency overflows or the carrying out of maintenance work or any other temporary situation, to require compliance with the

relevant provisions of subclause (1), water permits and discharge permits may be granted by the Southland Regional Council.

8. Scope of this order—

Nothing in this order limits the effect of section 14(3)(b) and (e) of the Act relating to the use of water for domestic needs, for the needs of animals, or for fire-fighting purposes.

MARIE SHROFF,
Clerk of the Executive Council.

EXPLANATORY NOTE

This note is not part of the order, but is intended to indicate its general effect.

This order declares that the Mataura River and the Waikaia River and various other rivers, streams, and tributaries include outstanding fisheries and angling amenity features.

The order includes various provisions to preserve and protect these features.

Issued under the authority of the Acts and Regulations Publication Act 1989.

Date of notification in Gazette: 10 July 1997.

This order is administered in the Ministry for the Environment.

Appendix B. Irrigation Demand Modelling

This appendix outlines the methodology utilised to model potential future irrigation water demand in the Mataura catchment.

B.1 Irrigable Areas

In New Zealand most pasture, horticulture and arable irrigation occurs on flat to undulating land (≤ 7º). However, recent developments in irrigation technology, including k-line systems and centre pivots, means irrigation of rolling land (up to 15º) is becoming more common. In a few locations in New Zealand, such as North Otago, there are isolated incidences of slopes up to 20º being irrigated. However, these steep slopes can be susceptible to run-off. For the purposes of this report it was assumed that irrigation will generally not occur on land slopes over 15º.

B.2 Soils

Soil plant available water at field capacity (PAW) was from the Topoclimate Southland Soils Information (Crops for Southland, 2003) where available, and the NZ Fundamental Soils Layer (Landcare Research, 2000) where Topoclimate soils information was unavailable. Soil PAW were adjusted to a rooting depth of 60 cm. A 60 cm rooting depth is more typical of high production irrigated pasture species, whereas the 90cm rooting depth from the Fundamental Soils Layer is more typical of more drought resistant pasture species. Soil PAW values were adjusted for rooting depth using the rule of thumb proposed by Trevor Webb of Landcare for North Otago (Brown and McIndoe, 2003):

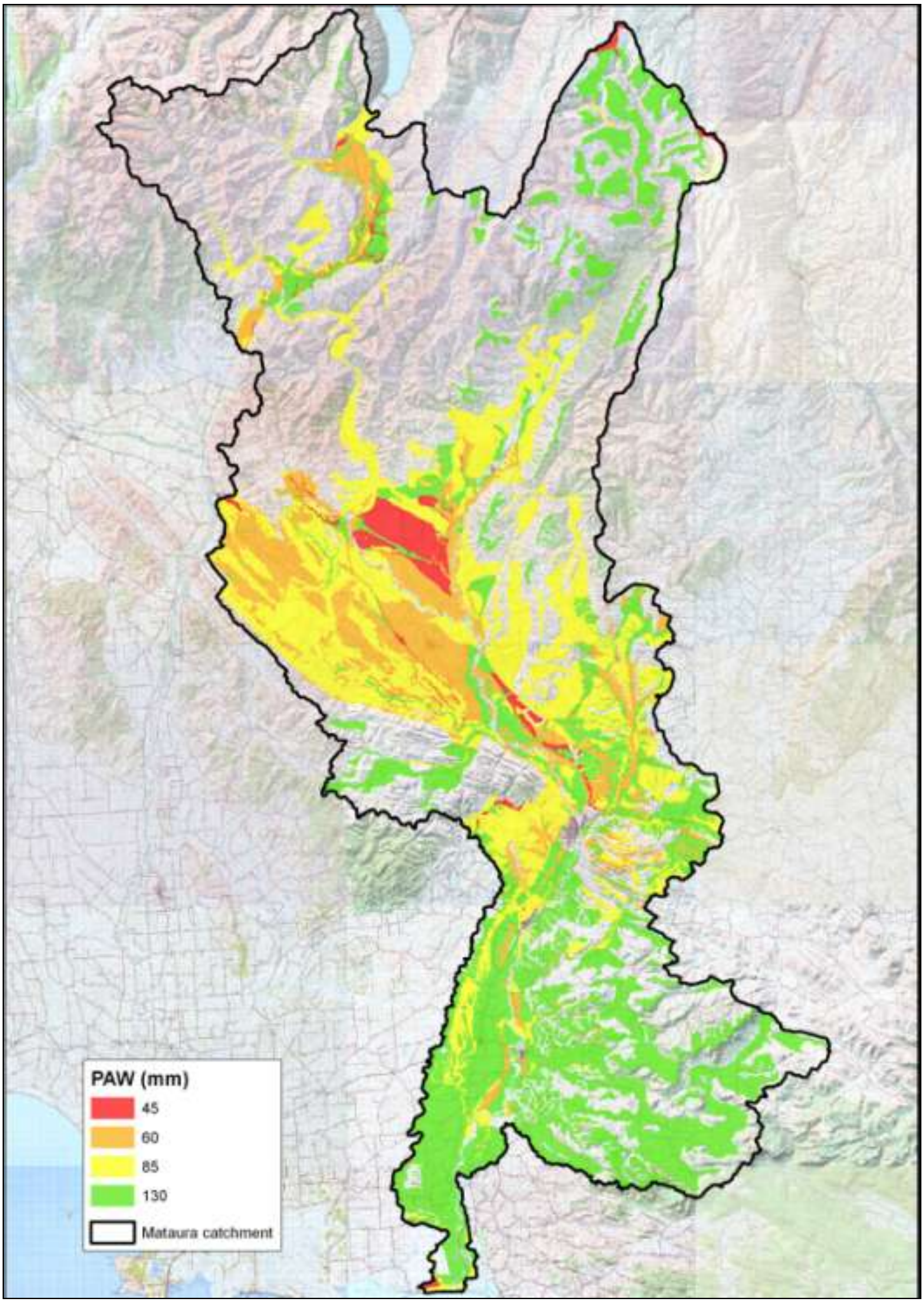
"*Assume the top 200 mm of topsoil contributes 40 mm of water, and the remainder of the soil profile down to a maximum of 900 mm contributes a constant amount of water per unit depth.*"

Soils were aggregated into the classes given in **Table B1.** The distribution of soil moisture classes in the Mataura catchment is shown in **Figure B1** below.

- **Table B1. Soil moisture classes utilised for irrigation demand modelling**

PAW range 90cm rooting depth	PAW class midpoint	
	90cm rooting depth	60cm rooting depth
30-60mm	45mm	45mm
60-90mm	75mm	60mm
90-150mm	120mm	85mm
150-250mm	200mm	130mm

Water demand modelling assumed soils were free draining, and the depth to groundwater is sufficient so that there was no capillary rise from the water table into the root zone. Where soil pans exist or where groundwater is close to the surface, water requirements will be less than modelled.

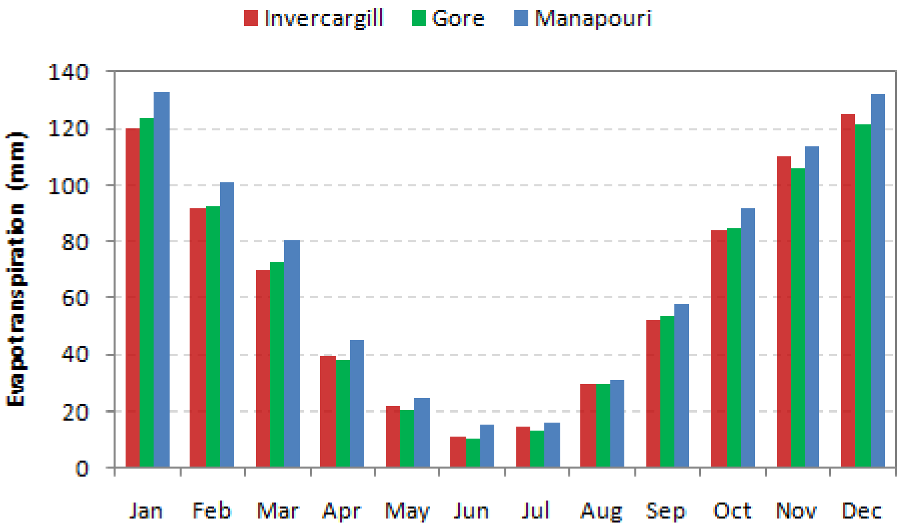


- **Figure B1. Soil PAW class in the Mataura catchment for 60cm rooting depth (for land<15^o slope)**

B.3 Climate

The only source of reference evapotranspiration (ET) data within the vicinity of the study area is from the MetService Gore AWS climate station. Calculated ET from this site was therefore assumed to be representative of the whole study area. This seems a reasonable assumption given that calculated

ET values are relatively constant across the Southland Region (**Figure B2**) and average temperatures are relatively constant across the study area.



- **Figure B2. Monthly evapotranspiration values in the Southland Region (source: NIWA National Climate Database)**

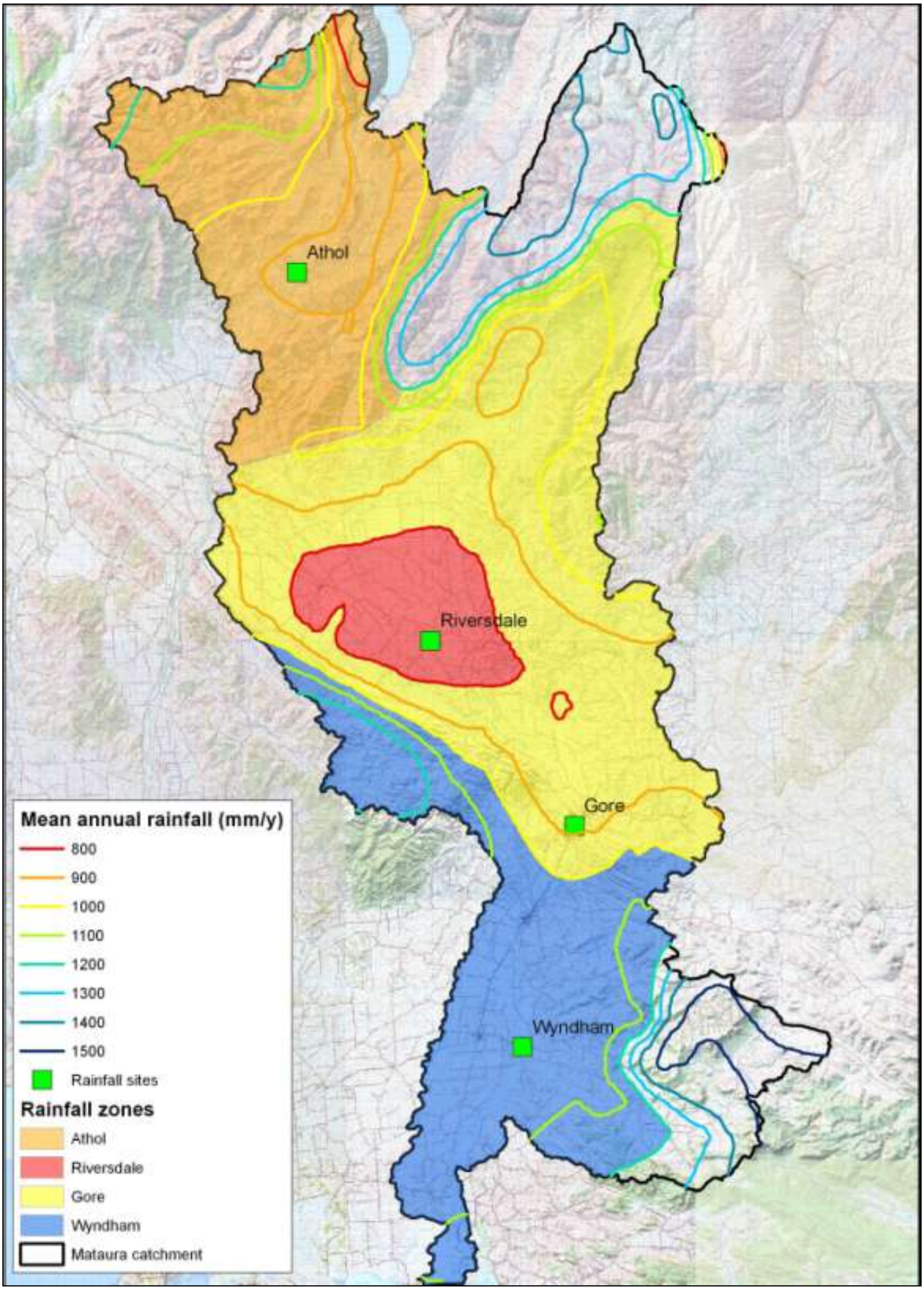
Mean annual rainfall across the Mataura catchment varies from 800 to 1,500 mm/year. In order to model potential irrigation demand the catchment was split into four rainfall zones, based on mean annual rainfall and data from Athol, Riversdale, Gore and Wyndham used to represent rainfall in each zone. **Figure B3** shows a plot of mean annual rainfall across the Mataura catchment showing the spatial extent of the four modelled rainfall zones. Areas where annual rainfall exceeded 1,200 mm/year were excluded from the analysis as it was assumed irrigation was unlikely to be economic in these higher rainfall areas. Climate data used for the calculation of irrigation demand is outlined in **Table B2** below.

- **Table B2. Climate data used for irrigation demand modelling**

Parameter	Location	Mean Annual Value (mm/year)
Reference ET	Gore	775
Rainfall	Riversdale	780
Rainfall	Athol	850
Rainfall	Gore	950
Rainfall	Wyndham	1,050

B.4 Irrigation

Irrigation was modelled assuming a well designed and managed centre-pivot irrigation system. The analysis also assumed that irrigators install Aquaflex or similar soil moisture monitoring equipment, and irrigate only when necessary. The assumed irrigation system modelling parameters are given in **Table B3** below.



- **Figure B3. Mean annual rainfall and rainfall zones used for irrigation demand modelling in the Mataura catchment**

- **Table B3. Modelled irrigation system parameters**

Parameter	Soil PAW (mm)			
	45	**60**	**85**	**130**
Application depth (mm)	20	20	58	35
Minimum return period (day)	5	5	7	10
System capacity (mm/day)	4.0	4.0	4.0	4.0
Application efficiency	80%	80%	80%	80%
Trigger soil moisture deficit (mm)	20	25	35	45

B.5 Crop Evapotranspiration

Modelling of crop evapotranspiration was based on relationship between crop and reference evapotranspiration outlined by Allen *et al*. (1998):

Crop evapotranspiration = $k_s \times k_c \times$ *Reference evapotranspiration*

- where k_s is the water stress reduction factor and k_c is the crop coefficient.

The water stress reduction factor was a function of soil moisture. As recommended by Allen *et al*., it was assumed that k_s equalled 1.0 when the soil moisture deficit was less than the plant readily available water, and k_s reduced linearly down to a value of zero at wilting point, when the soil moisture deficit was greater than the plant readily available water. Readily available water was assumed to be equal to 50% of the soil PAW. For pasture it was assumed k_c = 1.0.

Appendix C. Future Land Use Projections

Based on information provided by Environment Southland **Table C1** tabulates current irrigated areas in the Mataura catchment by sail class, rainfall zone and land use class. These data are presented spatially in **Figure C1**.

Tables **C2**, **C3** and **C4** present the equivalent breakdown of land use under the three growth scenarios (accelerated growth, conservative growth and 50 percent of conservative growth projections. Corresponding land use maps are shown in Figures **C2**, **C3** and **C4**.

