

Canterbury Groundwater Study: Findings for the Dunsandel-Te Pirita Area



Prepared for
Dunsandel Groundwater Users Association

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1 EXECUTIVE SUMMARY

The purpose of this project was to increase understanding of the response of the central Canterbury groundwater system to increasing levels of pumping so that estimates of the sustainable yield of the groundwater system could be improved. A firmer estimate of the groundwater system's carrying capacity, in terms of the amount of land that can be irrigated sustainably from the groundwater system, could then be made. This information is essential to the formulation of a long-term strategy for the co-ordinated development and management of central Canterbury's water resources

The central Canterbury groundwater study was initiated by the Dunsandel Groundwater Users Association, and was funded by this group in partnership with the AGMARDT Water Studies Fund (now administered by the Sustainable Farming Fund), MAF Policy, and Environment Canterbury.

The key findings of the Canterbury groundwater study that are relevant to the central Canterbury area are:

- The groundwater system is not being 'mined'. In terms of groundwater levels, the groundwater system in central Canterbury is resilient.
- The cumulative regional effects of additional abstraction are more significant than the localised interference between neighbours.
- Groundwater level fluctuations are driven by variability in recharge from rainfall and, to a lesser extent, recharge from rivers. The cumulative effect of abstraction is to increase the fluctuations and reduce the average groundwater level in a well, about which the level fluctuates.
- In the Te Pirita area, groundwater levels lowered by pumping fully recover to the no abstraction level each year once abstraction ceases. In some other areas (particularly nearer the coast), simulated groundwater levels decline and continue to do so each year (while the level of development is sustained) until a new equilibrium level is reached. The declining groundwater levels take about 10-15 years to reach a new equilibrium, and once reached continue to fluctuate approximately parallel to the less developed state.
- The increase in pump running costs as a result of the cumulative effects on groundwater levels from increased groundwater abstraction is relatively small. However, the potential costs required to deepen wells to access the deeper water may become significant. This would need to be assessed on an individual well basis.
- Access to groundwater (i.e. whether a well 'goes dry' or not) is primarily an economic issue, not an environmental issue. Increasing the amount of abstraction does increase the amount by which groundwater levels drop during summer. If this results in a well not being able to be used it is usually possible to solve the problem by deepening the well and/or lowering the pump.

- Increased abstraction does not significantly increase the overall risk of regional salt water intrusion. Under the scenarios tested there is still a significant offshore flow.
- There is a limit to how much water can be taken from the central Canterbury groundwater system on an ongoing basis (the 'sustainable yield'). How much water can be pumped from the groundwater system is primarily an environmental effects issue. The critical environmental effects are those relating to in-stream values in spring-fed streams and rivers. At present there are no explicit methods and criteria for determining when such effects become 'significant adverse effects'.
- A more refined estimate of the sustainable yield of aquifers in the Dunsandel-Te Pirita district has been made by using a groundwater model to simulate the response of the aquifers to abstraction over a 34-year period. Assumptions were necessary concerning when the effects on spring-fed streams became 'significant adverse effects'.
- The estimate of sustainable yield is greater than Environment Canterbury's current water allocation limit for the Selwyn-Rakaia groundwater zone. The difference is primarily due to the inclusion of the additional recharge from irrigation and differing methods to determine what level of effect is acceptable.
- The carrying capacity of the groundwater system, in terms of irrigated area, is approximately 50,100 ha between the Rakaia and Selwyn rivers, based on the findings of the study.
- The cumulative effects of abstraction in central Canterbury extend south of the Rakaia River, and abstraction in mid Canterbury affects levels north of the Rakaia River. Groundwater allocation limits for central Canterbury cannot be set in isolation from the setting of allocation limits for mid Canterbury.

The allocation limit estimated from the results of this groundwater study is based on an assumption about the level of effect on spring-fed stream flow that is acceptable in terms of the balance struck between in-stream values and the regional and private economic benefits of groundwater development. Whether the assumption made is acceptable to the community as a whole needs to be established as soon as possible, because of its significance to water management in Canterbury.

2 INTRODUCTION

2.1 Background

Due to the relatively dry climate in Canterbury, intensive farming is highly dependent on a reliable source of irrigation water. Development of groundwater as a source of this irrigation in the Te Pirita-Dunsandel area has been rapid over the past 15 years. During the early 1990's, deep groundwater in the area was discovered as an economically feasible irrigation water supply source. As such, a great proportion of this area has since been converted from traditional dryland beef and sheep farming to highly productive irrigated agriculture (primarily dairying and dairy support).

The level of groundwater development has outstripped the knowledge base needed to effectively manage groundwater allocation and avoid over-investment in groundwater development.

2.2 Project Purpose

The primary purpose of the project was to increase understanding of the response of the central Canterbury groundwater system to increasing levels of groundwater abstraction in the Dunsandel-Te Pirita area so that estimates of the sustainable yield of the groundwater system could be improved. A firmer estimate of the groundwater system's carrying capacity, in terms of the amount of land that can be irrigated sustainably from the groundwater system, could then be made. This information is essential to the formulation of a long-term strategy for the co-ordinated development and management of the central Canterbury's water resources.

2.3 Project Sponsors

The study was initiated by the Dunsandel Groundwater Users Association, and was funded by this group in partnership with the AGMARDT Water Studies Fund (now administered by the Sustainable Farming Fund), MAF Policy, and Environment Canterbury.

2.4 Previous Work

More detailed work on the Canterbury aquifers' capacity to meet abstractive demands was completed by Lincoln Environmental as part of Stage 1 of the Canterbury Strategic Water Study (Morgan *et al.*, 2002). The conclusion of this work was that the cumulative effects of abstraction on flows in lowland streams and rivers would limit groundwater takes. At the time there were no established criteria for determining when the adverse affects of abstraction had reached an unacceptably high level. This is still the case.

