Assessment of Effects of the Operation of the Scheme

8.1 Introduction

This section assesses the permanent effects of the proposed Central Plains Water Enhancement Scheme, and covers the effects of water diversions and various discharges, damming waters, and effects on biological, cultural, social, economic, landscape, soils, groundwater and other aspects of the environment. Matters to be covered include:

- Diverting water in the beds of the Rakaia and Waimakariri Rivers;
- Discharging water and sediment to the Rakaia and Waimakariri Rivers from the sediment flushing basins, and fish bypasses;
- Discharging bywash water to surface water in the Waimakariri, Rakaia, and Selwyn Rivers; and
- Discharging water to land in the wetlands.

Permanent effects of the Scheme on the following environments are also considered:

- Waianiwaniwa Valley;
- Groundwater and surface water environments of the Central Canterbury Plains, lowland streams and Lake Ellesmere, including water quantity and quality;
- Biological environments;
- Soil environments;
- Landscape and visual amenity values;
- Tangata whenua values;
- Economic effects; and
- Social effects.

The effects of taking water from the Rakaia and Waimakariri Rivers have been assessed in the previous water take applications as detailed above in Section 1. These have included assessments of the effects on flows, sediment transport, riparian vegetation, periphyton and benthic communities, fish, birdlife, recreation, visual amenity and landscape values, social, economic and cultural effects. The reader is referred to those reports for details of these matters.

8.2 Effects of Diverting Water

The operation of the two Waimakariri River intakes, and the Rakaia River intakes will all involve diverting water from the river, through the stilling basins and fish screens, and returning this water to the river a short distance downstream of where it had been abstracted. These diversions are required to operate the sediment flushing and fish screening facilities within the headworks sections of the headrace and inlet headrace.

At all three proposed intakes, the diversions will take the same general form. The intakes and headworks channels will be designed to accommodate flows necessary to enable the water take for the use of water for irrigation and ancillary purposes and sediment flushing (up to 40 m^3/s), and fish passes (up to 2 m^3/s), and water will be diverted away from the river channel to a stable part of the valley floor unaffected by flood events. The diverted water will therefore be taken out of the present river environment.

The fish screens will operate continuously while water is being taken from the river. They will require 1 – 2 m^3/sec flow past the screen, and this will be returned to the main rivers downstream of the sediment flushing channels. Depending on the proximity of the sediment flushing discharge, and the availability of natural channels in the river bed in which to discharge the fish bypass water, the discharge point could be between 2 and 3 km downstream of the original intake. Given the small volume of water in the fish bypasses, the effects of the diversion are considered to be very small.

It is expected that the sediment flushing diversions will only be operated once per week for a period of half to one hour. The full available flow will be discharged, and any sediment that has settled in the stilling basin will be flushed out along the diversion channel back to the main river. Given the small volume of water involved, the diversions for sediment flushing are expected to have a de minimus effect on the environment.

8.3 Effects of Water Discharges

A number of discharges require consents, including the discharge of water and sediment from the sediment flushing system; discharges of water from the fish bypasses; discharges of bywash water from the lower ends of the distribution network, and discharges to wetlands.

8.3.1 Sediment flushing

The discharges associated with the sediment flushing systems will carry water and bedload sediment to the river. It is expected that the initial flow will be at least as much as 80 m^3/sec as the flushing basin empties, but this would decline to average 40 m^3/sec over a half to one hour period, and it would occur approximately once per week. The flushing flow discharge would amount to < 0.6 % of the total volume of water take and would be less than 25 % of the total water discharged through the fish bypasses. In addition, the water is natural river water, taken from the river about 2 km upstream. Thus, the effect of discharging this water is considered to be de minimus.

The discharge of the water could cause erosion of the banks or bed where it enters the rivers. The discharge channels will be engineered so as to minimise these effects.