- **Table C1. Land use on current irrigated areas in the Mataura catchment**

Rainfall zone	**Soil PAW class (mm)**			
	45	**60**	**85**	**130**
		Dairying		
Athol	-	-	-	-
Gore	-	-	-	-
Riversdale	148 ha	2,518 ha	125 ha	1 ha
Wyndham	-	-	-	-
		Cropping and dairy support		
Athol	446 ha	190 ha	87 ha	66 ha
Gore	41 ha	16 ha	123 ha	44 ha
Riversdale	630 ha	151 ha	682 ha	16 ha
Wyndham	-	-	-	-
		Horticulture		
Athol	-	-	-	-
Gore	-	-	-	-
Riversdale	15 ha	44 ha	-	-
Wyndham	-	35 ha	160 ha	-

- **Table C2. Modelled 2030 irrigated areas - 50 percent of conservative growth scenario**

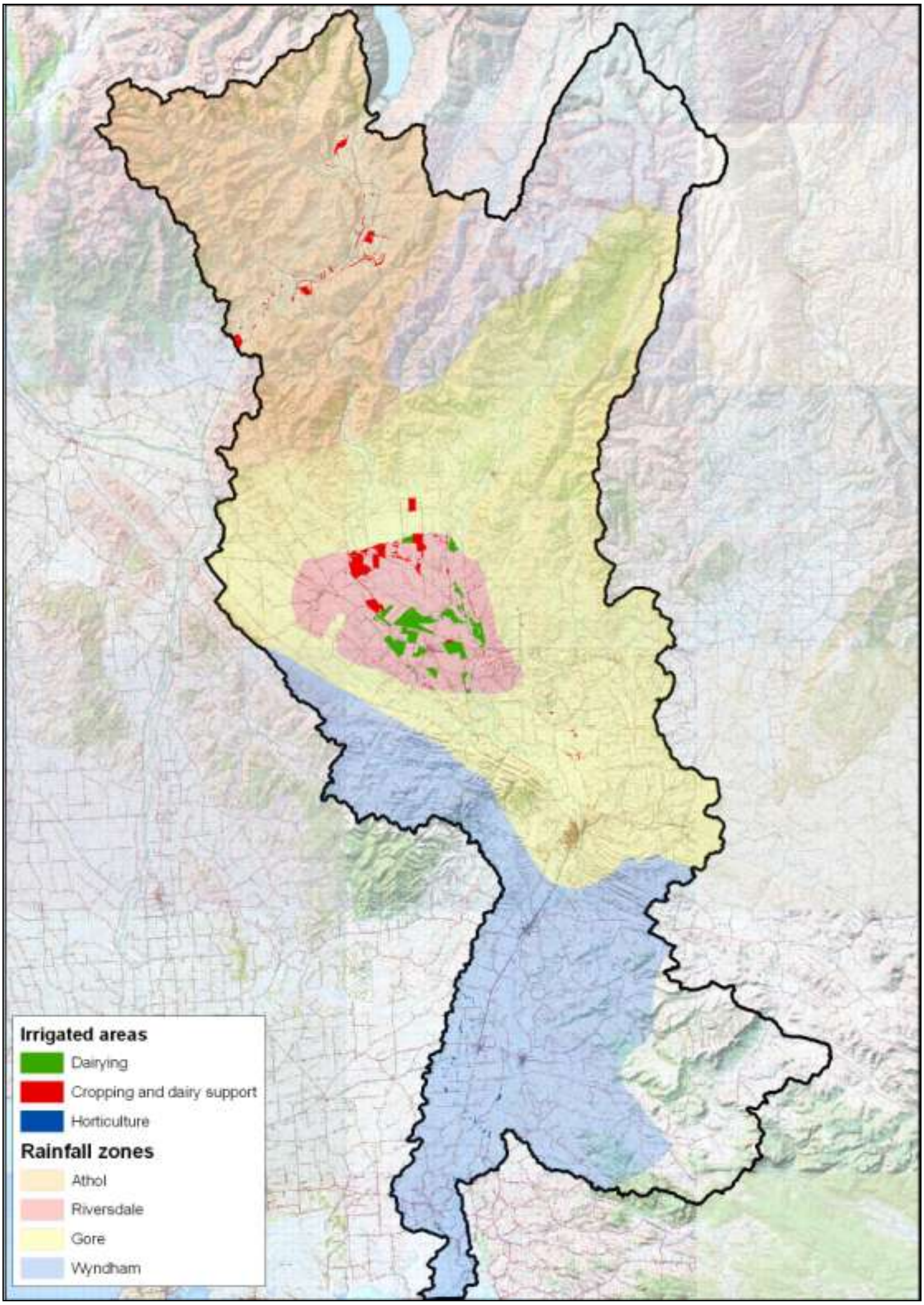
Rainfall zone	Soil PAW class (mm)			
	45	60	85	130
Dairying				
Athol	-	-	-	-
Gore	-	-	-	-
Riversdale	2,324 ha	4,079 ha	125 ha	1 ha
Wyndham	-	-	-	-
Cropping and dairy support				
Athol	446 ha	190 ha	87 ha	66 ha
Gore	41 ha	16 ha	123 ha	44 ha
Riversdale	630 ha	3,759 ha	682 ha	16 ha
Wyndham	-	-	-	-
Horticulture				
Athol	-	-	-	-
Gore	-	-	-	-
Riversdale	15 ha	208 ha	-	-
Wyndham	-	35 ha	160 ha	-

- **Table C3. Modelled 2030 irrigated areas - conservative growth scenario**

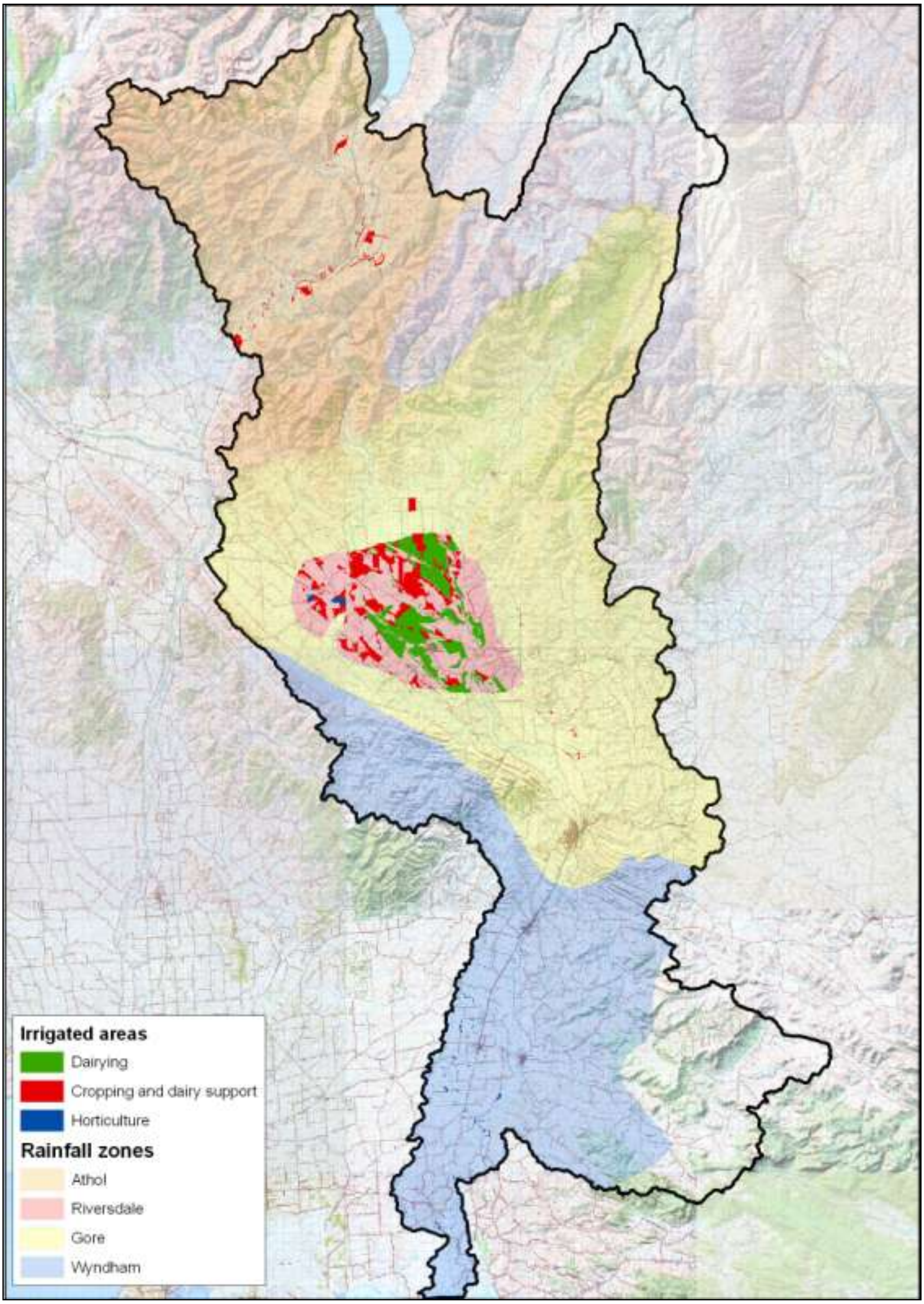
Rainfall zone	Soil PAW class (mm)			
	45	60	85	130
Dairying				
Athol	-	-	-	-
Gore	-	-	-	-
Riversdale	2,324 ha	7,623 ha	230 ha	1 ha
Wyndham	-	-	-	-
Cropping and dairy support				
Athol	446 ha	190 ha	87 ha	66 ha
Gore	41 ha	16 ha	123 ha	44 ha
Riversdale	630 ha	4,118 ha	3,926 ha	16 ha
Wyndham	-	-	-	-
Horticulture				
Athol	-	-	-	-
Gore	-	-	-	-
Riversdale	15 ha	44 ha	-	-
Wyndham	-	35 ha	160 ha	-

- **Table C4. Modelled 2030 irrigated areas - accelerated growth scenario**

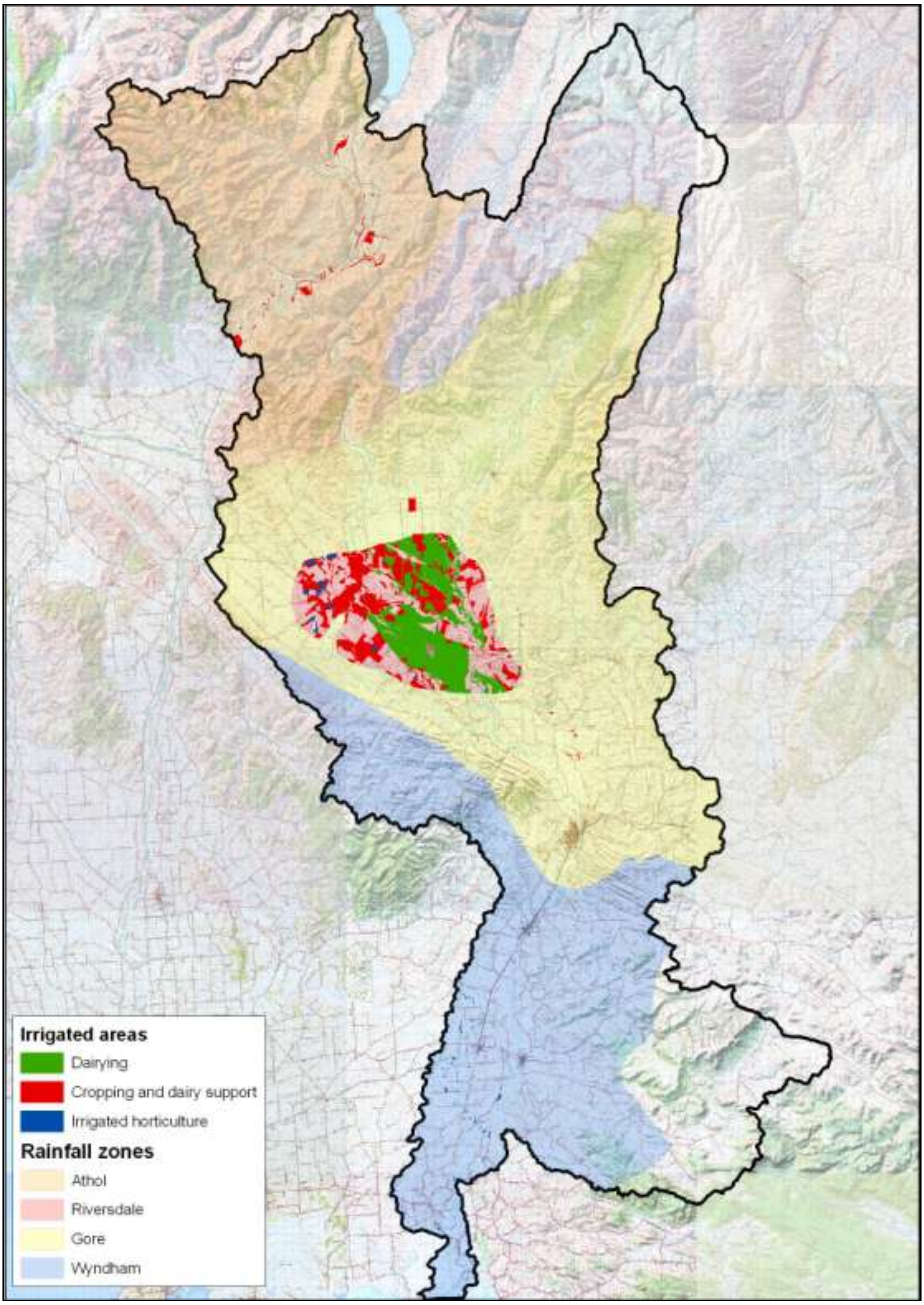
Rainfall zone	Soil PAW class (mm)			
	45	60	85	130
Dairying				
Athol	-	-	-	-
Gore	-	-	-	-
Riversdale	2,324 ha	7,623 ha	1,895 ha	1 ha
Wyndham	-	-	-	-
Cropping and dairy support				
Athol	446 ha	190 ha	87 ha	66 ha
Gore	41 ha	16 ha	123 ha	44 ha
Riversdale	630 ha	4,118 ha	6,515 ha	16 ha
Wyndham	-	-	-	-
Horticulture				
Athol	-	-	-	-
Gore	-	-	-	-
Riversdale	15 ha	44 ha	-	-
Wyndham	-	35 ha	160 ha	-



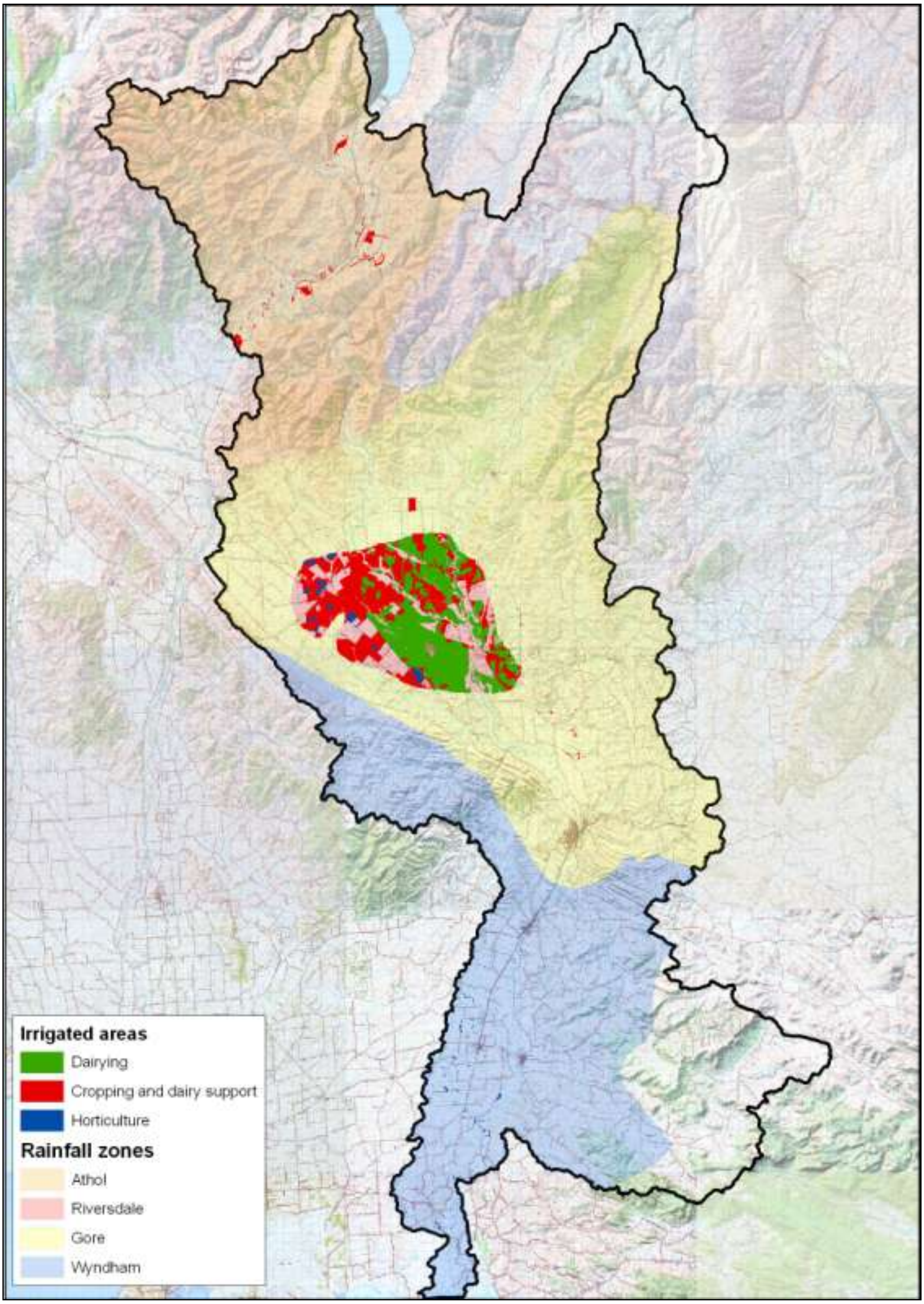
- Figure C1. Modelled existing (2010) irrigation areas



- **Figure C2. Modelled 2030 irrigation areas - 50 percent of conservative growth scenario**



- Figure C3. Modelled 2030 irrigation areas - conservative growth scenario



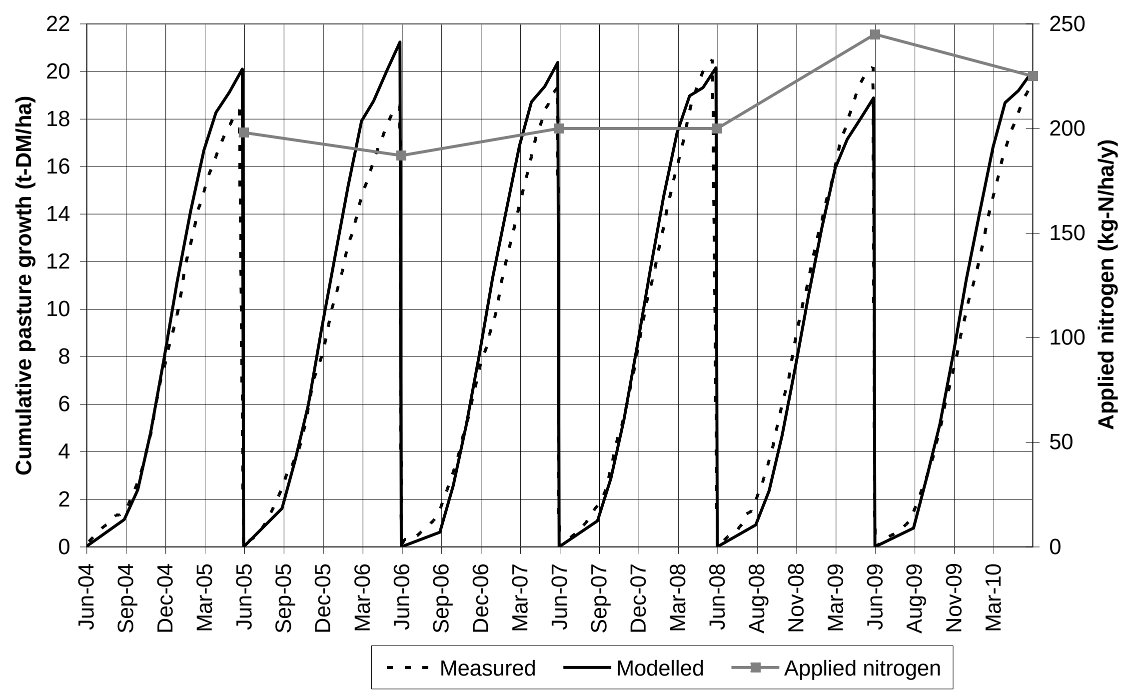
- Figure C4. Modelled 2030 irrigation areas - accelerated growth scenario

Appendix D. Dairy Economic Modelling

Irrigation and soil water dynamics were modelled using AusFarm, coupled with Aqualinc's custom irrigation component. AusFarm is a biophysical model of temperate climate pastoral systems, developed by CSIRO Australia. This model is widely used in Australia and internationally by farm advisors and researchers. For further information about AusFarm, see http://www.grazplan.csiro.au/ . Details of the soil water and pasture models are given by Moore et al. (1997). A perennial rye-grass, white clover mix was modelled. In the model, pasture is periodically cut to simulate typical grazing management, with the amount of pasture cut used to calculate growth rates. Aqualinc has compared AusFarm model predictions to pasture growth data from Lincoln University Dairy Farm (LUDF) (**Table D1** and **Figure D1**), and with farm advisor's experience from Canterbury and Southland, and have found that the model is suitable for use in these two regions.