In order to illustrate the significance of the relationship between groundwater abstraction and reduction in spring-fed stream flow, assumptions were made by Morgan *et al.* about the degree of effect that would be acceptable. An estimate of the

sustainable yield of the aquifers between the Rakaia and Waimakariri rivers was made on the basis of this assumption. The sustainable yield was calculated to be 491 Mm³ of water per year (calculated from Table 2.1 of Aitchson-Earl *et al.*, 2004). This is enough to apply 600 mm of irrigation water on 81,800 ha of land between the Rakaia and Waimakariri rivers.

In January 2004, Environment Canterbury proposed a groundwater allocation limit for the Rakaia-Selwyn area of 158.5 Mm³ of water based on rainfall only (based on Table 6.2 of Aitchson-Earl *et al.*, 2004). This is enough to irrigate about 25,400 ha, based on the 600 mm of water per year. This limit has been revised to include some additional recharge from intermittent streams. The revised allocation limit for the Rakaia-Selwyn area is 208.5 Mm³ (as of 20 April 2005). This is sufficient to irrigate about 34,750 ha between the Rakaia and Selwyn rivers, based on 600 mm of water per year.

This project was initiated to firm up estimates of the sustainable yield of the aquifers in the Dunsandel-Te Pirita district.

2.5 Overall Approach

The response of large groundwater systems to changes in climate and groundwater abstraction is complex. The most feasible way of predicting the response of aquifers to increasing levels of abstraction is to develop a regional groundwater computer model of the aquifer system and then use the model to predict changes in groundwater levels and flows resulting from changes in groundwater abstraction.

3 OVERVIEW OF THE GROUNDWATER MODEL

The regional groundwater model encompasses the aquifer system between the Waimakariri River and Rangitata River and simulates groundwater levels and stream flows over a 34-year period from 1970 to 2003. Figure 3-1 details the study area and the boundary of the numerical model.

Due to the size of the study area and the complexity of the hydrogeology, the computer model is complex and uses specialised software. The development, testing and application of the model is described in detail in Aqualinc (2005).

Groundwater levels simulated by the model compare favourably with measured groundwater levels in 154 wells located throughout the study area. Likewise, the simulated groundwater-fed component of stream flows generally compare well to the measured data, and overall mass balance outputs are acceptable. The level of performance indicated by these factors gives confidence in the use of the model for the intended purpose. However, there is need for further research and development to increase the usefulness and accuracy of the model, particularly with respect to simulated flows in some of the surface water features.

The study has quantified the recharge of Canterbury's aquifer system from both stream recharge and land surface recharge aspects. The dynamic response of the aquifer system is dominated by climatic patterns via land surface recharge. However, recharge from the major rivers is significant in maintaining a relatively stable base groundwater level.