The discharge of the flushed sediment to the river bed will be predominantly sand and gravel sized material. It will be material that was already in transport in the river when water was diverted into the intake structure. This discharge of sediment will therefore result in the return of material that had already been in transport in the Waimakariri or Rakaia Rivers. Two issues arise with the discharge: turbidity of the water entering the main river; and the potential for the accumulation of sediment at the discharge point. The turbidity of the water will be significantly greater than the existing river flow, but as it will be brief and localised, and as these are already rivers that carry significant suspended loads, there are unlikely be adverse effects associated with these discharges.

Sediment build-up is also not expected to be a significant problem, as the main flushing discharge will comprise very fast-flowing water that will transport sediment a considerable distance. There are now numerous water intakes in riverbeds, and sediment buildup associated with the discharge of sediment flushing systems does not appear to be a widespread problem. There is considerable experience available to draw on in designing an appropriate system to mitigate potential effects.

8.3.2 Fish Bypasses

The discharge of 1 – 2 m^3/sec of natural river water back to the same river, to an existing channel within the active riverbed will have a very minor effect on the environment.

8.3.3 Bywashes and Wetlands

There will be a number of bywash discharges at the lower end of the distribution network. Ten will be located along the Rakaia, Selwyn, and Waimakariri Rivers, and during normal operations a seasonal average of about 2 m^3/sec will be discharged into small wetlands varying from 200 m^2 to 0.5 ha in area. The water will soak to groundwater, and as each discharge will have maximum rate of flow under normal conditions of between 1.5 m^3/sec and 0.1 m^3/sec, it is considered the physical effects will be de minimus.

During emergency situations such as a district-wide power failure, it may be necessary to discharge all of the water in the headrace and distribution network. At these times, a further 3 discharge points on the Rakaia, Hororata and Waimakariri Rivers will be used, bringing the total to 13. These larger flows will be routed directly to surface water, and will bypass the wetlands to avoid damaging them. The total bywash during emergency discharges will be up to 45 m^3/sec, spread over the 11 discharge locations, with a maximum flow at any one location being 18 m^3/s. The discharge will only be for a few hours while the system is emptied. The discharge points will be designed to minimise any erosion of the bed or banks of the respective rivers. It is considered the physical effects of these discharges will be de minimus.

8.4 Effects of Damming the Waianiwaniwa Valley

8.4.1 Introduction

A very significant permanent effect on the environment associated with the Central Plains Water Enhancement Scheme will result from the construction and operation of the Waianiwaniwa Dam and Reservoir. The effects of this are assessed below, based largely on a report prepared by NIWA (2002).

Some details of the storage design have changed since then, and as these will not result in increased environmental effects, the NIWA analysis has been retained.

8.4.2 Effects on Water Quality

Hill (1975), and more recently Henriques (1987), have provided extensive reviews on water quality issues in New Zealand reservoirs. In newly constructed reservoirs, water quality issues commonly include eutrophication, sedimentation, stratification, oxygen depletion, and chemical changes in the deeper layers. The extent to which these occur is largely dependent upon the morphometric (i.e, size and depth) and limnological characteristics of the reservoir such as mixing (wind and seasonal factors), light penetration, and biological productivity, all of which are affected to some extent by the source of water, richness of the soils being flooded, and operation of the dam.

Water level fluctuations

Based on the availability of water and estimated irrigation demand, it is predicted that the reservoir would go completely dry in one out of 34 years, and be drawn down to less than 50 % capacity in 14 out of 34 years. Mean water volume of the reservoir over the 28-year period would be 235 MCM[1], or 84 % of full capacity. The lowest volume would occur during periods of high irrigation demand (January-May), with the reservoir being near full from June through to December. It is estimated that a mean 160 MCM of water/year would be exported from the reservoir for irrigation (based on data for the period 1967-2001), resulting in an average residence time of water in the reservoir of about 2 years.