- **Table D1: LUDF soil water balance, measured and predicted by AusFarm (June 2004-May 2009)**

Parameter	Measured	Predicted
Average annual rainfall	643 mm/y	643 mm/y
Average annual irrigation	469 mm/y	466 mm/y
Average annual drainage	235 mm/y	234 mm/y(2)
Average annual ET	870 mm/y(1)	874 mm/y
(1) Rainfall + irrigation – drainage		



- **Figure D1: LUDF pasture growth, measured and predicted by AusFarm.**

Aqualinc has developed a custom irrigation component for AusFarm that models various aspects of irrigation systems including how irrigators move around a series of paddocks in a rotation, and includes the impact of restrictions, seasonal limits, and on-farm storage ponds.

AusFarm pasture growth rates were used in a monthly timeseries feed budget. The model accounts for how baleage or silage would be cut when cow requirements are unable to keep up with pasture growth. The model assumes that farmers maintain constant annual milk production through using supplementary feed whenever stock requirements exceed pasture availability. A factory supply dairy platform, where cows are wintered off in June and July, was modelled. Key economic and operational parameters were estimated from MAF’s dairy economic model for southland and from advice from farm consultant Alistair Gibson. Parameters are given in **Table D2** and **Table D3**.

Modelling assumes there is no capillary rise of groundwater into the root zone. Where groundwater is close to the surface and plants source some water from groundwater, AusFarm will under-predict pasture growth.

Modelling assumed minimal use of imported feeds (e.g. cereals or PKE) on the dairy platform, since such high input/output systems are currently uncommon in Southland.

- **Table D2: Dairy economic modelling parameters - dryland**

Parameter	Value
General	
Stocking rate	Set so imported feed requirements are close to zero
Grazing management	Graze from 2,800-3,300kgDM/ha down to 1,500kgDM/ha.
Annual Nitrogen	100 kg-N/ha/y
Grazing pasture losses	20%
Total baleage ME losses from cutting to eaten	45%
Cow requirements	4.8 t-DM/cow/y (12 ME equivalent)
Milk production	390 kg-MS/cow/y
Income	
Long-term average milk payout	$5.50/ kg-MS
Other income (calves & culled cows)	$120×total no. cows milked/y
Expenses	
Re-grassing	$600/ha
Cutting and wrapping baleage	$0.25/kgDM 12 ME equivalent eaten
All other expenses	$850 × no. cows + $500/ha

- **Table D3: Dairy economic modelling parameters - irrigated**

Parameter	Value
General	
Stocking rate	Set so imported feed requirements are close to zero
Grazing management	Graze from 2,800-3,300kgDM/ha down to 1,500kgDM/ha.
Annual Nitrogen	200 kg-N/ha/y
Grazing pasture losses	20%
Total baleage ME losses from cutting to eaten	45%
Cow requirements	4.8 t-DM/cow/y (12 ME equivalent)
Milk production	390 kg-MS/cow/y
Income	
Long-term average milk payout	$5.50/ kg-MS
Other income (calves & culled cows)	$120×total no. cows milked/y
Expenses	
Re-grassing	$600/ha
Cutting and wrapping baleage	$0.25/kgDM 12 ME equivalent eaten
Irrigation (electricity, maintenance & labour)	$75/ha/y + $0.015/m^3/ha/y
All other expenses[57]	$850 × no. cows + $700/ha
Irrigation financing parameters	
Irrigation capital cost (including off-farm and consenting costs)	$5,000/ha
Loan period	15 years
Loan rate	8%
Annual financing cost	$575/ha

---

[57] Excludes interest or principle repayments, depreciation, and tax

Appendix E. Irrigation Cost Sensitivity Testing

- **Table E1. Net regional outcomes for different discount rates ($million per annum)**

	Discount rate		
Scenario	**0.05**	**0.08**	**0.1**
1	$3.68	$2.48	$1.68
2a	$3.73	$2.51	$1.69
2b	$4.22	$2.62	$1.55
2c	$4.06	$2.10	$0.80
3a	$3.74	$2.52	$1.70
3b	$4.84	$3.21	$2.13
3c	$5.90	$3.85	$2.49
3d	$6.71	$4.25	$2.61
3e	$8.31	$5.13	$3.00
4a	$3.74	$2.52	$1.70
4b	$4.86	$3.23	$2.14
4c	$5.90	$3.85	$2.49
4d	$6.85	$4.38	$2.73
4e	$8.34	$5.15	$3.02
5a	$3.73	$2.51	$1.69
5b	$4.61	$3.00	$1.92
5c	$5.46	$3.43	$2.07
5d	$6.19	$3.75	$2.13
5e	$7.44	$4.30	$2.20

- **Table E2. Net regional outcomes for different feed prices ($million per annum)**

	Feed price ($/kgDM)		
Scenario	**0.14**	**0.18**	**0.22**
1	$2.13	$2.60	$3.07
2a	$2.16	$2.63	$3.11
2b	$2.19	$2.77	$3.34
2c	$1.64	$2.27	$2.90
3a	$2.17	$2.64	$3.12
3b	$2.75	$3.38	$4.00
3c	$3.28	$4.06	$4.83
3d	$3.58	$4.49	$5.40
3e	$4.27	$5.43	$6.59
4a	$2.17	$2.64	$3.12
4b	$2.76	$3.39	$4.01
4c	$3.28	$4.05	$4.83
4d	$3.70	$4.62	$5.53
4e	$4.30	$5.45	$6.61
5a	$2.16	$2.63	$3.11
5b	$2.54	$3.15	$3.76
5c	$2.87	$3.62	$4.37
5d	$3.10	$3.98	$4.86
5e	$3.49	$4.59	$5.69

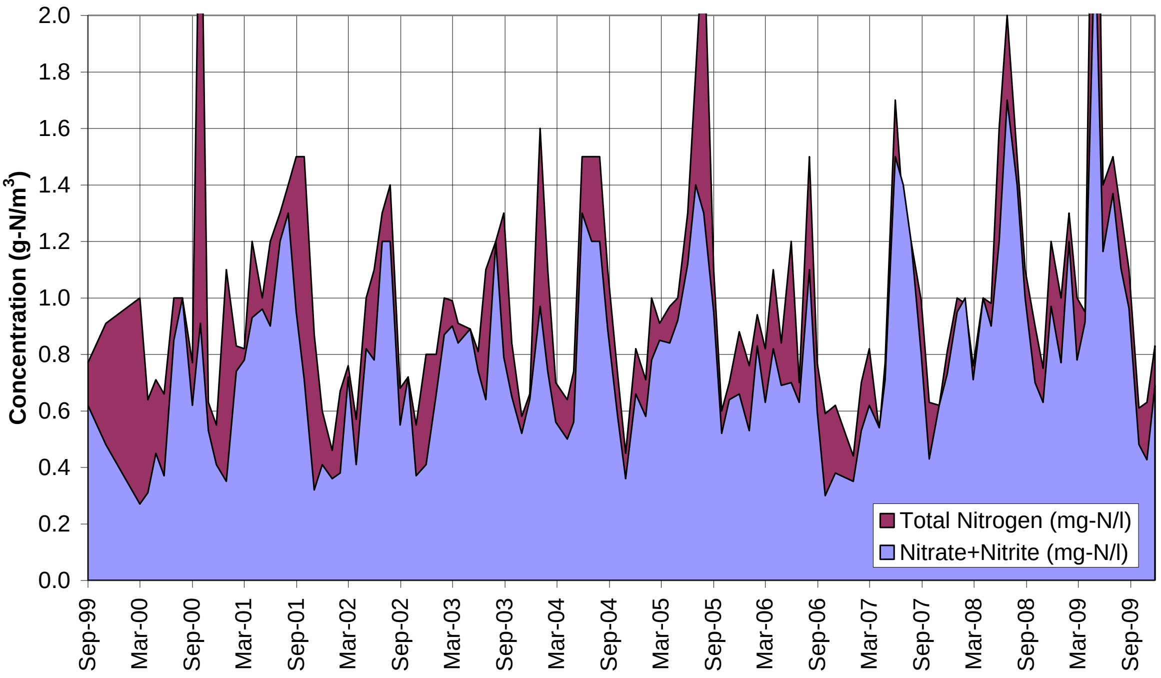
- **Table E3. Net regional outcomes for different capital costs ($million per annum)**

	Capital cost (proportion of base)		
Scenario	**0.8**	**1**	**1.2**
1	$3.30	$2.60	$1.91
2a	$3.34	$2.63	$1.92
2b	$3.69	$2.77	$1.85
2c	$3.40	$2.27	$1.14
3a	$3.35	$2.64	$1.94
3b	$4.32	$3.38	$2.43
3c	$5.24	$4.06	$2.87
3d	$5.91	$4.49	$3.07
3e	$7.27	$5.43	$3.59
4a	$3.35	$2.64	$1.94
4b	$4.33	$3.39	$2.45
4c	$5.24	$4.05	$2.87
4d	$6.04	$4.62	$3.19
4e	$7.29	$5.45	$3.61
5a	$3.34	$2.63	$1.92
5b	$4.09	$3.15	$2.22
5c	$4.79	$3.62	$2.45
5d	$5.39	$3.98	$2.57
5e	$6.40	$4.59	$2.77

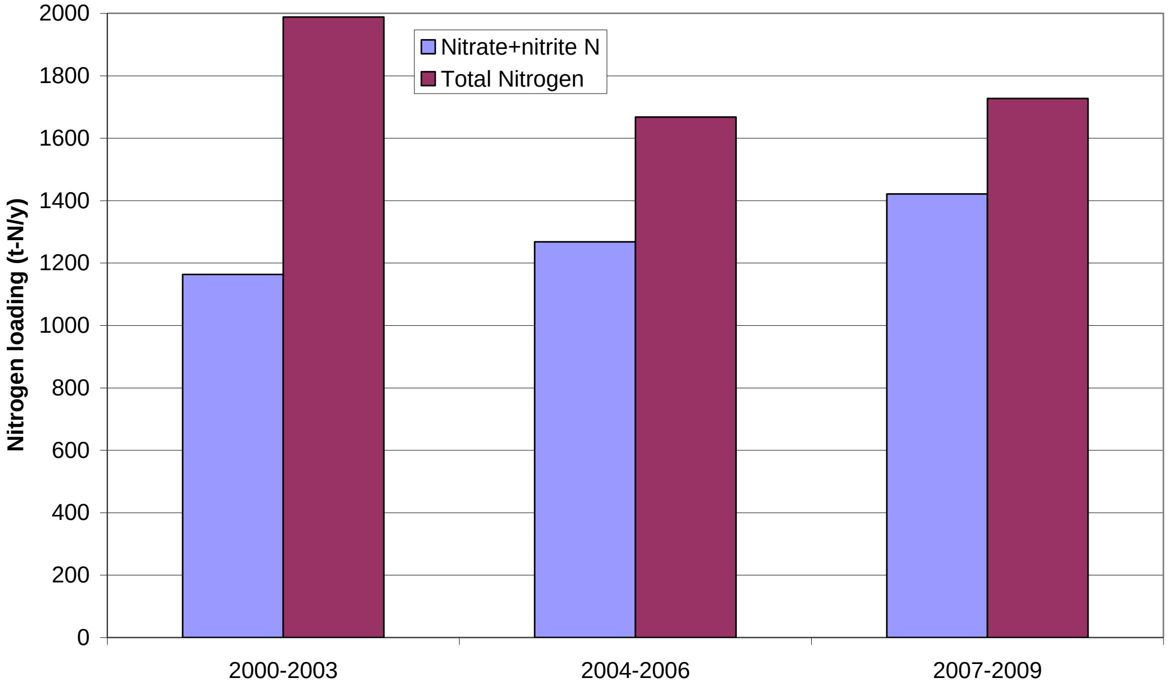
Appendix F. Spreadsheet Assessment of Land Use Change Scenario Nutrient Loadings

F.1 Measured Nitrogen loadings

About 80% of the total nitrogen in the Mataura River at Gore is in the form of nitrate; with the remaining 20% is organic nitrogen (**Figure F1**). The high proportion of nitrate-N, together with the relatively consistent concentrations suggests that most nitrogen in the river originates from land surface recharge, entering the river through the groundwater system. **Figure F2** presents the nitrogen loading at Gore. From **Figure F2** it is not possible to conclude whether or not nitrogen loadings are increasing with time.



- Figure F1: Measured nitrogen in the Mataura River at Gore



- Figure F2: Nitrogen loadings in the Mataura River at Gore, 2000 to 2010

F.2 Calculated Nitrogen losses

Annual nitrogen loadings were calculated based on the land use cover. Current land use is shown in Figure F3 and summarised in F1 below. Current land use was estimated from the Land Cover Database version 2 (Terralink 2004). Dairy farmers and arable farms in 2010 were identified by Environment Southland (2010) and FAR (2010), respectively. Typical total nitrogen losses for each land use type were based on estimates by AgResearch (2010).

- Table F1: Estimated current total nitrogen losses by land use type, for the Mataura River catchment at Gore

Land use or cover	Area (km^2)	Nitrogen loss	
		kg-N/ha/y	t/y
Dairying	212	25	530
Arable	64	25	160
High production sheep and beef	1,135	8	908
Low production sheep and beef	626	4	250
Forest and scrub	439	2	66
Tussock	968	2	194
Other (alpine, rock, lakes, urban)	130	0	0
	3,574		**2,108**

From Table F1 the estimated total nitrogen loss in the Mataura catchment at Gore is approximately 2,100 t-N/y. This compares with a measured loading of between 1,700 to 2,000 t-N/y. Overall, the calculated nitrogen loss is close to the measured loading. Denitrification or nitrogen uptake by plants can partly explain why measured loadings are less than calculated losses.

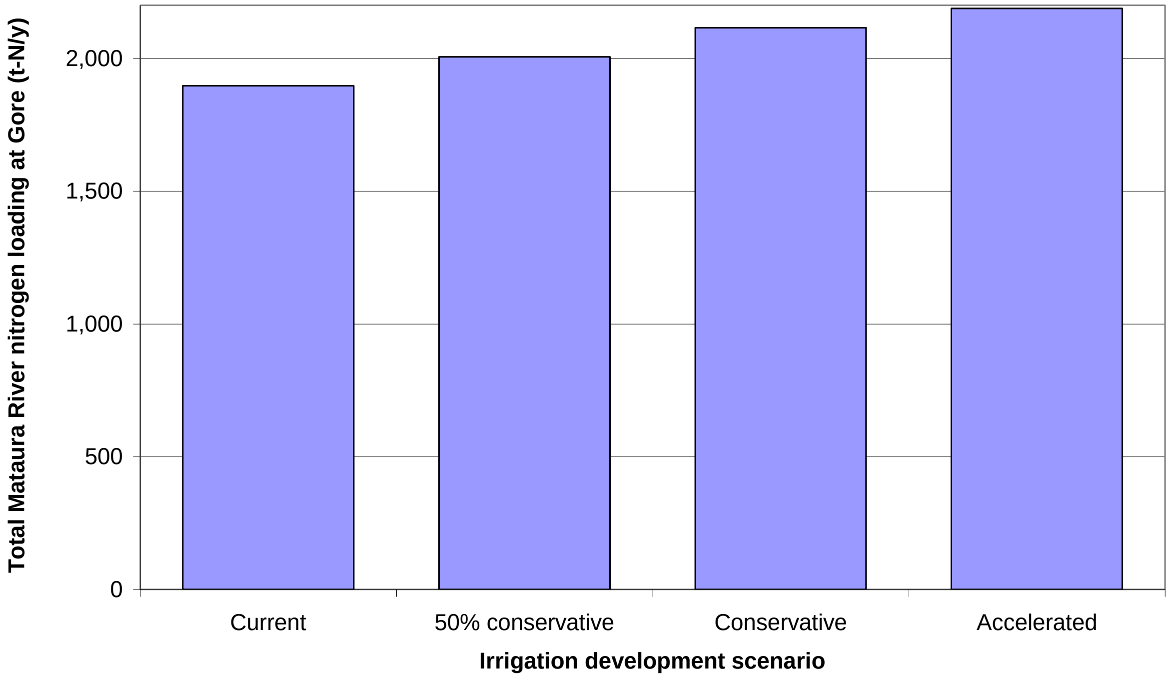
F.3 Predicted Nitrogen loadings

Predicted changes in land use for the three irrigation development scenarios are given in Table F2. These scenarios are more fully described in Appendix C. Given the predicted changes in land use, resulting impacts on total nitrogen loading in the Mataura River at Gore are given in Figure F3 based on the typical nitrogen losses listed in Table F2.