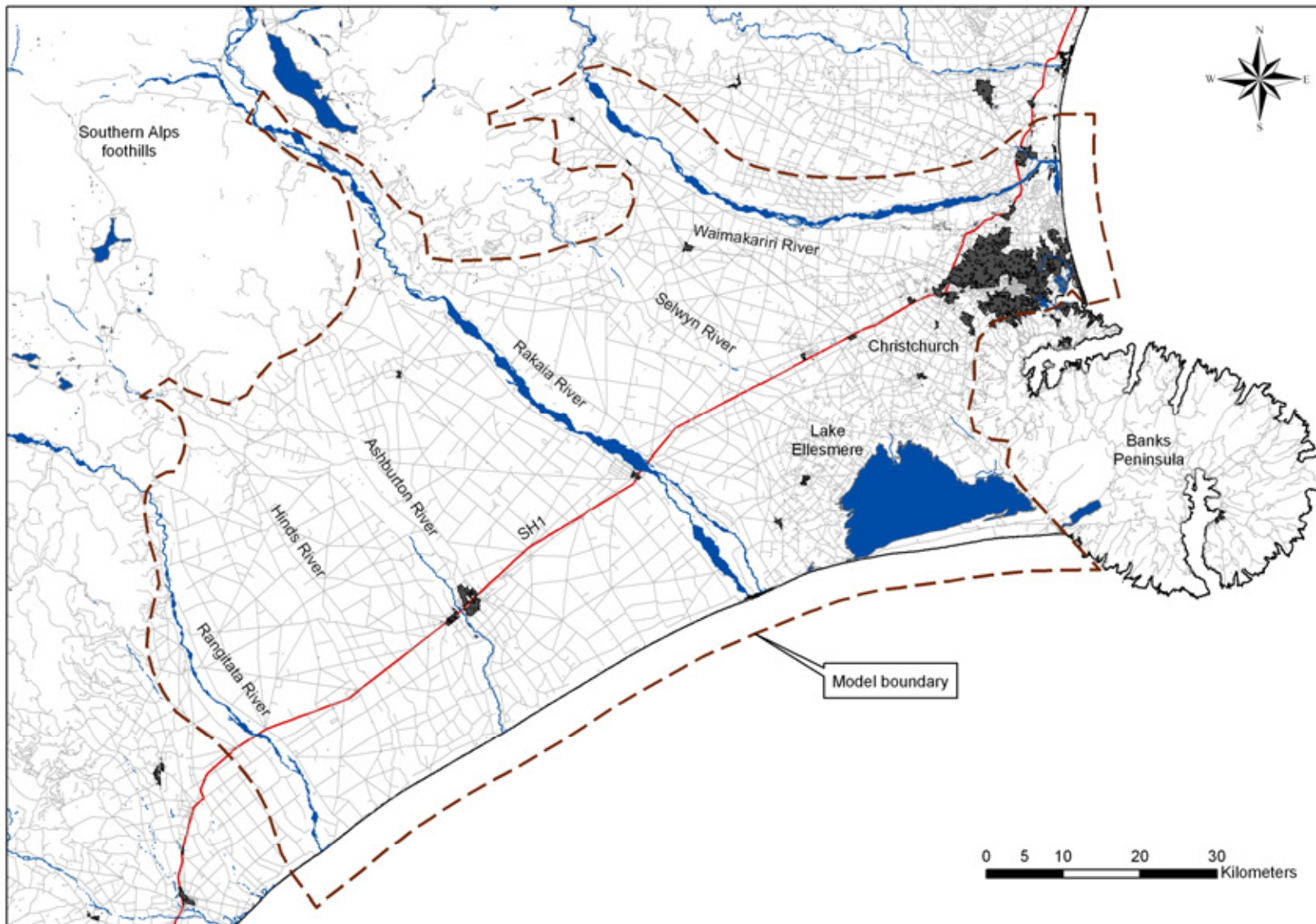


Figure 3-1: Study area and computer model boundary

4 DEVELOPMENT SCENARIO ANALYSIS

The calibrated model has been used to evaluate different development scenarios in order to predict how the aquifer system responds to stresses applied (e.g. changes in abstraction and land surface recharge). An overview of these simulations will be given along with the results from a comparison of groundwater levels and stream flows for each scenario considered. More detailed results are presented in Aqualinc (2005).

4.1 The Scenarios

To assist in determining the carrying capacity (or sustainable yield) of the groundwater system, four development scenarios have been considered. Land use for each scenario is based on Morgan *et al.* (2002) and is described in Aqualinc (2005).

Results for Scenario 4, relating to development in the coastal mid Canterbury area, are described in Aqualinc (2005) and have not been included herein.

4.1.1 Scenario 1: No Abstraction

All farm areas are assumed to be unirrigated except for the surface water supplied farms in the major border-dyke scheme areas. Land use as of 30 June 2002 has been assumed.

No abstractions for Christchurch city and other municipal or industrial uses have been included.

4.1.2 Scenario 2: Status Quo

Irrigation according to the area of land developed for irrigation as of 30 June 2002 applied to the full simulation period from 1970 to 2003. Major border-dyke areas remain as for scenario 1.

Municipal groundwater takes for Christchurch city have been included.

Figure 4-1 shows the distribution of irrigation wells which have been taken into account under the status quo scenario.

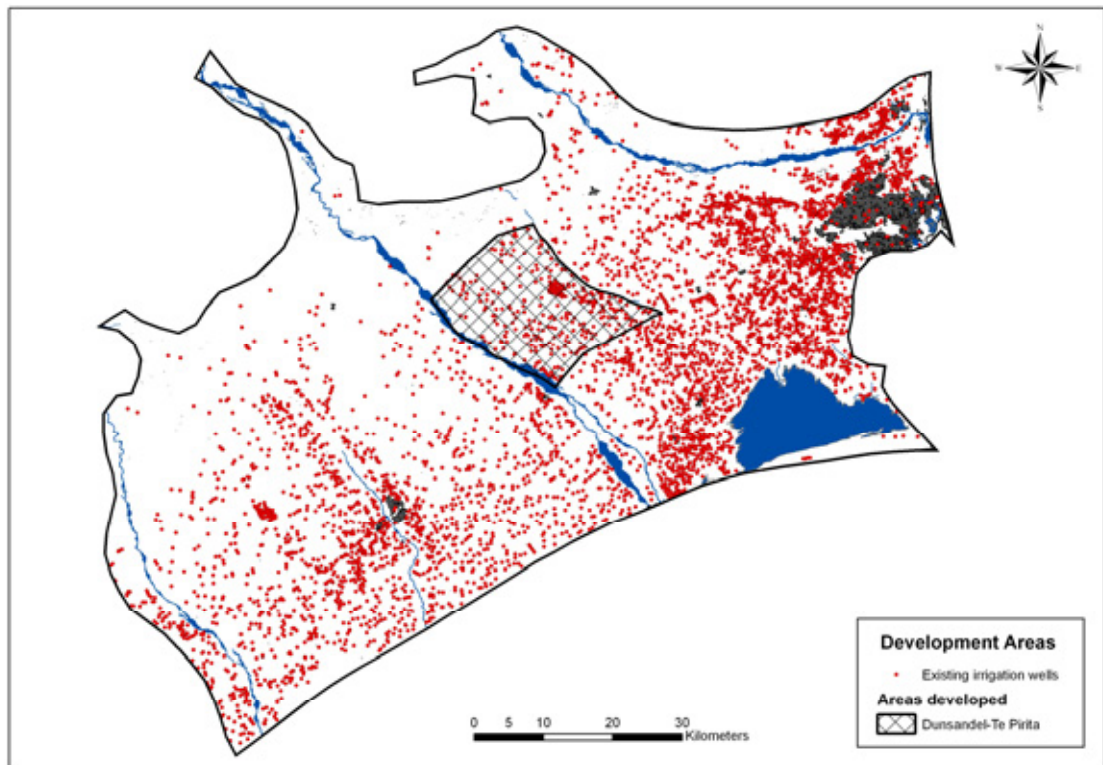


Figure 4-1: Existing irrigation wells and areas developed under the Dunsandel-Te Pirita fully developed scenario

4.1.3 Scenario 3: Dunsandel-Te Pirita Area Fully Developed

Maximum irrigation development of the Dunsandel-Te Pirita area. The location of this fully developed area is shown in Figure 4-1.

It has been assumed that all irrigable land within the area is fully developed for irrigation as per the Canterbury Strategic Water Study (Morgan *et al.*, 2002).

The relative proportion of abstraction assigned to each aquifer is assumed to be the same as of 30 June 2002.

4.1.4 Scenario 4: Coastal mid Canterbury fully developed

Maximum irrigation development of the mid Canterbury area between approximately 5 km inland from State Highway 1 (SH1) through to the coast.

Table 4-1 summarises the area of land developed and the average annual abstraction for the scenarios considered. The average annual abstraction volumes reported are the abstraction volumes only for the Dunsandel-Te Pirita area, and are not the full abstractions for all zones represented in the model.