Limnological properties

Limnological features of the Waianiwaniwa Reservoir are expected to vary with water level fluctuations in the reservoir (Table 8-1). At 100 % full, the mean depth of the reservoir would be 24 m, with a maximum depth of 50 m along the southern margin of the reservoir next to the dam. The Reservoir would be sinuous, shallow, and have several shallow sub-basins, which branch off the main body along the western and eastern borders. At 50 % storage capacity, mean depth would decrease to 19 m and the surface area would decrease by 36 % (12 to 7 km^2). The decrease in surface area would occur mainly in the shallow sub-basins. As such, this would have only minor effects on the fetch of the reservoir, which controls the depth of wind mixing. Deep wind mixing in the reservoir would occur mainly during periods of south-west and north-east winds.

Water clarity

Water supplied from the Waimakariri River could be quite turbid if extracted during freshes and floods.

[1] MCM = millions of cubic metres

Table 8-1: Some predicted limnological features of the Waianiwaniwa Reservoir and fetch at varying reservoir capacities (% full).

Waianiwaniwa Reservoir			
Parameter	**100%**	**50%**	**25%**
Volume (MCM)	280	140	70
Area (km^2)	12	7	5
Mean depth (m)	24	19	13
Thermocline (m)	14	12	11
Fetch (km)	5.9	5.1	4.7

Suspended sediment inflows

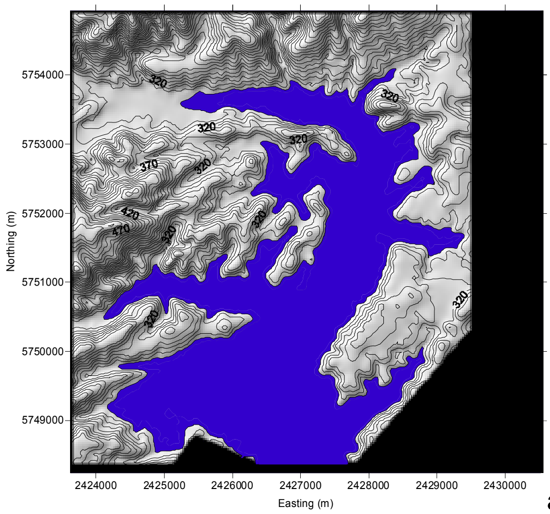
It is expected that the sediment trap on the upper Waimakariri River intake for the inlet canal would be similar to that of the Rangitata Diversion scheme. This trap has been found to be highly efficient (84-92 %) in trapping sand-size suspended sediments, but not those of the finer silt and clay particles (Waugh 1983). For the purpose of determining suspended sediment inflows to the Waianiwaniwa Reservoir, it was assumed that 84 % of the sand and none of the silt-clay fractions would be trapped in the settling basin at the intake. It is assumed that the intake structures would be adequately designed to divert bedload.

Suspended sediment data is not available from the Waimakariri River. However, the Rakaia River is very similar, and data is available from the State Highway 1 Bridge for a 2,844 m^3/sec event in 1995, when suspended sediment concentration was 5,647 g/m^3. Table 8-2 gives the sand, silt and clay fractions by mass based on particle-size analysis results. Since there are no major tributaries of the Rakaia River between the intake and SH1 Bridge, the particle size distribution of the suspended sediment at the Rakaia intake is expected to be similar to that at the SH1 Bridge, and these results have been used without modification. The mass fractions for the Waianiwaniwa inflow show the proportion of the sand, silt and clay fractions, after allowing for removal of 84 % of the sand fraction within the intake structures.