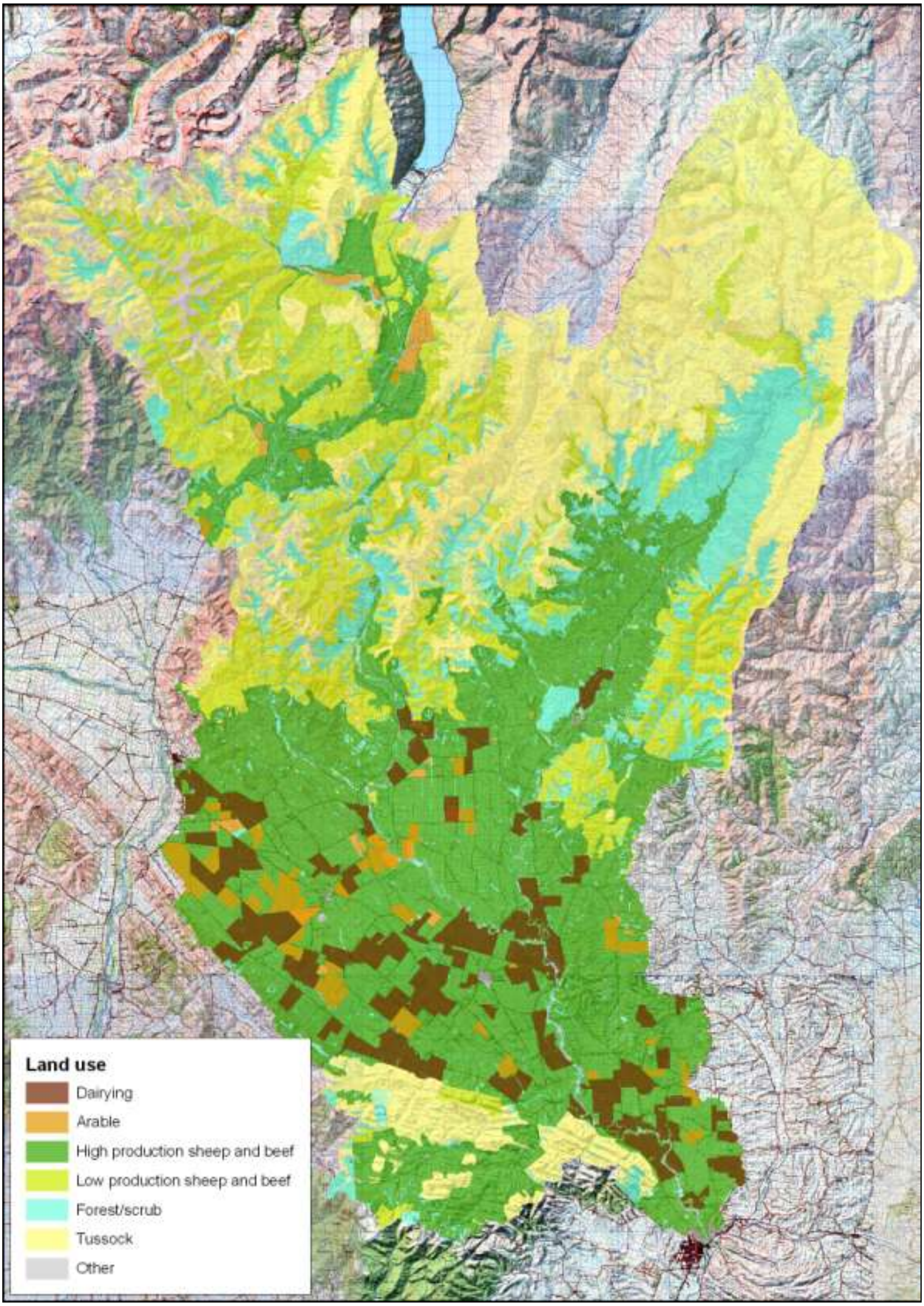
Figure F3 results assume 10 percent of nitrogen is lost from the system through denitrification and/or nitrogen uptake by plants and suggest the 50 percent conservative growth scenario could increase the nitrogen loading in the Mataura River at Gore by about 6 percent, with an increase of approximately 20 percent occurring under the accelerated growth scenario.

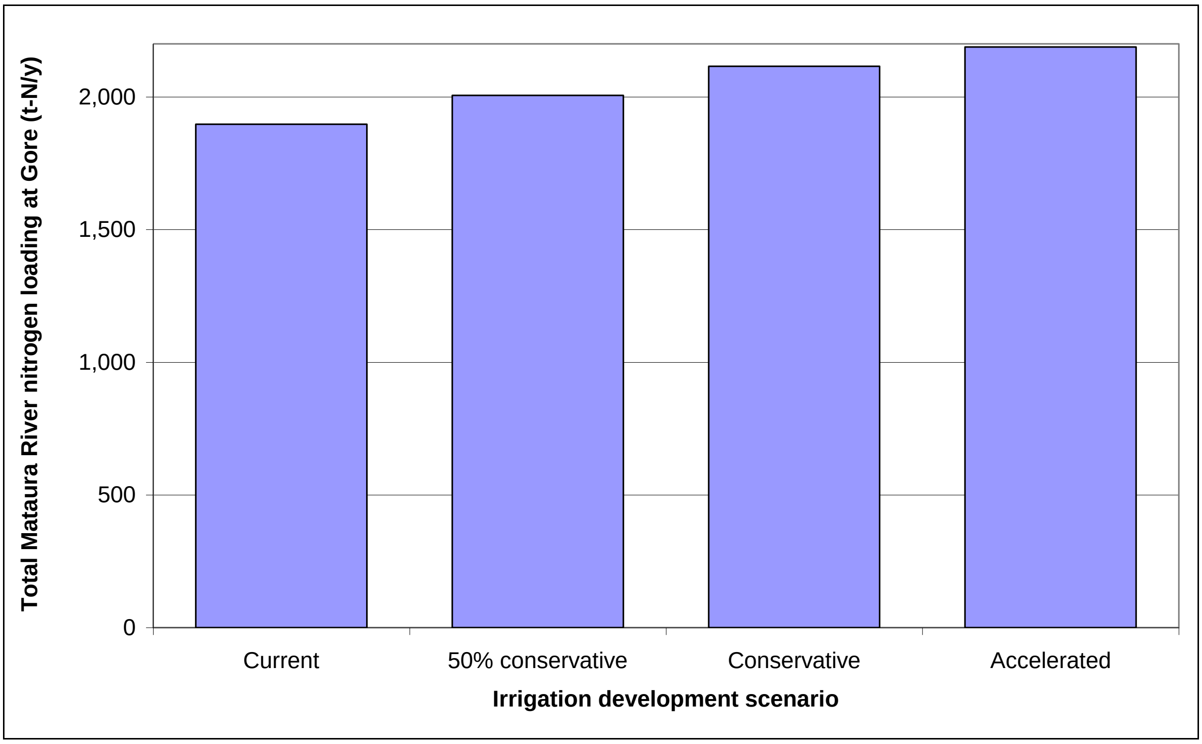
- **Table F2: Predicted changes in land use (km^2) for irrigation development scenarios**

Land use or cover	Irrigation development scenario			
	Current	50%	Conservative	Accelerated
Dairying	212	248	283	307
Arable	64	100	135	159
High production sheep and beef	1,135	1,064	993	945
Low production sheep and beef	626	626	626	626
Forest and scrub	439	439	439	439
Tussock	968	968	968	968
Other (alpine, rock, lakes, urban)	130	130	130	130
Total	**3,574**	**3,574**	**3,574**	**3,574**



- **Figure F3: Predicted changes in nutrient loads for the various land use scenarios modelled**


Land use
Dairying
Arable
High production sheep and beef
Low production sheep and beef
Forest/scrub
Tussock
Other



- **Figure F4: Predicted total nitrogen loading in the Matura River at Gore for the three modelled land use change scenarios**

References

AgResearch (2010). “Land use and land management risks to water quality in Southland”. Report prepared for Environment Southland by AgResearch Ltd. April 2010.

Environment Southland (2010). “Dairy farms as identified by Environment Southland”. GIS files supplied September 2010.

FAR (2010). “Cropping farms as identified by the Foundation of Arable Research”. GIS files supplied September 2010.

Terralink (2004). “Land Cover Database version 2”. Terralink International Ltd.

Appendix G. Water Quality and Land Use Scenario Modelling

Impacts of land use and farm mitigation practices on nutrients

Application of CLUES to the Mataura Catchment

Prepared for Environment Southland

March 2011

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Contents

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1. Background

Environment Southland (ES) has contracted NIWA to simulate the effects of land use change and farm mitigation practices on water quality (loads and concentrations of total nitrogen, TN and total phosphorus, TP) for the Mataura River catchment (5350 km^2) using the Catchment Land Use for Environmental Sustainability model version 3 (CLUES 3.0).

CLUES was run for combinations of four land use and two farm practice or nutrient mitigation scenarios giving a total of eight runs; a base-case (current land use and farm practices) and seven possible futures. The land use scenarios were prepared by Aqualinc Research Ltd for ES and were provided to NIWA. The farm practice scenarios are based on those developed by Monaghan et al. (2010) for the Oreti River catchment. The results for the base-case are compared to observed water quality data from 23 ES monitoring sites and two sites from the national water quality database. Comparisons between the base-case and the future scenarios were carried out to determine the possible impacts of changes in land use and farm practices.

2. CLUES

CLUES is a modelling system for assessing the effects of land use change on water quality and socio-economic factors at a minimum scale of sub-catchments (~10 km^2 and above). CLUES was developed for the Ministry of Agriculture and Forestry (MAF) in association with the Ministry for the Environment (MfE) by NIWA, in collaboration with Lincoln Ventures, Harris Consulting, AgResearch, HortResearch, Crop and Food Research, and Landcare Research. CLUES couples a number of existing models within a GIS-platform and is provided to users as a front-end interface for ArcGIS which queries a geo-spatial database (**Error! Reference source not found.**). The CLUES interface has tools which allow users to develop land use change scenarios. This study uses a pre-release version of CLUES (CLUES 3.0) which also allows users to vary stocking rates and apply mitigation factors to simulate the impacts of various farming practices on water quality.

CLUES integrates the following models into one tool within a GIS platform:

- **SPARROW** (Spatially Referenced Regression on Watershed attributes) - predicts annual average stream loads of total nitrogen, total phosphorus, sediment and *E. coli*. It includes extensive provisions for stream routing and loss processes (storage and attenuation). This modelling procedure was originally developed by the USGS (Smith et al. 1997) and has since been applied and modified in the New Zealand context with extensive liaison with the developers. **SPARROW** has been applied to nitrogen and phosphorus in the Waikato (Alexander et al. 2002) and subsequently to the whole New Zealand landscape (Elliott et al. 2005). The **SPARROW** sediment transport routines were assessed by Elliott et al. (2008) and simulations compared favourably with measured sediment load data.

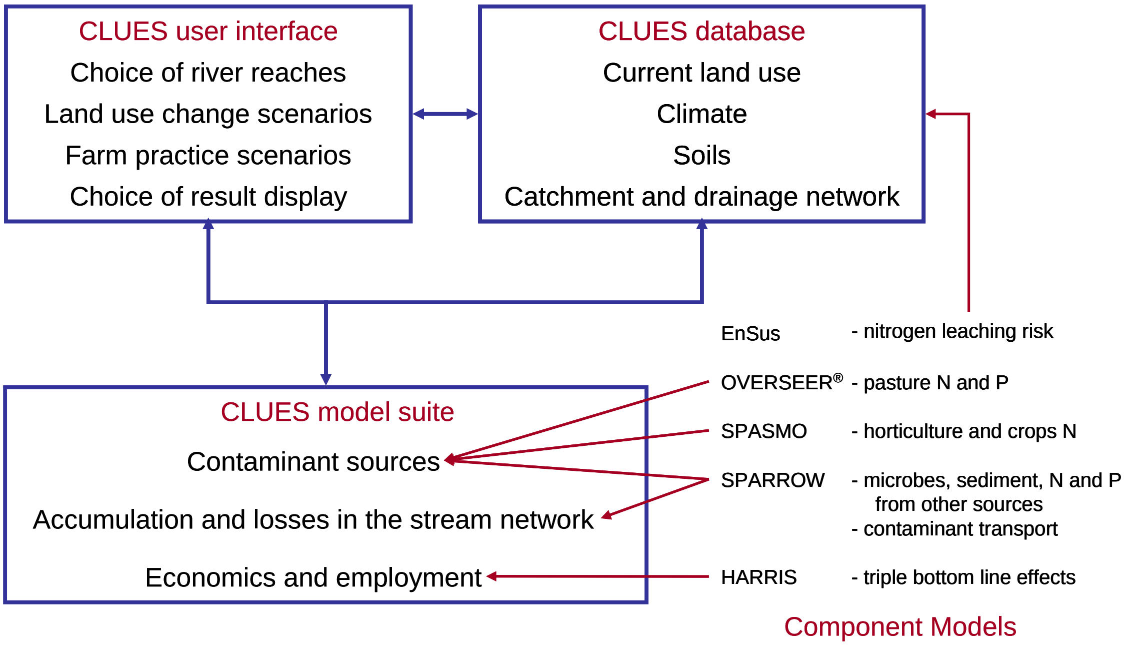

Figure 78: CLUES modelling framework (source: Semadeni-Davies et al., 2011)

- **SPASMO** (Soil Plant Atmosphere System Model, HortResearch) - calculates the nitrogen budget for a range of horticultural enterprise scenarios. Detailed simulations for many cases (combinations of crops, climate, fertiliser use) have been run (using a daily time step) to build look-up tables that CLUES queries. It has been validated against data from grazed pasture (Rosen et al. 2004) and pasture treated with herbicide (Close et al. 2003, Sarmah et al. 2004).

- **OVERSEER®** (AgResearch, Wheeler et al. 2006) - computes nutrient leaching for dairy, sheep and beef and deer farming. It provides annual average estimates of nutrient losses from these land uses, given information on rainfall, soil order, topography and fertiliser applications. Within CLUES, OVERSEER losses vary as a function of soil order, rainfall, stocking rate, land use class and region. For other variables, such as fertiliser application rates, typical values are used based on the region and land use.

- **TBL** (Triple Bottom Line, Harris Consulting) - estimates economic output from different land use types (pasture, horticulture, forestry and cropping), in terms of Cash Farm Surplus (CFS), Total GDP and Total Employment from that land use, given as a function of output. The calculations are based on the MAF farm monitoring models.

- **EnSus** (Environmental Sustainability, Landcare Research) - provides maps of nitrogen leaching risk, used as an adjunct to interpretation of CLUES results. It is based on studies of nitrogen losses at national and regional scales (Hewitt and Stephens, 2002; Parfitt et al. 2006).

CLUES does not contain a groundwater model. That is, the water quality effects of groundwater are not simulated - rather, it is assumed that water percolating into the ground will emerge in the same surface river reach sub-catchment.

The base areal unit of CLUES is the sub-catchment which comes from the NIWA River Environment Classification (REC) of the national stream and sub-catchment network[58]. Each sub-catchment is associated with a river reach and has a unique identity number — there are 12,149 reaches in the Mataura catchment. Predictions of the water quality and financial indicators given above can be made for any reach.

Geo-spatial data needed to run CLUES are provided at national, regional, catchment and sub-catchment levels. Terrain data is at 30 m resolution. In addition to REC, data provided are land use, runoff (derived from rainfall less evapotranspiration), slope, soil data (from the Land Resources Inventory, LRI, Fundamental Soils Layer[59] – Wilde et al., 2004), contaminant point sources and lakes. The land use layer provided with CLUES was developed with extensive reference to the LCDB2 (Land Cover Database)[60], AgriBase (AsureQuality Ltd)[61], and LENZ (Land Environments of New Zealand)[62] land use geo-databases and refers to land use in 2002. Considerable effort was expended, with Landcare Research, to ensure that the spatial data coverage was as accurate as possible. Further details on the modelling framework can be found in Woods et al. (2006).

New to CLUES 3.0 is the ability to create farm practice scenarios which enhance or mitigate contaminant yields at the sub-catchment scale. These can be applied to river reaches affected using interactive selection tools or by supplying CLUES with a scenario table for those catchments affected. Percentage changes in stocking rates, nutrient losses to water and *E. coli* release from dairy, sheep and beef and deer farms can be used to simulate farm practices. These tools are at the heart of this study.
Water quality results generated by CLUES are:

- Nutrient loads (kg/year) - in-stream cumulative loads for total nitrogen (TN) and total phosphorus (TP) for each river reach.
- Sediment load (kilo-tonnes/year) - in-stream cumulative load of total suspended solids (TSS) for each river reach
- *E. coli* loads (10^{15} or one “peta” of organisms/year) – in-stream cumulative organism count for each river reach
- Nutrient concentration (g/m^3) - in-stream nitrogen and phosphorus median concentration for each river reach.
- Nutrient yields (kg/ha/year) - nutrient load divided by the contributing area. Provided in two forms:
  Cumulative yield - the in-stream cumulative yield which represents the total yield for each reach and its up-stream tributaries.
  Generated yield - the yield generated by each sub-catchment which is delivered to the stream network.
- Generated Sediment yield (tonnes/ha/year) - yield of TSS generated by each sub-catchment. This information can be used to identify sources of sediment.

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[58] http://www.niwa.co.nz/ncwr/rec
[59] http://soils.landcareresearch.co.nz/contents/index.aspx
[60] http://www.mfe.govt.nz/issues/land/land-cover-dbase/classes.html
[61] http://www.asurequality.com/corporate/it_services/agribase.cfm
[62] http://www.landcareresearch.co.nz/services/informatics/LENZ/about.asp

- Total nitrogen loss risk (scale from very low to very high) - the leaching risk for nitrogen based on land use from EnSus.