Table 4-1: Summary of developed areas and abstraction volumes for developed zones

			Dunsandel-Te Pirita area
Development scenario	No abstraction	Area developed for g/w abstraction (excl. border-dyke areas) (ha)	0
		Avg. annual abstraction (from zones developed) (Mm ³ /year)	0
	Status quo	Area developed for g/w abstraction (excl. border-dyke areas) (ha)	12,600
		Avg. annual abstraction (from zones developed) (Mm ³ /year)	74.3
	Fully developed	Area developed for g/w abstraction (excl. border-dyke areas but incl. border-dyke areas converted to spray irrigation sourced from groundwater) (ha)	37,600
		Avg. annual abstraction (from zones developed) (Mm ³ /year)	223.4
Additional development between status quo and fully developed		Additional Area developed (ha)	25,000
		Additional Volume abstracted (Mm³/year)	149.1

4.2 Summary of Results

The future development scenario considered for Dunsandel-Te Pirita is one of many possibilities for potential development and presents a maximum potential development for the area. If development elsewhere in the study area is simulated then the effects on the aquifer system and surface water features will differ from the development scenario considered.

4.2.1 Groundwater Levels

In most areas, simulated groundwater levels fall as abstraction increases. The magnitude and duration of this reduction depends on the location, the time period considered and the development scenario.

Under irrigation, some of the water pumped returns to the groundwater system as increased land surface drainage and recharges the upper aquifer. In some areas this results in higher groundwater levels for some of the time, relative to the no-development scenario. This is apparent in the upper Selwyn area where simulated groundwater levels in the shallow aquifer increase (opposite to what occurs elsewhere) due to a transfer of water from deep to shallow layers.

In all areas, additional groundwater abstraction increases the amplitude of seasonal groundwater level fluctuations.

Table 4-2 summarises the differences in the average annual lowest simulated groundwater level between scenarios for selected zones in the study area for aquifers with wells used in model development.

Table 4-2: Change in the average annual lowest simulated groundwater level for selected zones.

Zone	Aquifer/ aquitard	Change in the average annual lowest simulated groundwater level (m)		
		Comparison to no abstraction scenario		Comparison to status quo scenario
		Status quo	Dunsandel-Te Pirita fully developed	Dunsandel-Te Pirita fully developed
1	Aquifer 1	-0.1	-0.1	0
	Aquifer 2	-0.1	-0.1	0
4	Aquifer 1	-1.9	-1.9	-0.1
	Aquitard 2	-1.6	-1.7	0
7	Aquifer 1	-0.8	-0.9	-0.2
	Aquitard 1	-2.3	-2.9	-0.6
	Aquifer 2	-8.1	-9.1	-1.0
	Aquifer 3	-1.4	-1.6	-0.2
	Aquitard 3	-9.9	-12.5	-2.6
	Aquifer 4	-9.9	-12.5	-2.6
13	Aquifer 5	-9.2	-12.1	-2.9
	Aquifer 1	-1.6	-1.8	-0.2
	Aquitard 1	-2.8	-3.7	-0.9
	Aquifer 2	-4.4	-6.0	-1.6
14	Aquitard 2	-3.6	-4.8	-1.2
	Aquifer 1	0	1.8	1.8
	Aquitard 1	-0.4	1.2	1.6
	Aquitard 2	-11.2	-19.2	-8.0

Note: Zone 1 is coastal mid Canterbury, between the Rangitata and Hinds Rivers.
 Zone 4 is coastal mid Canterbury, between the Hinds and Ashburton Rivers.
 Zone 7 is coastal mid Canterbury, between the Ashburton and Rakaia Rivers.
 Zone 13 is coastal central Canterbury, between the Rakaia and Selwyn Rivers.
 Zone 14 is the Dunsandel-Te Pirita area.

Figure 4-2 shows the changes in the average annual lowest simulated groundwater levels due to abstraction between the no abstraction and the status quo scenarios for wells considered during development of the model. Similarly, Figure 4-3 compares changes in the average annual lowest simulated groundwater levels between the status quo and the fully developed scenario for the same set of wells.

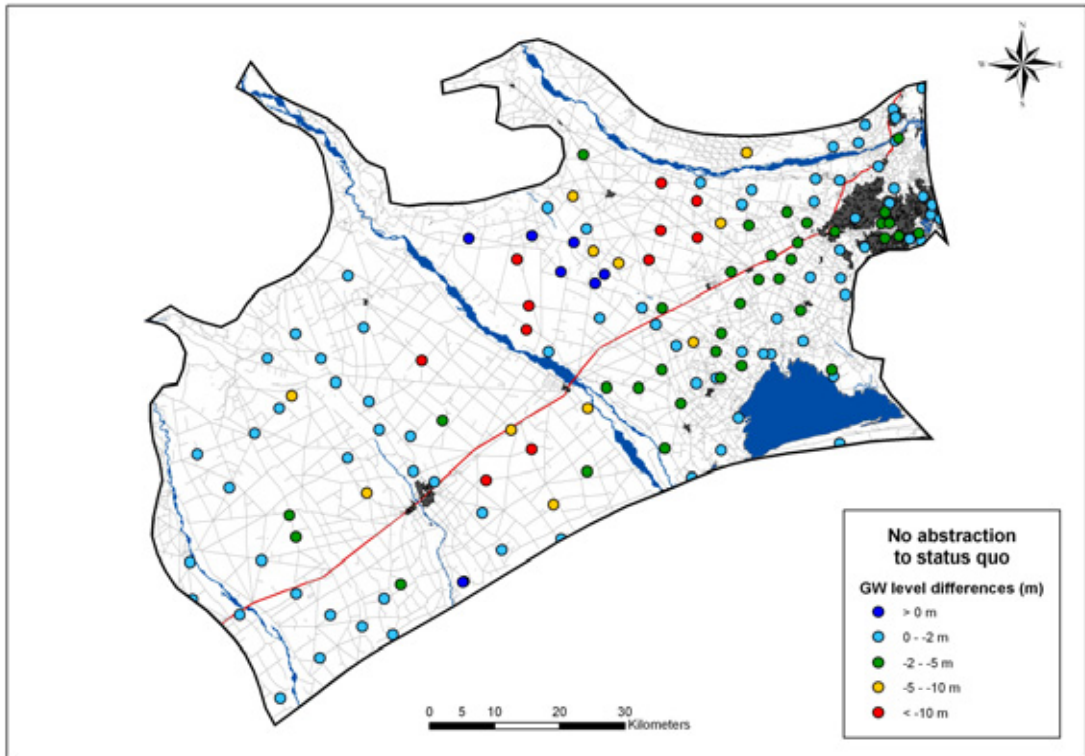


Figure 4-2: Comparison of changes in average annual lowest simulated groundwater levels between the no abstraction scenario and the status quo scenario