3. Water quality observations

Monitored water quality was used for comparison with model predictions. Water quality is monitored at monthly intervals at 25 sites in the catchment; 23 of these sites are maintained by ES, the other two (Mataura at Seaward Downs and Mataura River at Parawa) are maintained by NIWA as part of the National River Water Quality Network (NRWQN). The sites are listed in **Error! Reference source not found.** in order of the direction of flow which is approximately north (head waters) to south (lower reaches), and their locations are given in **Error! Reference source not found.**.

The monitoring site, Mataura River at Gorge Road, is around 13 km from the coast and can be considered representative of water quality at the river mouth. CLUES results predicted for this site are very similar to those of the terminal reach.

Note that some sites, such as Mataura River at Gore, are located at the upstream end of a river reach and have been assigned the preceding NZ reach number for comparison with CLUES. This is because CLUES returns cumulative results which refer to the water quality leaving a reach.

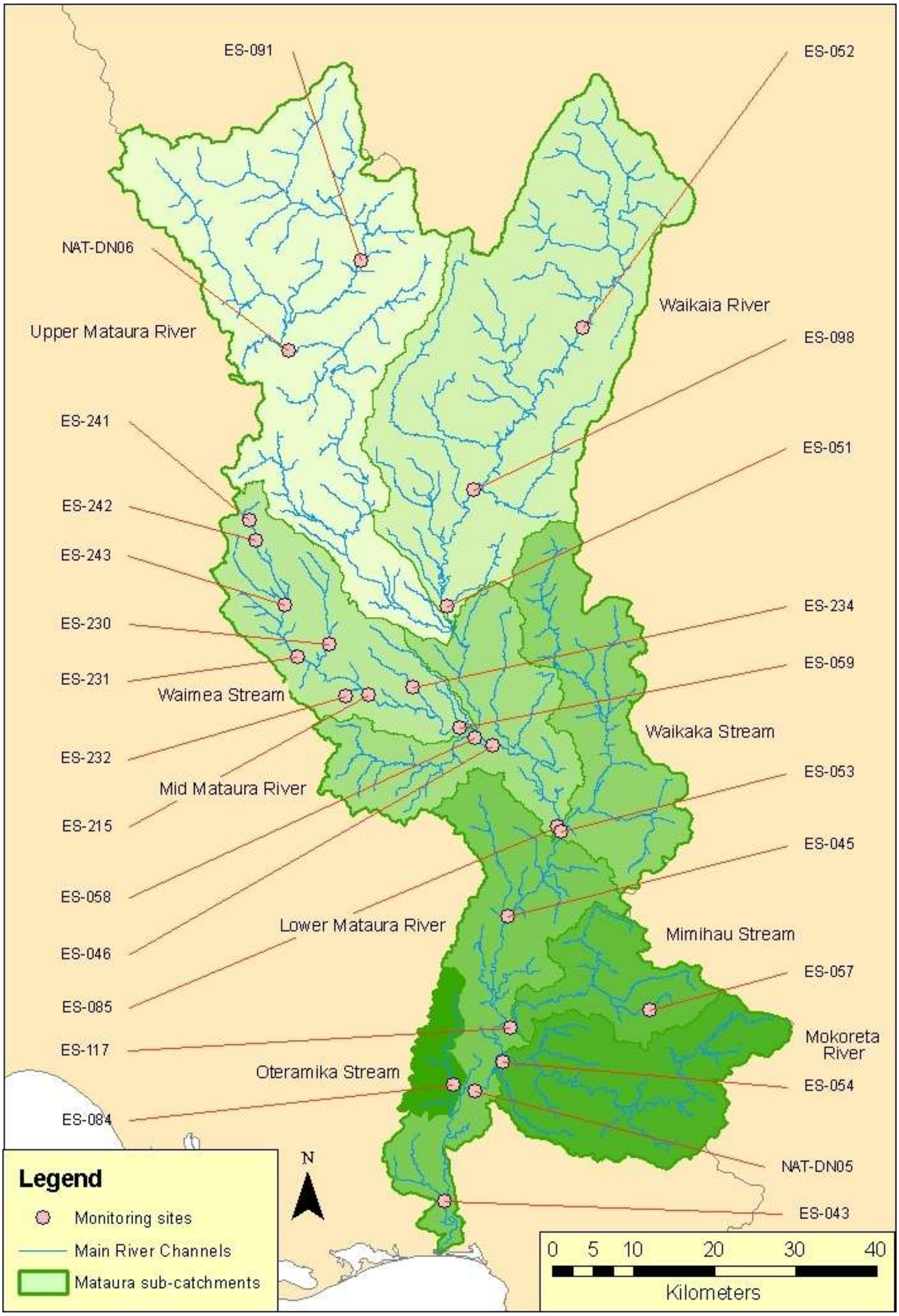
CLUES simulates long term water quality including annual average nutrient concentrations. These results were compared to five year median concentrations from the monitoring sites. Medians for the NIWA sites were taken from the NRWQN and refer to the period 2003-2007 (Unwin et al., 2010). The records provided by ES vary and in length, and median concentrations were calculated for the last five years (July 2005 – June 2010) as being indicative of recent land use changes. If fewer than 48 samples (i.e., 4 years of data) were available for the period, the data was discarded in favour of medians calculated for the earlier period of 2003-7 by Unwin et al. (2010). It was found that there was insufficient data to calculate a median TP concentration for the Waikaia site at Waikaia (ES 98), hence, this site has been excluded from the study for TP.

- **Table 23: Water quality monitoring sites in the Mataura catchment listed by sub-catchment in the direction of flow from north (head waters) to south (mouth).** .

Sub-catchment	Site Name	ID*	Easting	Northing	NZREACH
Upper Mataura River	Mataura River at Garston	ES-091	2172500	5518400	15021648
	Mataura River at Parawa (NZRWQ)	NAT-DN06	2163536	5507277	15025929
Waikaia River	Waikaia River u/s Piano Flat	ES-052	2199869	5510155	15024871
	Waikaia River at Waikaia	ES-098	2186300	5490200	15032882
	Waikaia River at Waipounamu Bridge Road	ES-051	2183066	5475811	15038511
Waimea Stream	Waimea Stream Tributary at McCale Road	ES-105	2158700	5486300	15034414
	Waimea Stream at Old Balfour Road	ES-103	2159500	5483800	15035323
	Waimea Stream at Murphy Road	ES-101	2163100	5475900	15038595
	Waimea Stream at Pahiwi-Balfour Rd	ES-231	2164700	5469500	15041058
	Longridge Stream at Sandstone	ES-230	2168600	5471000	15040591
	North Peak Stream at Waimea Valley Road	ES-232	2170600	5464600	15043151
	Waimea Stream at Nine Mile Road	ES-215	2173480	5464820	15043125
	Sandstone Stream at Kingston Crossing Rd	ES-234	2178807	5465711	15041998
	Waimea Stream at Mandeville	ES-059	2184674	5460690	15044764
Mid Mataura River	Otamita Stream at Mandeville	ES-058	2186483	5459549	15045155
	Mataura River at Otamita Bridge	ES-046	2188771	5458506	15045551
	Mataura River at Gore	ES-085	2196731	5448625	15049205
Waikaka Stream	Waikaka Stream at Gore	ES-053	2197140	5447918	15049464
Mimihau Stream	Mimihau Stream Tributary at Venlaw Forest	ES-057	2208092	5426004	15056983
	Mimihau Stream at Wyndham	ES-117	2190966	5423802	15057618
Oteramika Stream	Oteramika Stream at Seaward Down	ES-084	2183809	5416639	15058925
Mokoreta River	Mokoreta River at Wyndham River Road	ES-054	2189969	5419604	15058499
Lower Mataura River	Mataura River 200m d/s Mataura Bridge	ES-045	2190639	5437453	15053378
	Mataura @ Seaward Downs (NZRWQ)	NAT-DN05	2186569	5416006	15059190
	Mataura River at Gorge Road	ES-043	2182700	5402300	15061418

* ES refers to Environment Southland sites and NAT to NRWQN sites.

** excluded from study for estimates of TP



- **Figure 79:** Water quality monitoring sites in the by sub-catchment: ES refers to Environment Southland sites and NAT to NRWQN sites.

4. GIS Input data

4.1 Land use

Shape files of dominant land use classes were provided to NIWA by Aqualinc Ltd. (contact person, John Bright) for four land use scenarios with a spatial resolution comparable to CLUES (documented in Hughes et al., 2011, in preparation). The land use scenarios are:

a. Consented (current) land use;

b. 2030 conservative demand growth;

c. 2030 accelerated demand growth; and

d. 50% 2030 conservative demand growth.

The consented land use is indicative of current land use and differs from the CLUES default land use which is based on land use in 2002. The future scenarios are for land use change to the year 2030.

As the land use classes in the scenarios differed from those required by CLUES, they were re-classified for the simulation according to a key supplied for this purpose by Aqualinc (Table 2). The proportion of each land use type in the entire catchment is given in **Error! Reference source not found.**. Pastoral and arable land uses under the four scenarios are mapped in **Error! Reference source not found.** and are summarised for each sub-catchment in **Error! Reference source not found.**.

Error! Reference source not found. shows that the future scenarios patchy and are restricted to the Waimea, Mid Mataura, Upper Mataura and Waikaia sub-catchments. The main land use change for all the future scenarios is from intensive sheep and beef farming to cropping and dairying for the Waimea, and Upper Mataura sub-catchments, although the Waimea sub-catchment also has an increase in market gardening. The land-use change in the Mid Mataura and Waikaia sub-catchments is from intensive sheep and beef to dairy farming. Comparing Tables 3 and 4, indicates that while the changes in land use may be a substantial proportion of the affected land uses in these sub-catchments, the total land use change for both the sub-catchments and the entire catchment is minimal. The maximum area subject to land use change (i.e., accelerated growth demand) is around 200 km^2, which is some 4% of the total catchment area. Of the affected sub-catchments, the Waimea sees the greatest change, depending on the scenario 12-44% of sheep and beef is converted which amounts to 6-18% of the sub-catchment area.

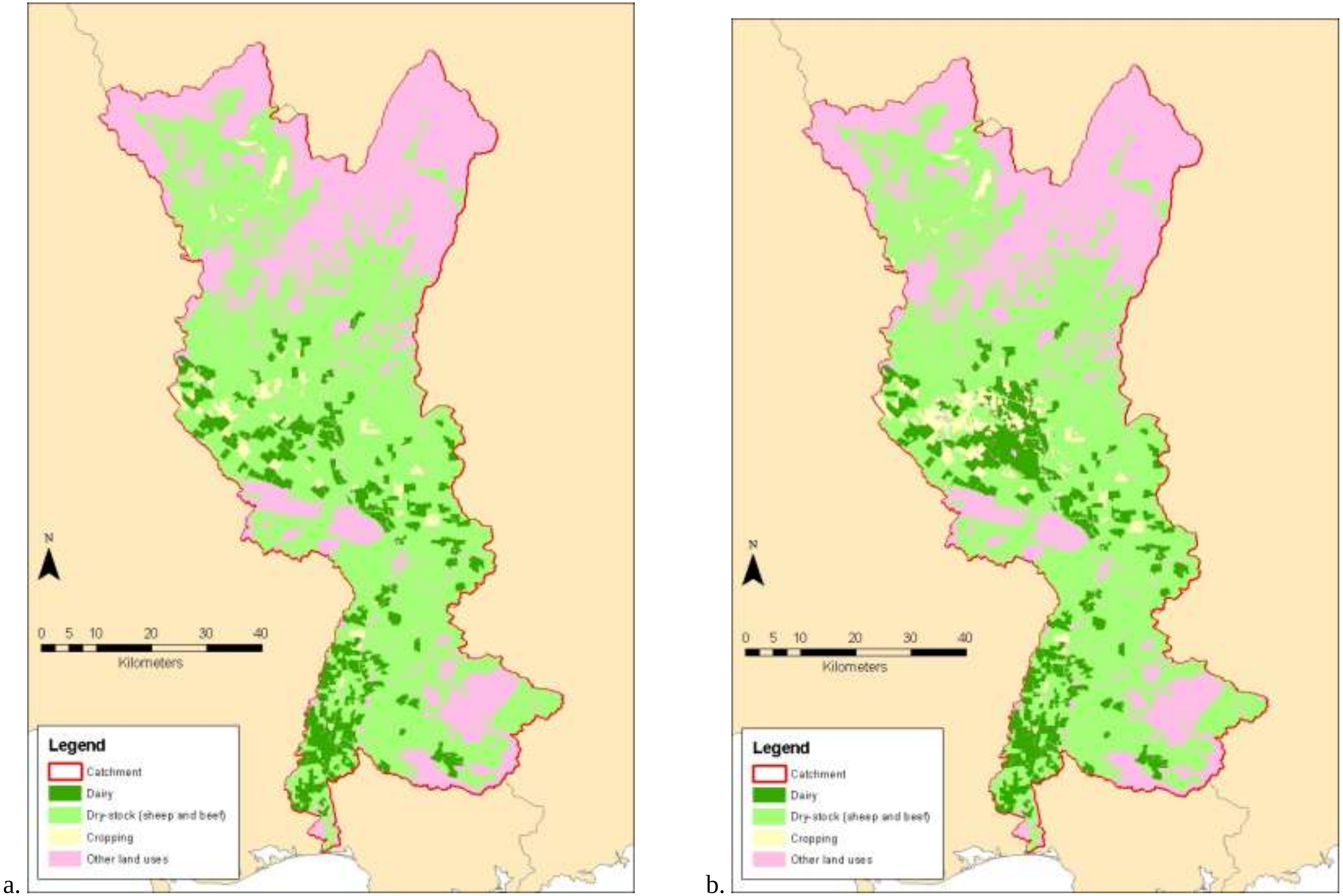
It should be noted that there is some uncertainty surrounding the nutrient yields for some of the land use classes, notably market gardens (including flowers) and cropping. Crop nutrient yields were adjusted following initial model runs (see Section **Error! Reference source not found.**), however, since the proportional area of market gardens is less than 0.2%, this land use was deemed to have negligible impact on total catchment loads. To illustrate, with an assumed TN yield of 60 kg/ha/yr, market gardens would contribute a maximum load of 15 t/yr less storage and attenuation in the stream network. This is only 0.3% of the total load from the catchment.

Table 24: Land use classes supplied by Aqualinc and corresponding CLUES land use class.

Supplied land use class	**CLUES land use class**	
	Class	**Description**
Afforestation (imaged, post LCDB 1)	PFor	planted exotic forest, forestry
Afforestation (not imaged)	PFor	planted exotic forest, forestry
Alpine Grass-/Herbfield	Scrub	scrubland
Alpine Gravel and Rock	Other	other land covers (e.g., ice, bare soil etc.)
Broadleaved Indigenous Hardwoods	Nat	native forest
Built-up Area	Urban	urban areas
Deciduous Hardwoods	PFor	planted exotic forest, forestry
Depleted Tussock Grassland	SMO	high country sheep and beef
Dryland cropping	ARA	arable crops (e.g., maize and barley)
Dryland dairy	Dairy	dairying
Fernland	Scrub	scrubland
Flaxland	Scrub	scrubland
Forest Harvested	PFor	planted exotic forest, forestry
Gorse and Broom	Scrub	scrubland
Grey Scrub	Scrub	scrubland
Herbaceous Freshwater Vegetation	Other	other land covers (e.g., ice, bare soil etc.)
High Producing Exotic Grassland	SBI	low land intensive sheep and beef
Indigenous Forest	Nat	native forest
Irrigated cropping	ARA	arable crops (e.g., maize and barley)
Irrigated dairy	Dairy	dairying
Irrigated horticulture	Veg	market gardens (including flowers)
Lake and Pond	Other	other land covers (e.g., ice, bare soil etc.)
Landslide	Other	other land covers (e.g., ice, bare soil etc.)
Low Producing Grassland	SBH	hill country sheep and beef
Major Shelterbelts	PFor	planted exotic forest, forestry
Manuka and/or Kanuka	Nat	native forest
Matagouri	Scrub	scrubland
Mixed Exotic Shrubland	Scrub	scrubland
Orchard and Other Perennial Crops	Summer	“summer” stone fruit
Other Exotic Forest	PFor	planted exotic forest, forestry
Pine Forest - Closed Canopy	PFor	planted exotic forest, forestry
Pine Forest - Open Canopy	PFor	planted exotic forest, forestry
River	Other	other land covers (e.g., ice, bare soil etc.)
River and Lakeshore Gravel and Rock	Other	other land covers (e.g., ice, bare soil etc.)
Short-rotation Cropland	ARA	arable crops (e.g., maize and barley)
Sub Alpine Shrubland	Scrub	scrubland
Surface Mine	Other	other land covers (e.g., ice, bare soil etc.)
Tall Tussock Grassland	Tussock	tussock
Transport Infrastructure	Other	other land covers (e.g., ice, bare soil etc.)
Urban Parkland/ Open Space	Other	other land covers (e.g., ice, bare soil etc.)
Blank (no nutrient input)	Other	other land covers (e.g., ice, bare soil etc.)

- **Table 25: Proportion of total catchment area (%) coved by CLUES land use class for the four scenarios.**

CLUES land use class	Consented land use	Conservative demand growth	Accelerated demand growth	Fifty percent of conservative demand growth
ARA	2.06	3.39	3.87	2.72
Dairy	8.54	9.90	10.21	9.23
Nat	8.68	8.68	8.68	8.68
Other	2.90	2.90	2.90	2.90
PFor	2.74	2.74	2.74	2.74
SBH	12.02	12.02	12.02	12.02
SBI	41.92	39.16	38.33	40.54
Scrub	2.61	2.61	2.61	2.61
SMO	0.01	0.01	0.01	0.01
Summer	<0.01	<0.01	<0.01	<0.01
Tussock	18.28	18.28	18.28	18.28
Urban	0.20	0.20	0.20	0.20
Veg	0.05	0.12	0.16	0.08



a. b.

- **Figure 80: Change in pastoral land use and cropping for the four land use scenarios: a. consented (current) land use; b. conservative demand growth.**

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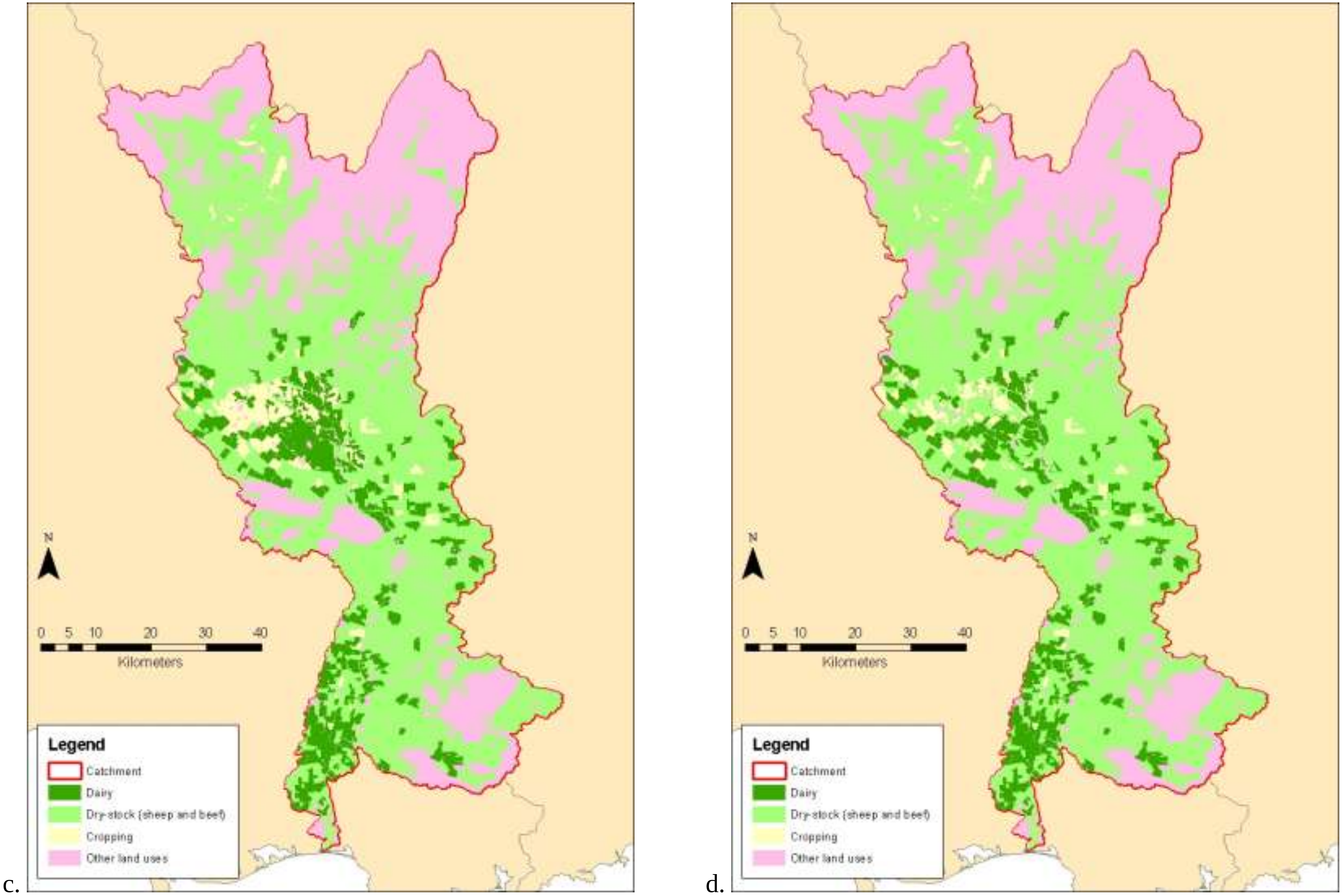


- Error! Reference source not found. **continued: c. accelerated demand growth; and d. 50% conservative demand growth.**

Table 26: Area of arable and pastoral land use by sub-catchment (%).

Sub-catchment	Land use	Consented land use	Conservative demand growth		Accelerated demand growth		Fifty percent of conservative demand growth	
		Area (km^2)	Area (km^2)	Change (%)	Area (km^2)	Change (%)	Area (km^2)	Change (%)
Upper Mataura River	Cropping	33	55	39	63	46	48	30
	Dairy	23	43	46	45	49	33	30
	Other land uses	573	573	0	573	0	573	0
	Sheep and beef (high country)	432	432	0	432	0	432	0
	Sheep and beef (intensive)	267	226	-18	216	-24	243	-10
	Sheep and beef (high country)	1	1	0	1	0	1	0
Sub-catchment area		1330						
Waikaia River	Cropping	5	13	62	14	64	9	44
	Dairy	22	37	41	39	45	33	35
	Other land uses	823	823	0	823	0	823	0
	Sheep and beef (high country)	182	182	0	182	0	182	0
	Sheep and beef (intensive)	302	279	-8	276	-10	287	-5
Sub-catchment area		1333						
Waimea Stream	Cropping	42	78	46	94	55	59	28
	Dairy	108	129	17	130	18	118	9
	Other land uses	28	32	12	34	18	29	6
	Sheep and beef (high country)	6	6	0	6	0	6	0
	Sheep and beef (intensive)	264	203	-30	184	-44	235	-12
Sub-catchment area		448						

Sub-catchment	Land use	Consented land use	Conservative demand growth		Accelerated demand growth		Fifty percent of conservative demand growth	
Mid Mataura River	Cropping	11	18	38	20	45	13	14
	Dairy	58	76	24	85	32	63	8
	Other land uses	115	115	0	115	0	115	0
	Sheep and beef (hill country)	4	4	0	4	0	4	0
	Sheep and beef (intensive)	280	255	-10	243	-15	273	-3
Sub-catchment area								468
Waikaka Stream	Cropping	10	10	0	10	0	10	0
	Dairy	47	47	0	47	0	47	0
	Other land uses	28	28	0	28	0	28	0
	Sheep and beef (hill country)	17	17	0	17	0	17	0
	Sheep and beef (intensive)	361	361	0	361	0	361	0
Sub-catchment area								465
Mimihau Stream	Dairy	5	5	0	5	0	5	0
	Other land uses	79	79	0	79	0	79	0
	Sheep and beef (intensive)	144	144	0	144	0	144	0
Sub-catchment area								228
Oteramika Stream	Cropping	2	2	0	2	0	2	0
	Dairy	54	54	0	54	0	54	0
	Other land uses	5	5	0	5	0	5	0
	Sheep and beef (intensive)	22	22	0	22	0	22	0
Sub-catchment area								83
Mokoreta River	Dairy	25	25	0	25	0	25	0
	Other land uses	171	171	0	171	0	171	0
	Sheep and beef (hill country)	1	1	0	1	0	1	0
	Sheep and beef (intensive)	265	265	0	265	0	265	0
Sub-catchment area								462

Sub-catchment	Land use	Consented land use	Conservative demand growth		Accelerated demand growth		Fifty percent of conservative demand growth	
Lower Mataura River	Cropping	7	7	0	7	0	7	0
	Dairy	121	121	0	121	0	121	0
	Other land uses	67	67	0	67	0	67	0
	Sheep and beef (intensive)	336	336	0	336	0	336	0
Sub-catchment area		532						

4.2 Soil drainage class

Soil drainage classes are required for two of the mitigation practices. Soil data available for the Matura catchment was supplied by ES from their Tope-climate database. However, this data did not cover the entire catchment. For the areas where the Topo-climate soil data was not available, soil data was taken from the Land Resource Inventory: Fundamental soil Layer (Wilde et al., 2004) to create a catchment wide combined soil layer. Both datasets classify soils into have five drainage classes: 1. very poor, 2. poor; 3. imperfect; 4. moderately well; and 5. well. On the basis of these classes, the catchment was split into poor (drainage classes 1 and 2) and free-draining (drainage classes 3 to 5) areas, these areas are shown in **Error! Reference source not found.**.

▪ **Figure 81: Areas of free and poorly draining soils in the Mataura catchment (derived from data supplied by ES and the LRI Fundamental soil Layer).**

4.3 Land use capability (LUC)

Land Use Capability (LUC), which is used for the farm mitigation scenarios, was taken from the LRI (Newsome, 1995). **Error! Reference source not found.** shows areas with a LUC suitable for pastoral land use and nutrient mitigation (i.e., classes 1-4) in green. A full description of LUC classes and their application nationwide can be found in Lynn et al. (2009).

There is very little LUC 1 land in the catchment with a small pocket in central catchment that is predominantly dairy. LUC 2 land is largely confined to the central lower reaches and is predominantly dairy farming with intensive sheep and beef.

Comparison with **Error! Reference source not found.** shows that the areas most affected by the land use change scenarios have an LUC of 3 and are located in the up-lands to the central north-east.

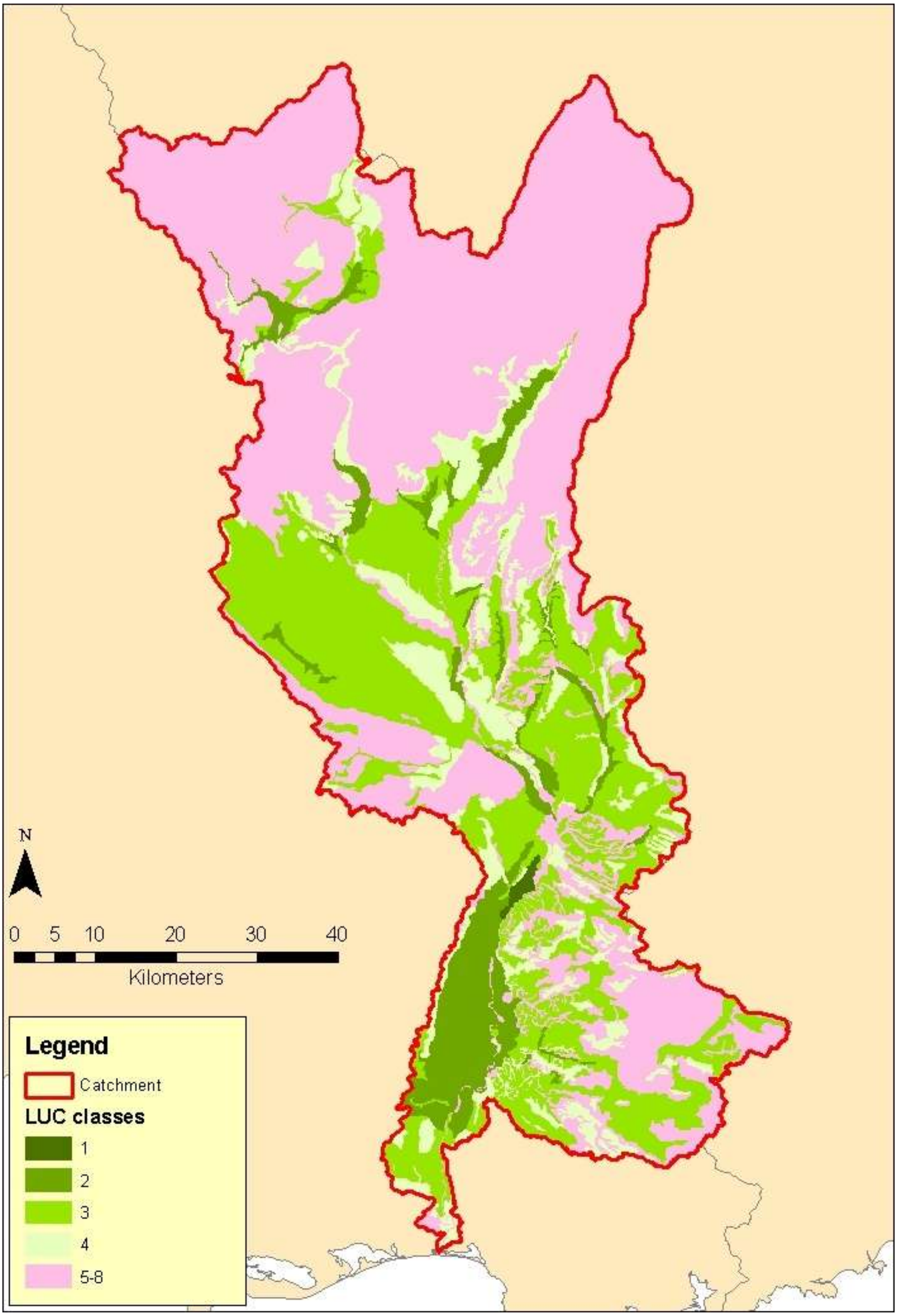
4.4 Point sources

CLUES includes nutrient yields from point sources in its geo-database. These yields are added to the in-stream yield for the river reach where the source is located. ES requested that the point sources in the Mataura Catchment be re-evaluated and if necessary, updated, for this application. Point sources identified by ES for inclusion in the CLUES runs were the Gore and Mataura sewage oxidation ponds and the Alliance meat processing plant. Monthly water quality and daily discharge data were provided by ES for the calculation of mean daily loads to the stream network.

On the basis of this data, the point sources discharge the following loads:

- Gore oxy-ponds (calculated period; 2009-2010)
    - 89 TN kg/day and 8 TP kg/day
- Mataura oxy-ponds (calculation period 2007-2010),
    - 11 TN kg/day and 2 TP kg/day
- Alliance (loads supplied by ES for 2009)
    - 267 TN kg/day and 24 TP kg/day

Two other point sources, the Fonterra dairy plant at Edendale and the Dong Wah pulp fibre mill, were deleted from the default CLUES set-up as these sources use effluent land-disposal methods which result in minimal nutrient loads to the stream network.



- Figure 82: Land Use Capability classes for the Mataura catchment (from the LRI; Newsome, 1995). Classes 1-4 are subject to mitigation.

5. Mitigation scenarios

The effect of implementing mitigations in a particular sub-catchment or selection of sub-catchments was simulated using CLUES 3.0 by specifying the percentage reduction in nutrient loss that would be expected given the land use, LUC and soil drainage class. Two scenarios were developed based on the scenarios created by Monaghan et al. (2010) for the Oreti Catchment (**Error! Reference source not found.**):

1. Current mitigation practice (stock exclusion from streams); and
2. Future mitigation comprising an amalgamation of practices including stock exclusion, nitrification inhibitors, herd shelters, improved farm dairy effluent (FDE) management and constructed wetlands.

The nutrient reductions which represent the farm mitigation practices are the same as those developed by AgResearch for the Oreti River catchment (Monaghan et al., 2010), however, unlike the Oreti study, the farm practice scenarios assume that the mitigations are applied in combination. The reductions given in **Error! Reference source not found.** were amalgamated by first grouping land use, LUC and drainage into unique combinations representing different sets of criteria for the mitigation practices, and then applying each mitigation sequentially. The reductions were capped at a maximum of 60% for TN and 50% for TP (set in consultation with Ross Monaghan at AgResearch). The amalgamated reductions for each set of criteria are given in **Error! Reference source not found.**. For each sub-catchment, the mitigation factors were weighted according to the proportional area satisfying the mitigation criteria given in **Error! Reference source not found.**.

- **Table 27:** Assumed mitigation factors in nutrient losses under a range farm practices (from Monaghan et al., 2010).

Mitigation type	Mitigation Criteria			Mitigation (% reduction)	
	Soil drainage	Land Use Capability	Landuse	N	P
CLUES default (no mitigation)	All	All	All	0%	0%
Stock exclusion from streams – current situation[1]	Not specified	1-3	Dairy	15%	30%
			Dry stock (all sheep and beef)	3.5%	10.5%
Stock exclusion from streams – future mitigation[2]	Not specified	1-3	Dairy	20%	40%
			Dry stock (all sheep and beef)	10%	30%
Nitrification inhibitors[3]	Not specified	1-4	Dairy and dry-stock (sheep and beef intensive)	30%	0%
Herd shelters[3]	Not specified	1-4	Dairy	30%	10%
Wetlands[3]	Poorly drained	Not specified	Dairy and dry-stock (all sheep and beef)	25%	0%
Improved FDE management[3]	Free draining	Not specified	Dairy	5%	5%
	Poorly draining	Not specified	Dairy	10%	10%

[1] Assumes current stock exclusion of 75% dairy cattle and 35% sheep and beef in LUC classes 1-3.
[2] Assumes total stock exclusion of all stock in LUC classes 1-3.
[3] Scenario simulated in combination with current stock exclusion.