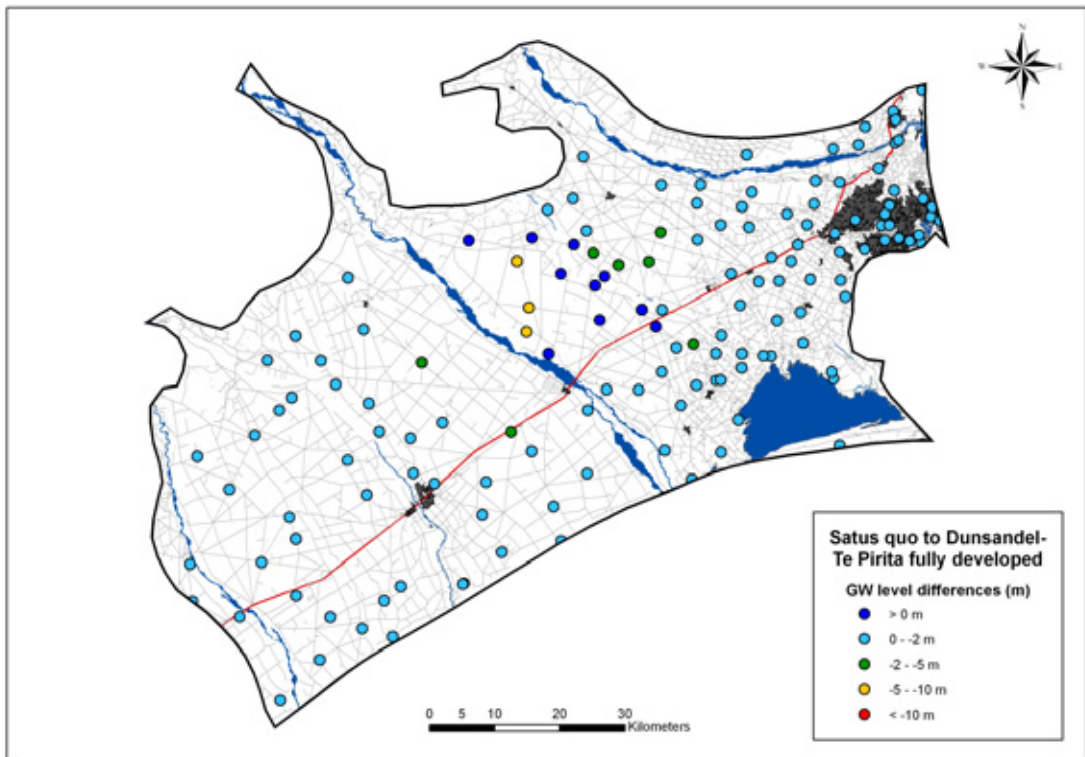


Figure 4-3: Comparison of changes in average annual lowest simulated groundwater levels between the status quo scenario and the Dunsandel-Te Pirita fully developed scenario

Figure 4-4 is a contour map of the changes in the 10-percentile simulated groundwater levels, comparing the status quo and the full development scenario for aquifer 3. Simulated groundwater level changes between these scenarios were equal to, or less than, the values represented by the contours for 90% of the time during the 34 years modelled. These figures provide an overview of the spatial influence of the development scenarios considered in the Dunsandel-Te Pirita area.

Only aquifer 3 is presented as this aquifer is vertically central in the model and is reasonably utilised in the areas of development considered.