- **Table 28:** Amalgamated mitigation nutrient reductions (%) by land use, LUC and drainage criteria groupings

Mitigation criteria		Dairy					
		LUC 1-3 Poor drainage	LUC 1-3 Free drainage	LUC 4 Poor drainage	LUC 4 Free drainage	LUC 5-8 Poor drainage	LUC 5-8 Free drainage
Current	TN	15	15	0	0	0	0
	TP	30	30	0	0	0	0
Future	TN	60	60	60	53	10	5
	TP	50	49	19	15	10	5
Mitigation criteria		Dry-stock - sheep and beef					
		LUC 1-3 Poor drainage	LUC 1-3 Free drainage	LUC 4 Poor drainage	LUC 4 Free drainage	LUC 5-8 Poor drainage	LUC 5-8 Free drainage
Current	TN	3.5	3.5	0	0	0	0
	TP	10.5	10.5	0	0	0	0
Future	TN	52.75	37	52.75	30	25	0
	TN	3.5	3.5	0	0	0	0

6. Results

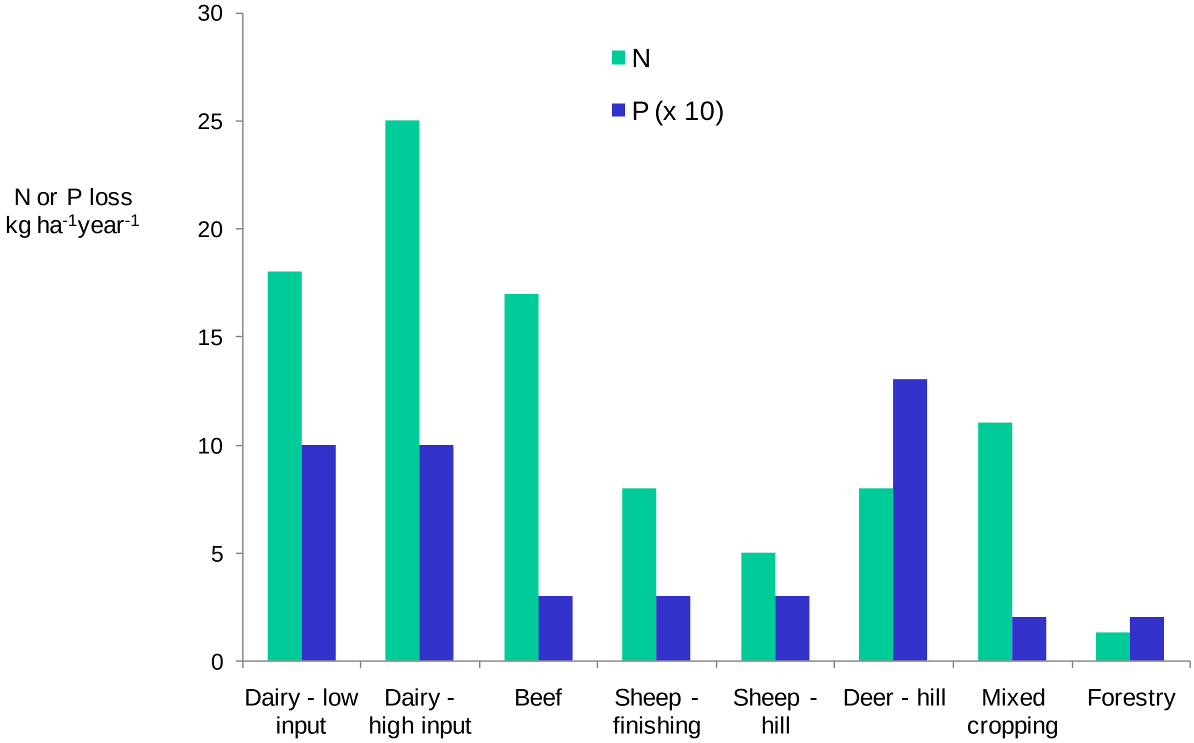
6.1 CLUES comparison with observations

CLUES concentrations and loadings for the base-line scenario (consented land use with current mitigation) were compared to the 5-year median concentrations calculated for the 25 monitoring sites in the catchment (**Error! Reference source not found.** and **Error! Reference source not found.**). The model has been adjusted for the Mataura Catchment by changing CLUES default settings and correcting results as discussed below.

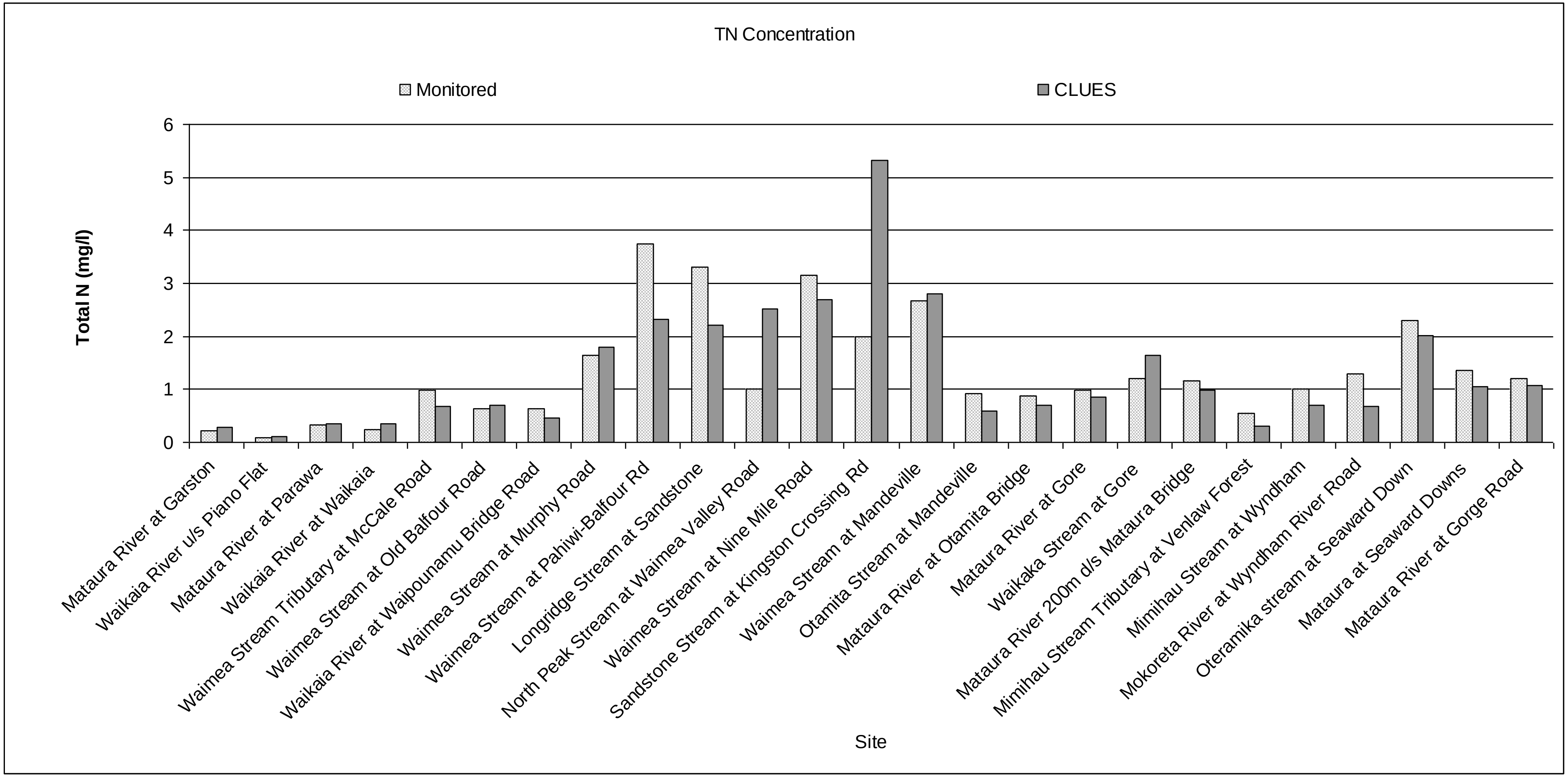
It was found that CLUES needed to be adjusted to achieve a reasonable fit to concentration measured in the Mataura catchment. The following modifications were made:

- Nitrogen in-stream decay was set to zero, because CLUES was consistently under-predicting loads and concentrations throughout the catchment.
- Examination of initial model results revealed the need to modify default losses for cropping. The P loss rate for cropping was set to 0.2 kg/ha/yr in accordance to the findings presented by Monaghan et al., (2010, see **Error! Reference source not found.**) for mixed cropping in the Bog Burn sub-catchment of the Oreti River. The cropping loss rate for N was set to 7.5 kg/ha/yr which, although less than suggested by Monaghan et al. (2010; 11 kg/ha) is in the range that can be expected for cropping on deep soil in Canterbury (e.g., Lilburne et al., 2010; 5-14 kg/ha/yr).
- For P, the factor used to convert flow-weighted concentrations to median concentrations was increased from the CLUES default of 0.4 to 0.8 in the Waimea Stream sites listed below because the monitoring data indicated the higher factor was more appropriate. The Waimea Stream catchment has a considerable proportion of poorly-drained soils, and it this could be responsible for the fairly high concentration ratio compared with the default CLUES value for the following sites.
  - Waimea Stream Tributary at McCale Road
  - Waimea Stream at Old Balfour Road
  - Waimea Stream at Murphy Road
  - Waimea Stream at Pahiwi-Balfour Rd
  - Waimea Stream at Nine Mile Road
  - Waimea Stream at Mandeville
- The erosion component of P loss (which is added to OVERSEER and other base-line yield values) was removed because concentrations were over-predicted in the headwaters of the upper catchment (i.e., Mataura River at Garston and at Parawa and Waikaia River u/s Piano Flat).
- The decay factor for P was halved, because CLUES was under-predicting loads and concentrations in the lower catchment.

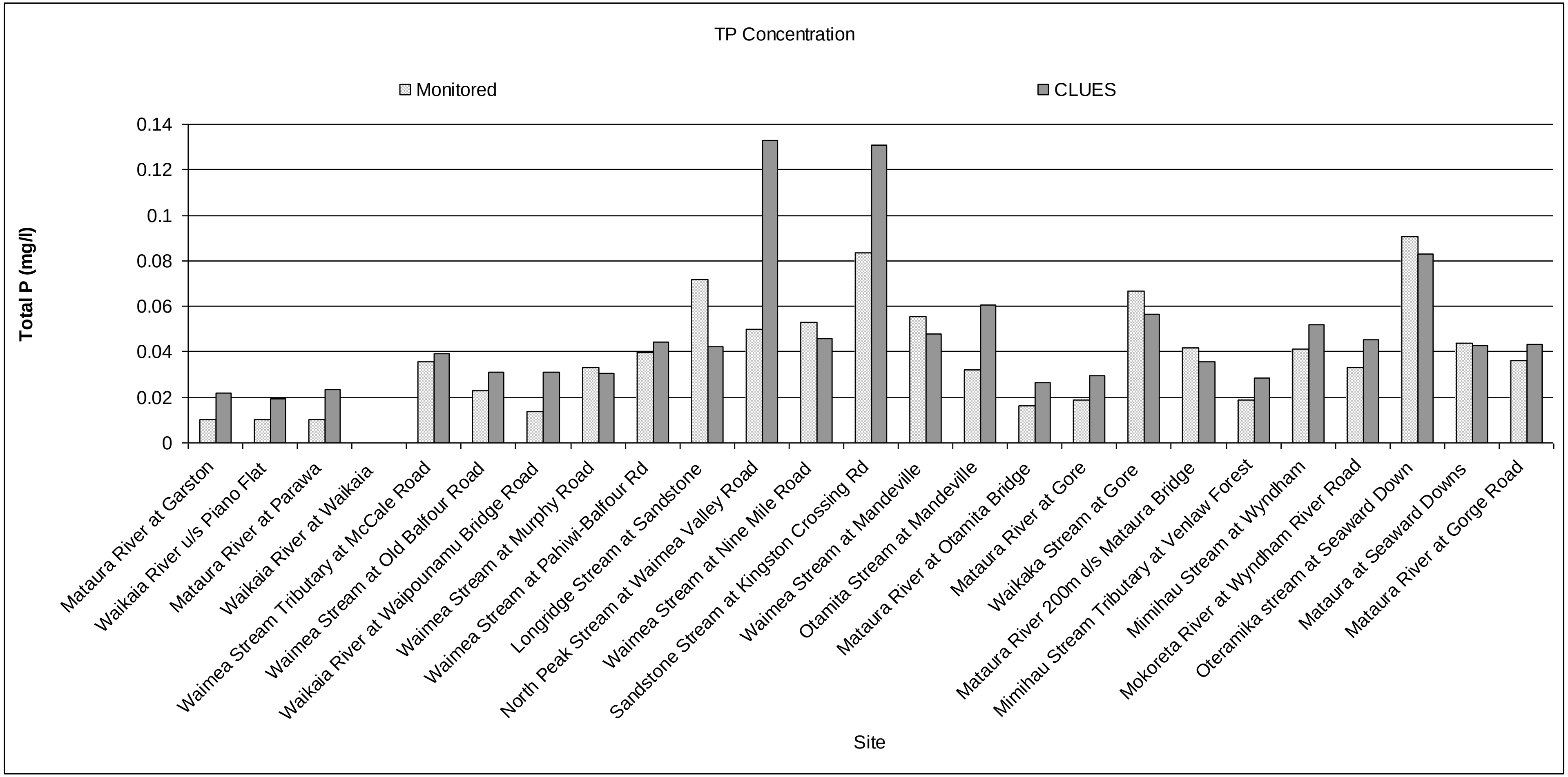
Comparisons between CLUES predicted concentrations and those measured improved considerably after the corrections described above. Column plots comparing the five- year median concentrations for all sites with concentrations predicted by CLUES with to the adjustments above are given in **Error! Reference source not found.** and **Error! Reference source not found.**.



- **Figure 83: OVERSEER estimates of N and P (x 10) losses for contrasting model farm types set within the Bog Burn catchment, Southland. (source, Monaghan et al., 2010)**



- **Figure 84:** Simulated and monitored TN concentrations. The monitored concentrations are 5-year medians derived from a combination of ES data and the NRWQN.



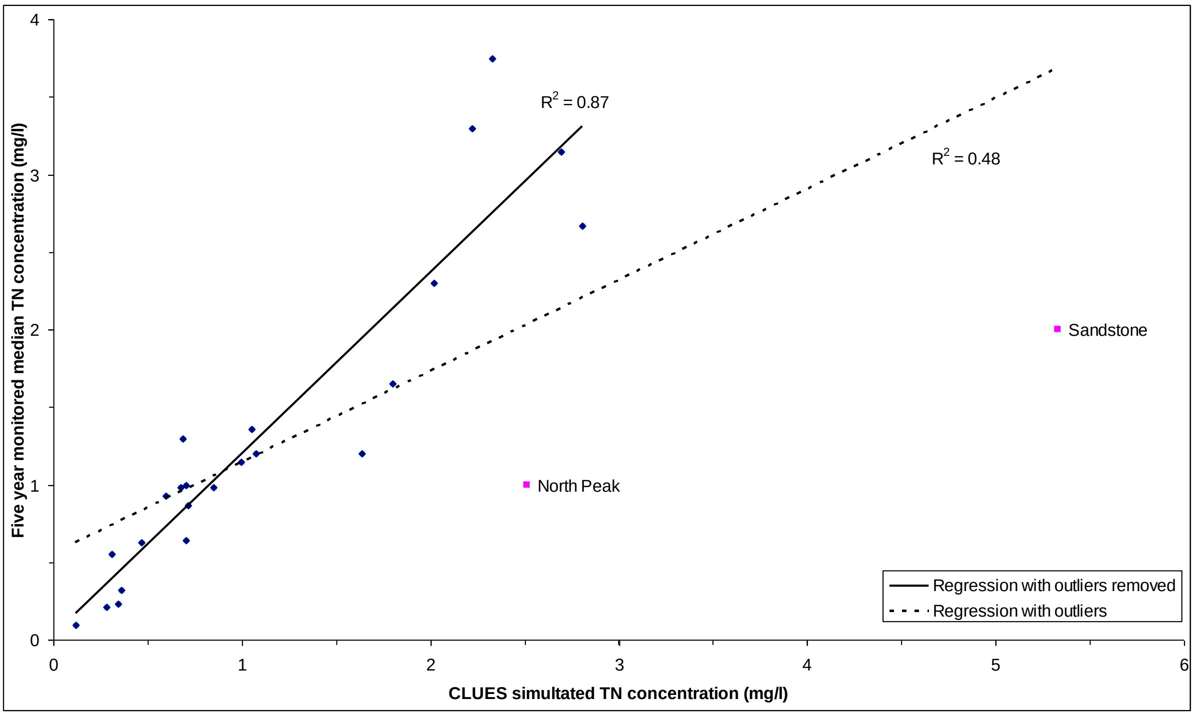
- **Figure 85:** Simulated and monitored TP concentrations. The monitored concentrations are 5-year medians derived from a combination of ES data and the NRWQN. CLUES results have been corrected for the Waimea Stream.

Following the corrections, two key outliers for both TP and TN were identified using regression analysis of predicted and monitored concentrations (**Error! Reference source not found.** and **Error! Reference source not found.**); Sandstone Stream (ES-234) and North Peak Stream (ES-232). These sites are quite close to each other and are located in head waters of the Waimea Stream; both are relatively minor tributaries. With these two sites removed, the coefficient of determination for concentrations R^2, increases from 0.47 to 0.70 for TP and from 0.48 to 0.87 for TN.

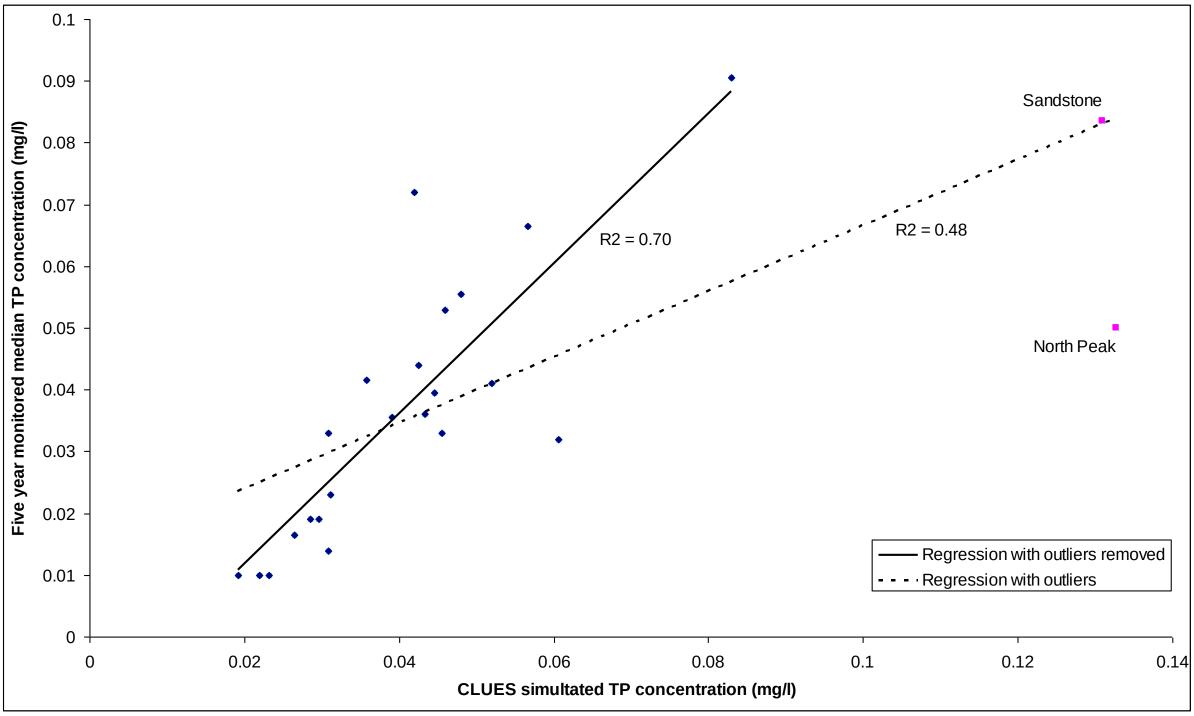
We suspect that the high concentrations simulated for the Sandstone Stream site are due to recent conversion of the stream catchment to dairying. We note that the monitored water quality data has been fluctuating and that there have been some very high concentrations recorded over the last few years. TN concentrations ranged between 5 and 19 g/m^3 between May and September 2008, while TP concentrations greater than 0.12 g/m^3 are fairly common from 2007 onwards and a peak of 0.32 g/m^3 was reached in February 2008. The five-year median values are lower than these recent values, however, because the concentrations at the start of the five-year averaging period were lower (<3 g/m^3 for TN and < 0.08 g/m^3 for TP). The recent concentrations are in the same order as the CLUES results, suggesting that CLUES is providing a good prediction of the most recent data. For this reason, the stream has been included in the comparison of land use and mitigation scenarios.

The North Peak stream is fed by the Hokonui Hills, and is at the transition between hills and the plains. The hydrology at this site is uncertain. For this reason, we have removed this site from further analysis.

On the basis of the comparisons, we are confident that CLUES is correctly predicting nutrient concentrations on the basis of land use.



- **Figure 86:** Regression between modelled and observed TN concentration. Outliers shown in pink.



- **Figure 87:** Regression between modelled and observed TP concentration. Outliers shown in pink.

6.2 Scenario analysis

CLUES was run for the four land use and two farm practice scenarios giving eight sets of results. The results are in **Error! Reference source not found.** for TN and **Error! Reference source not found.** for TP. Note the results are based on the adjusted inputs outlined in the previous section. The consented land use scenario with current mitigation is the base-line scenario for comparison and reflects current land use and farm practices. Note that downstream monitoring sites reflect changes in land use or mitigation that occur upstream as well as in their immediate sub-catchment and the loads calculated include simulation of in-stream storage and attenuation.

10.1.1. Mitigation of current land use

Applying mitigation strategies on the consented land use scenario has a modest impact on total loads in the Upper Mataura sub-catchment (a reduction of <20% for TN and only 1% for TP). This sub-catchment is dominated by tussock and high country sheep and beef farming with some intensive sheep and beef farming. Only the lower section of the sub-catchment is subject to mitigation; this area is largely downstream of the monitoring sites, hence the impact on nutrient loads at these sites is relatively low.

The Waikaia Stream sub-catchment also has extensive coverage of land uses not subject to mitigation. Two of the three Waikaia monitoring sites are in areas that could potentially have mitigation, the reductions in nutrient loads for these sites ranges from 15-21% for TN but only 1-2% for TP.

The greatest potential impact of mitigation is seen in the Waimea Stream sub-catchment where TN loads are reduced by up to 50% and TP loads by up to 30%.

This sub-catchment is dominated by intensive sheep and beef farming (~60% of the sub-catchment area) with large areas of dairying (~25% of the sub-catchment area). Both of these land uses are subject to mitigation. The Waimea at McCale Road and Old Balfour Road sites are in the headwaters of the sub-catchment and are dominated by sheep and beef farming which as less potential for mitigation than dairying, hence the relatively low impact of mitigation compared to the four sites downstream.

The Mid Mataura sub-catchment is also dominated by intensive sheep and beef farming (60% of the sub-catchment area) with some dairying (around 12% of the area) and shows similar nutrient reductions in the river (20-30 reduction for TN and ~5% for TP). However, it is difficult to determine actual impact of mitigation in the sub-catchment itself as the sub-catchment receives flows from the Upper Mataura and Waikaia sub-catchments (modest mitigation potential) as well as the Waimea sub-catchment (high mitigation potential).

The Waikaka, Mimihau and Mokoreta sub-catchments are dominated by intensive sheep and beef farming (over 50% of land cover) which is subject to mitigation, but not the same extent as dairying. Mitigation in these sub-catchments can reduce TN by between 20 - 40% and TP by between 6-15%. The Mimihau Stream tributary at Venlaw Forest site shows no change as it is directly downstream of plantation forest which has no mitigation.

The Oteramika sub-catchment is dominated by dairying (65% of land use) and, as a result has the highest nutrient reduction due to mitigation. In this sub-catchment, half of TN and a quarter of TP are predicted to be removed by mitigation. While the Lower Mataura sub-catchment also has high proportions of dairying with some intensive sheep and beef farming (62 and 23% of the sub-catchment area, respectively), the impact of mitigation on water quality is less apparent than for the Oteramika or Waimea sub-catchment as the lower reaches also receive flows from sub-catchments with limited mitigation which dilutes the signal. Reductions are in the order of 30% for TN and 5% for TP in this sub-catchment.

10.1.2. Land use change

The land use change scenarios affect the Waimea, Upper Mataura, Waikaia and Mid Mataura sub-catchments. The nutrient results did not change for the Oteramika, Mokoreta and Mimihau streams which neither have land use change in their own sub-catchment nor are downstream of affected sub-catchments.

Despite land use change, no change in loads is seen at the Upper Mataura sites as these are located upstream of the area affected by the future scenarios. Land use change in this sub-catchment is from intensive sheep and beef to a mixture of dairy and cropping and is restricted to a small section of the lower part of the sub-catchment (~3% of the sub-catchment area).

The Waikaia River at Waipounamu Bridge Road site in the Waikaia sub-catchment shows a slight increase in loads (<5%) for all the land use change scenarios. While the site is in the area with land use change, the upstream area is not affected so that any increase in load is minimal compared to the total load. The land use change is mainly intensive sheep and beef to dairying and affects only 2% of the sub-catchment area. The sites upstream of land use change show no differences in predicted loads.

The Waimea sub-catchment shows the greatest change in nutrient loads for all the land use change scenarios. Land use change is predominantly intensive sheep and beef to cropping and dairying and affects 14% of the sub-catchment area. TN loads are decreased (1-10%), however, TP loads are increased (up to 14%). The explanation for the decrease in TN is the relatively lower TN yield from cropping compared to stock so that while and increase in TN would be expected from dairying, the overall impact is a reduction in loads. In contrast, the TP yield for cropping is relatively high. This can be seen clearly for the Longridge at Sandstone site which has a large proportion of its upstream area changed to from sheep and beef to cropping (15 km^2 out of a total area of 42 km^2). It should be noted that there is some degree of uncertainty surrounding the yields from cropping (see Section 6.1) which could affect the model results for the Waimea sub-catchment.

The impact of land use change on the Mid Mataura sites is complicated by the fact that they are affected by flows from the Waimea, Upper Mataura and Waikaia sub-catchments as well as changed yields from the sub-catchment itself. Given that the main land use change is from intensive sheep and beef to dairying, the increases in nutrient load are not surprising. However, the area affected by land use change in this sub-catchment is only 5% making it likely that the change in nutrient loads reflects land use change upstream. TN increase in TN is around 1 or 2% while TP increases by around 5% for all the land use change scenarios .

While there is no land use change in the Lower Mataura sub-catchment, there is change in loads due to flows from affected sub-catchments. However, the impact is fairly minimal due to flows from areas unaffected by land use change. Moreover, CLUES simulates stream storage and attenuation which further reduces the impact on loads from upstream. Even with the accelerated demand growth scenario, the increase at the river mouth is only 1% for TN and 4% for TP.

10.1.3. Land use change and mitigation

The impact of mitigation on nutrient loads generated by the land use change scenarios is very similar to that simulated for the consented land use scenario. As explained above for the effects of land use change, there are no in changes in load for the Oteramika, Mokoreta and Mimihau sub-catchments. In the lower catchment, load reductions due to mitigation are around 30% for TN and a more conservative 6% for TP. The results show that the impacts of land use on water quality for all the scenarios, current and future, can be substantially reduced by implementing farm practices to reduce nutrient yields. Implementing mitigation as part of land use change can improve water quality from today’s land use and farm practices.

- **Table 29:** The combined impact of land use change and mitigation on total nitrogen concentration. Percentage change has been calculated with respect to consented land use and current farm practices. A positive value indicates an increase in TN. Percentage change in concentration is equal to the percentage change in load.

Sub-Catchment	**Monitoring Site**	**Consented land use**			**Conservative demand growth**		**Accelerated demand growth**		**Fifty percent of accelerated demand growth**	
		Current mitigation (base-line)		**Future mitigation (% change)**	**Current mitigation (% change)**	**Future mitigation (% change)**	**Current mitigation (% change)**	**Future mitigation (% change)**	**Current mitigation (% change)**	**Future mitigation (% change)**
		Conc. (g/m^3)	**Load (t/yr)**							
Upper Mataura	Mataura River at Garston	0.28	111	-11	0	-11	0	-11	0	-11
	Mataura River at Parawa	0.36	237	-15	0	-15	0	-15	0	-15
Waikaia River	Waikaia River u/s Piano Flat	0.12	47	0	0	0	0	0	0	0
	Waikaia River at Waikaia	0.34	258	-15	0	-15	0	-15	0	-15
	Waikaia River at Waipounamu Bridge Road	0.47	442	-21	2	-21	2	-21	1	-21
Waimea Stream	Waimea Stream Tributary at McCale Road	0.67	2	-1	0	0	0	0	0	0
	Waimea Stream at Old Balfour Road	0.70	11	-8	0	-8	0	-8	0	-8
	Waimea Stream at Murphy Road	1.80	115	-41	-1	-41	-1	-41	0	-41
	Waimea Stream at Pahiwi-Balfour Rd	2.33	233	-42	-2	-42	-2	-42	-1	-42
	Longridge Stream at Sandstone	2.22	77	-45	-10	-44	-13	-42	-4	-45
	North Peak Stream at Waimea Valley Road	-	-	-	-	-	-	-	-	-
	Waimea Stream at Nine Mile Road	2.69	425	-43	-3	-43	-4	-43	-1	-43
	Sandstone Stream at Kingston Crossing Rd	5.33	41	-50	-5	-49	-13	-51	-2	-50
	Waimea Stream at Mandeville	2.81	546	-44	-3	-44	-5	-43	-1	-44
Mid	Otamita Stream at Mandeville	0.59	65	-17	0	-17	0	-17	0	-17

Sub-Catchment	Monitoring Site	Consented land use			Conservative demand growth		Accelerated demand growth		Fifty percent of accelerated demand growth	
		Current mitigation (base-line)		Future mitigation (% change)	Current mitigation (% change)	Future mitigation (% change)	Current mitigation (% change)	Future mitigation (% change)	Current mitigation (% change)	Future mitigation (% change)
		Conc. (g/m^3)	Load (t/yr)							
Mataura	Mataura River at Otamita Bridge	0.71	1830	-29	2	-28	2	-28	1	-29
	Mataura River at Gore	0.85	2080	-30	1	-29	2	-29	1	-30
Waikaka Stream	Waikaka Stream at Gore	1.64	474	-37	0	-37	0	-37	0	-37
Mimihau Stream	Mimihau Stream Tributary at Venlaw Forest	0.31	2	0	0	0	0	0	0	0
	Mimihau Stream at Wyndham	0.70	132	-21	0	-21	0	-21	0	-20
Oteramika Stream	Oteramika stream at Seaward Down	2.02	80	-50	0	-50	0	-50	0	-50
Mokoreta River	Mokoreta River at Wyndham River Road	0.69	281	-26	0	-26	0	-26	0	-26
Lower Mataura	Mataura River 200m d/s Mataura Bridge	0.99	2850	-30	1	-30	1	-29	0	-30
	Mataura at Seaward Downs	1.05	3579	-30	1	-30	1	-30	0	-30
	Mataura River at Gorge Road	1.08	3829	-32	1	-31	1	-31	0	-31

- **Table 30:** The combined impact of land use change and mitigation on total phosphorus concentration. Percentage change has been calculated with respect to consented land use and current farm practices. A positive value indicates an increase in TP. Percentage change in concentration is equal to the percentage change in load.

Sub-Catchment	Monitoring Site	Consented land use			Conservative demand growth		Accelerated demand growth Future mitigation		Fifty percent of accelerated demand growth	
		Current mitigation (base-line)		Future mitigation (% change)	Current mitigation (% change)	Future mitigation (% change)	Current mitigation (% change)	Future mitigation (% change)	Current mitigation (% change)	Future mitigation (% change)
		Conc. (mg/l)	Load (t/yr)							
Upper Mataura	Mataura River at Garston	0.02	20.6	0	0	0	0	0	0	0
	Mataura River at Parawa	0.02	41.7	-1	0	-1	0	-1	0	-1
Waikaia River	Waikaia River u/s Piano Flat	0.02	11.9	0	0	0	0	0	0	0
	Waikaia River at Waikaia	-	-	-	-	-	-	-	-	-
	Waikaia River at Waipounamu Bridge Road	0.03	45.6	-2	3	1	4	1	2	0
Waimea Stream	Waimea Stream Tributary at McCale Road	0.04	0.2	-5	0	0	0	0	0	0
	Waimea Stream at Old Balfour Road	0.03	1.0	-1	0	-1	0	-1	0	-1
	Waimea Stream at Murphy Road	0.03	3.0	-18	1	-17	1	-17	0	-17
	Waimea Stream at Pahiwi-Balfour Rd	0.04	7.0	-20	1	-19	1	-18	0	-19
	Longridge Stream at Sandstone	0.04	1.1	-23	14	-6	21	2	6	-15
	North Peak Stream at Waimea Valley Road	-	-	-	-	-	-	-	-	-
	Waimea Stream at Nine Mile Road	0.05	12.1	-20	2	-18	3	-17	1	-19
	Sandstone Stream at Kingston Crossing Rd	0.13	0.9	-28	11	-17	16	-11	6	-21
	Waimea Stream at Mandeville	0.05	15.6	-20	2	-18	3	-17	1	-19
Mid	Otamita Stream at Mandeville	0.06	6.9	-4	0	-4	0	-4	0	-4

Sub-Catchment	**Monitoring Site**	**Consented land use**			**Conservative demand growth**		**Accelerated demand growth Future mitigation**		**Fifty percent of accelerated demand growth**	
		Current mitigation (base-line)		**Future mitigation (% change)**	**Current mitigation (% change)**	**Future mitigation (% change)**	**Current mitigation (% change)**	**Future mitigation (% change)**	**Current mitigation (% change)**	**Future mitigation (% change)**
		Conc. (mg/l)	**Load (t/yr)**							
Mataura	Mataura River at Otamita Bridge	0.03	142.7	-4	5	0	6	1	3	-2
	Mataura River at Gore	0.03	149.1	-5	5	0	6	0	3	-3
Waikaka Stream	Waikaka Stream at Gore	0.06	13.6	-15	0	-15	0	-15	0	-15
Mimihau Stream	Mimihau Stream Tributary at Venlaw Forest	0.03	0.1	0	0	0	0	0	0	0
	Mimihau Stream at Wyndham	0.05	10.3	-6	0	-6	0	-6	0	-6
Oteramika Stream	Oteramika stream at Seaward Down	0.08	2.7	-24	0	-24	0	-24	0	-24
Mokoreta River	Mokoreta River at Wyndham River Road	0.05	17.9	-11	0	-11	0	-11	0	-11
Lower Mataura	Mataura River 200m d/s Mataura Bridge	0.04	185.8	-5	4	-2	5	-1	2	-4
	Mataura at Seaward Downs	0.04	224.4	-6	3	-4	4	-3	2	-5
	Mataura River at Gorge Road	0.04	233.7	-7	3	-4	4	-4	2	-6

7. Concluding remarks

This report documents an application of CLUES 3.0 to the Mataura catchment to simulate the possible impact of land use change on water quality, as indicated by TN an TP loads and concentrations, and the extent to with mitigation can reduce those impacts. The land use change scenarios were developed by Aqualinc. Land use change is mostly from sheep and beef farming to dairying and cropping and is restricted to the Waimea and Mid Mataura, Upper Mataura and Waikaia sub-catchments. The mitigation strategies include stock exclusion, nitrification inhibitors, herd shelters, improved farm dairy effluent management and constructed wetlands. Whether or not particular type of mitigation is applied to a location depends on the land use, the LUC and the soil drainage class.

The overriding result for the future land change scenarios is that while there can be substantial changes in predicted nutrient yields associated with land use change, which in turn affect localised water quality, the net impact on water quality is fairly minimal in the lower reaches. The results predicted with assumed mitigation suggests that mitigation can be used to offset increases in nutrient loads associated with land use change. Without mitigation, the catchment TN load could increase by around 1 % and the TP load by 2 to 4% due to land use change. With mitigation and no land use change, reductions of 32% for TN and 7% for TP are predicted. With both and use change and mitigation, the loads are decreased by around 31% for TN and 4-6% for TP.

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