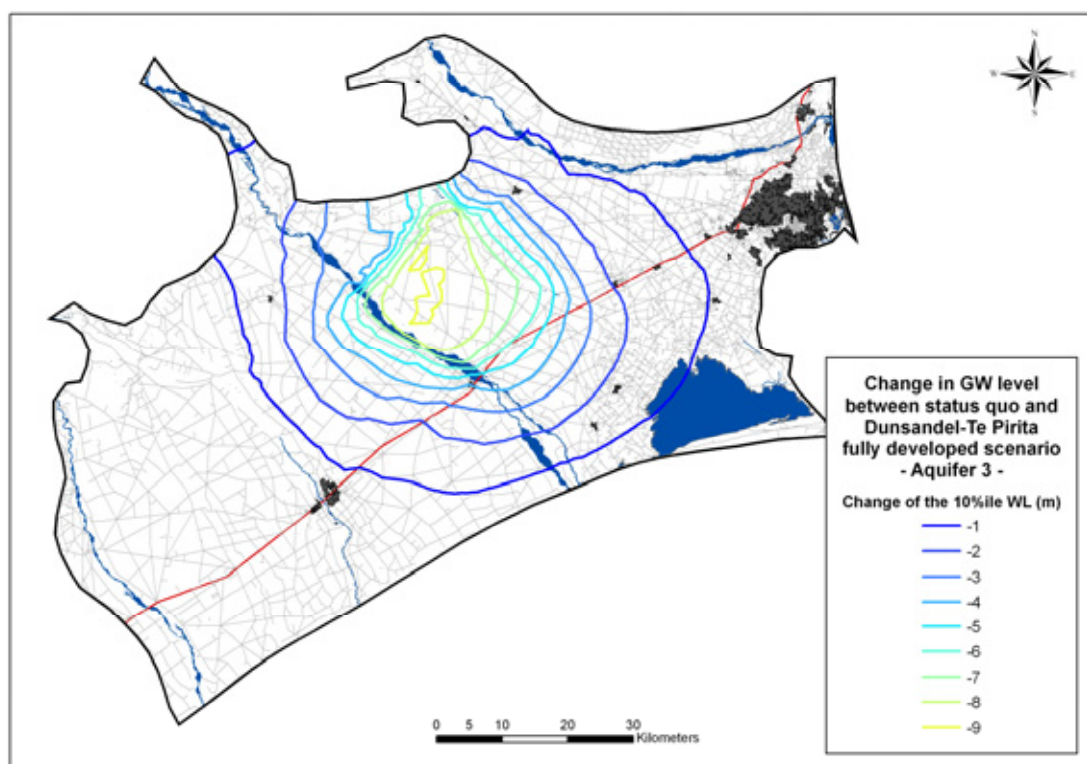


Figure 4-4: Change of the 10-percentile simulated groundwater levels between status quo and Dunsandel-Te Pirita fully developed scenario (aquifer 3)

4.2.2 Rivers, Streams and Drains

Most rivers, streams and drains are hydraulically connected to shallow groundwater and gain water from, or lose water to, groundwater. This trend remains regardless of the development scenario, although the gain is reduced, or the loss is increased, with greater groundwater abstraction.

In most areas there is a reduction of flows in groundwater dependent rivers, streams and drains with increased groundwater abstraction. In some localised areas, there is a net increase in stream flow due to the transfer of groundwater from deep to shallow layers.

There is a large variation in the effects of groundwater abstraction on changes in stream flows, which is dependent on:

- Stream properties;
- The location of the stream in relation to the additional abstraction;
- The development scenarios being compared.

The largest river between the Waimakariri and Rakaia rivers is the Selwyn River. In its upper reaches the Selwyn River is dominated by rainfall runoff. In its lower reaches, flows are dominated by groundwater discharge. Statistics of simulated river flows for the Selwyn River at Coes Ford under different development scenarios are presented in Table 4-3.

Significant to Christchurch city is the Avon River. This is a groundwater dependent river and is directly affected by the lowering of groundwater levels within and near the city. Statistics of simulated river flows under different development scenarios for the Avon River at Gloucester Street bridge are presented in Table 4-3.

Comparing the status quo with the Dunsandel-Te Pirita fully developed scenario, the lowland streams and rivers north of the Selwyn River are not noticeably affected by irrigation development south of the Selwyn River.

The smaller streams and drains flowing into Lake Ellesmere between the Selwyn and the Rakaia rivers are generally all affected by additional groundwater abstraction inland. Summaries of the reduction in simulated flows in these streams at the coast are provided in Table 4-3.

Table 4-3: Statistics of simulated flows for selected central Canterbury rivers

Stream	Site	Flow unit	Simulated median flow			Simulated average annual low flow		
			No abstraction	Status Quo	Dunsandel-Te Pirita fully developed	No abstraction	Status Quo	Dunsandel-Te Pirita fully developed
Selwyn	Coes Ford	ℓ/s	820	630	590	700	500	460
Avon	Gloucester St bridge	ℓ/s	1,299	1,054	1,020	1,251	968	931
Various lowland streams	Coast	% change	4-32%		-	12-52%		-
			-	0-8%		-	23-50%	

4.2.3 Deep Aquifer Continuity Under Rivers, Streams and Drains

Deep aquifers have been modelled as continuous under rivers, streams and drains. The development scenarios simulated reveal a lowering of groundwater levels due to abstraction in these deeper aquifers on the opposite side of the rivers, although the effect was often dampened. Figure 4-4 shows the extent of the influence of abstraction in central Canterbury on mid Canterbury.

4.2.4 Salt Water Intrusion

Salt water intrusion on a regional scale is unlikely to occur under the development scenarios considered. However, this does not preclude the possibility of it occurring locally.

4.2.5 The Groundwater Balance

As irrigation development occurs, additional groundwater abstraction is balanced predominantly by increased land surface drainage, a reduction of groundwater flow to streams, and a reduction of discharge to Lake Ellesmere and offshore. To a lesser extent, the additional groundwater abstraction is also balanced by a small increase in recharge from surface water. The amount of water that is stored in the aquifer system is also reduced, which is seen by the lowering of groundwater levels.

Figure 4-5 and Figure 4-6 enable comparison of water inflows and outflows between scenarios.

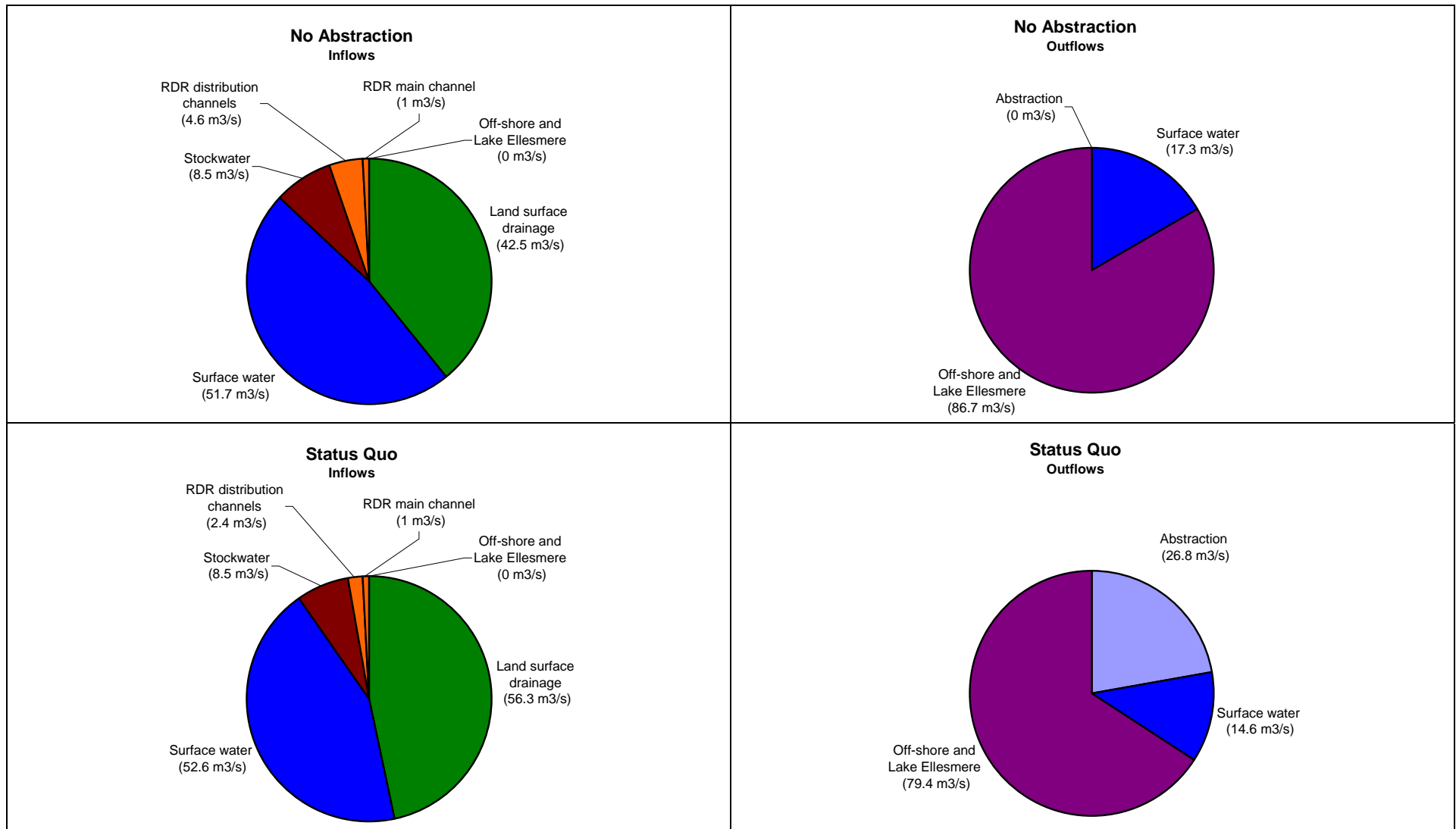


Figure 4-5: Total mass balance plots for no abstraction and status quo scenarios

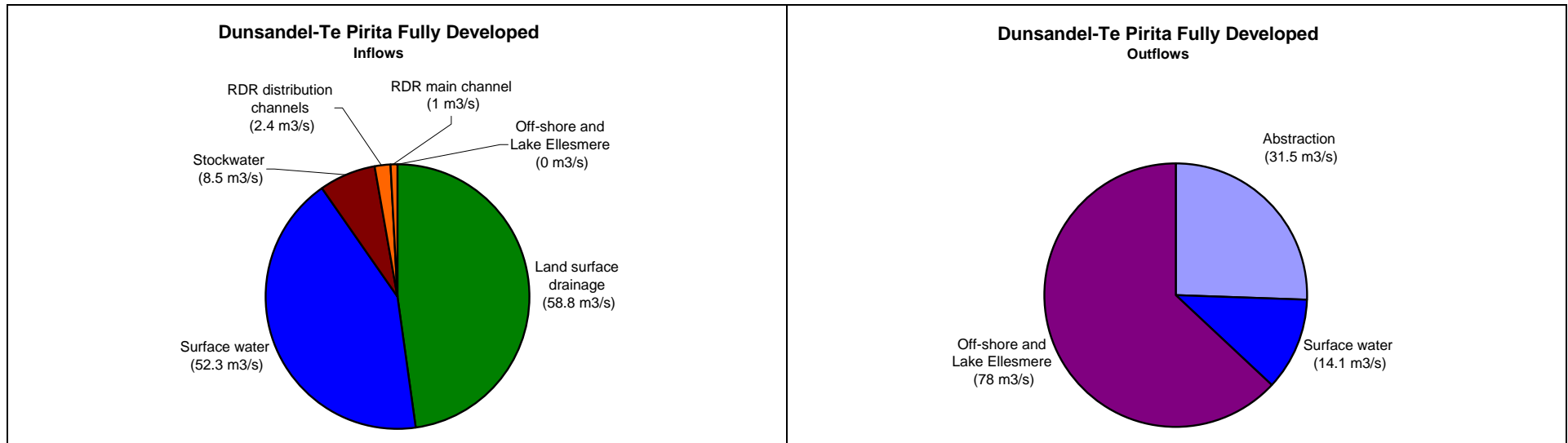


Figure 4-6: Total mass balance plots for coastal mid Canterbury fully developed scenario

5 CARRYING CAPACITY

There is a limit to how much water can be pumped from central Canterbury aquifers. The limit is reached when the cumulative adverse effects of abstraction on existing takes, or on the environment, become unacceptable to stakeholders.

The cumulative adverse effects of abstraction on existing takes are:

- 1) Increased cost of pumping and accessing groundwater
- 2) Reduced reliability of supply from:
 - Groundwater (groundwater levels drop below pumps or restrictions incurred more frequently)
 - Hydraulically connected surface water bodies (restrictions on surface water takes incurred more frequently)

The cumulative adverse effects on the environment potentially include:

- 3) Mining the resource
- 4) Ground subsidence
- 5) Effects on the flow regime of hydraulically connected surface water bodies
- 6) Salt water intrusion
- 7) Adverse effects on groundwater quality induced by abstraction.

Computer modelling the response of groundwater levels and stream flows to increased abstraction enables the carrying capacity of the groundwater system to be determined. The groundwater model does not directly determine groundwater abstraction limits; it simply predicts the system response to changes in abstraction. A decision can then be made on the degree of change considered acceptable and sustainable.

5.1 An Allocation Limit

The Canterbury Strategic Water Study (Morgan *et al.*, 2002) discusses how spring-fed stream flows are a suitable indicator of the cumulative effects of groundwater abstraction. To determine a limit of groundwater abstraction, Morgan *et al.* made an assumption about the level of effect on stream flows that would be acceptable. This method is one of several that could be used to calculate an allocation limit. Scott (2004) and Aitchison-Earl *et al.* (2004) discuss the relevance and implications of the method proposed by Morgan *et al.* to the Canterbury region and suggest an alternative method to determine an allocation limit, not based on the cumulative effects of groundwater abstraction. The method proposed by Morgan *et al.* has been used because it is effects based.

The reduction in flow regimes assumed by Morgan *et al.* to be acceptable is based on stream flow measurements which incorporate the effects of the status quo level of groundwater development. It was assumed that additional abstraction would be acceptable so long as the proportion of flows below the current median increased from 50% to no more than 70%. Another way of stating this is the additional abstraction that causes the median flow to reduce from the 50-percentile flow to the 30-percentile.

Scenario 3 – the full development of irrigation in the Dunsandel-Te Pirita area from groundwater – results in changes in spring-fed stream flow less than the change

Morgan *et al.* assumed was acceptable. Consequently, the additional development areas and volumes calculated by the method assumed by Morgan *et al.* have been scaled up to a level such that the flows in the most limiting river for the region reduces to no less than the 30-percentile flow as simulated under the status quo scenario. The most limiting of the rivers in central Canterbury that were modelled is Birdlings Brook (at Feredays Road). The resulting allocation limit is presented in Table 5-1.

Table 5-1: Allocation limits calculated using the method described in the Canterbury Strategic Water Study

		Dunsandel-Te Pirita area
Additional development over and above status quo	Area developed (ha)	37,500
	Avg. annual abstraction (Mm ³ /year)	223.7
Total development	Area developed (ha)	50,100
	Avg. annual abstraction (Mm ³ /year)	298.0

Environment Canterbury's current groundwater allocation for the Rakaia-Selwyn area is 158.5 Mm³/year, based on rainfall recharge only. If additional sources of recharge are included the allocation increases to 208.5 Mm³/year. These figures have been taken from Table 6.2 of Aitchison-Earl *et al.* (2004), with values updated as of 20 April 2005.

The groundwater allocation limit estimated from the results of applying the groundwater model is greater than Environment Canterbury's limit. This is primarily due to the inclusion of the additional recharge from irrigation and differing methods to determine what level of effect is acceptable.

It is important to realise that the allocation limit estimated in this study is based on an assumption about the level of effect on spring-fed stream flow that is acceptable in terms of the balance struck between in-stream values and the regional and private economic benefits of groundwater development. Whether the assumption made is acceptable to the community as a whole needs to be established as soon as possible, because of its significance to water management in Canterbury.

5.2 Alternative Development Scenarios

The allocation limits discussed above have been determined by assuming the limit is completely reached by development in the Dunsandel-Te Pirita area alone. However, should development occur elsewhere, then the limit will differ. Additional simulations will be required to present a broader picture of development options for Canterbury's aquifer system.

6 CONCLUSIONS

The following is a summary of the key findings of the Canterbury groundwater study that are relevant to the central Canterbury area (particularly the Dunsandel-Te Pirita area).

- 1) The groundwater system is not being 'mined'. In terms of groundwater levels, the groundwater system in central Canterbury is resilient.
- 2) The cumulative regional effects of additional abstraction are more significant than the localised interference between neighbours.
- 3) Groundwater level fluctuations are driven by variability in recharge from rainfall and, to a lesser extent, recharge from rivers. The cumulative effect of abstraction is to increase the fluctuations and reduce the average groundwater level in a well, about which the level fluctuates.
- 4) In the Te Pirita area, groundwater levels lowered by pumping fully recover to the no abstraction level each year once abstraction ceases. In some other areas (particularly nearer the coast), simulated groundwater levels decline and continue to do so each year (while the level of development is sustained) until a new equilibrium level is reached. The declining groundwater levels take about 10-15 years to reach a new equilibrium, and once reached continue to fluctuate approximately parallel to the less developed state.
- 5) The increase in pump running costs as a result of the cumulative effects on groundwater levels from increased groundwater abstraction is relatively small. However, the potential costs required to deepen wells to access the deeper water may become significant. This would need to be assessed on an individual well basis.
- 6) Access to groundwater (i.e. whether a well 'goes dry' or not) is primarily an economic issue, not an environmental issue. Increasing the amount of abstraction does increase the amount by which groundwater levels drop during summer. If this results in a well not being able to be used it is usually possible to solve the problem by deepening the well and/or lowering the pump.
- 7) Increased abstraction does not significantly increase the overall risk of regional salt water intrusion. Under the scenarios tested there is still a significant offshore flow.
- 8) There is a limit to how much water can be taken from the central Canterbury groundwater system on an ongoing basis (the 'sustainable yield'). How much water can be pumped from the groundwater system is primarily an environmental effects issue. The critical environmental effects are those relating to in-stream values in spring-fed streams and rivers. At present there are no explicit methods and criteria for determining when such effects become 'significant adverse effects'.

- 9) A more refined estimate of the sustainable yield of aquifers in the Dunsandel-Te Pirita district has been made by using a groundwater model to simulate the response of the aquifers to abstraction over a 34-year period. Assumptions were necessary concerning when the effects on spring-fed streams became 'significant adverse effects'.
- 10) The estimate of sustainable yield is greater than Environment Canterbury's current water allocation limit for the Selwyn-Rakaia groundwater zone. The difference is primarily due to the inclusion of the additional recharge from irrigation and differing methods to determine what level of effect is acceptable.
- 11) The carrying capacity of the groundwater system, in terms of irrigated area, is approximately 50,100 ha between the Selwyn and Rakaia rivers, based on the findings of the study.
- 12) The cumulative effects of abstraction in central Canterbury extend south of the Rakaia River, and abstraction in mid Canterbury affects levels north of the Rakaia River. Groundwater allocation limits for central Canterbury cannot be set in isolation from the setting of allocation limits for mid Canterbury.

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