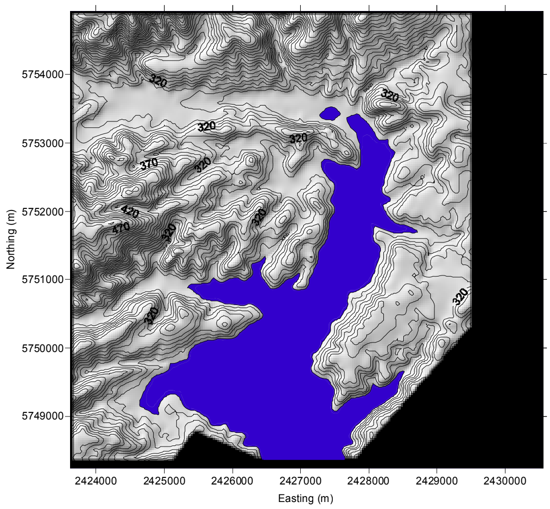
Based on an analysis of synthetic daily takes from the Waimakariri River for 10 years of historical flow data (1990-2000), it is estimated that, on average, the suspended sediment load into the Waianiwaniwa Reservoir would be 26,150 t/year.

Table 8-2: Sand, silt and clay mass fractions for the Rakaia River at SH1 Bridge (sampled) and for Waianiwaniwa Reservoir inflows (estimated).

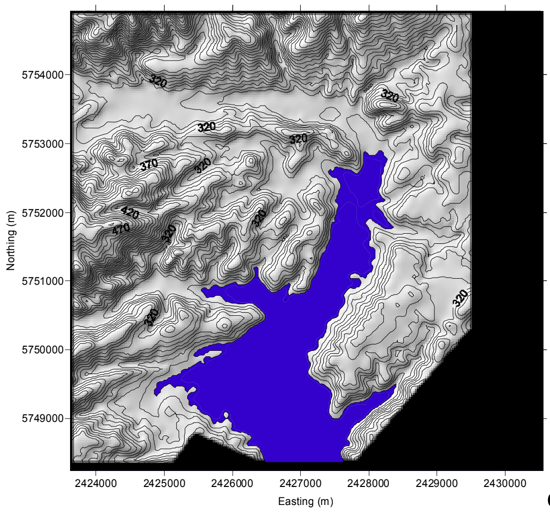
	Mass fraction (%)	
	Rakaia at SH1 bridge	**Waianiwaniwa inflow**
Sand (63 – 2000 µm)	26.7	5.5
Silt (4 – 63 µm)	37.7	48.6
Clay (<4 µm)	35.6	45.9



a) Lake Height 280 m, ~280 million m^3



b) Lake Height 263 m, ~140 million m^3



c) Lake Height 253 m, ~70 million m^3

Figure 8-1: Plan views of the Waianiwaniwa Reservoir at a) 100 % capacity, b) 50 % capacity, and c) 25 % capacity.

Sediment deposition and re-suspension

The sediment trap efficiency for the Waianiwaniwa Reservoir for long-term average inflows is estimated to be 95 % for the reservoir between 50 % and 100 % full, reducing to 90 % with the reservoir at 25 % full (Table 8-3). These estimates are based on Brune's 1953 empirical relationship (Vanoni, 1977).

Table 8-3: Sediment trapping efficiency for the Waianiwaniwa Reservoir

	Reservoir % Full		
	100%	**50%**	**25%**
Capacity/Inflow Ratio (or Residence time) (years)	1.9	0.94	0.47
Trap Efficiency (%)	95	95	90

Assuming an average bulk trap efficiency of 95 %, 24840 t of sediment would be deposited in the reservoir per year. This incoming sediment would be deposited largely in the shallow areas of the reservoir subject to periodic wetting and drying. For the predicted clay-sand-silt mix (Table 8-1), the specific weight of the depositing sediment is estimated by the Lara-Pemberton method to be 0.88 t m^{-3} (Morris & Fan, 1997). Loss of storage volume due to sedimentation is therefore expected to be approximately 28,300 m^3/year (0.028 MCM/yr).

The estimated settling time for 1-μm clay particles over an average depth of 24 m in the reservoir is 167 days. This is less than the mean residence time for water in the reservoir of 2 years, and thus clay-size particles would have time to settle in the deeper areas of the reservoir and water clarity would be expected to improve over time.

Re-suspension of sediments by wind-driven waves is not likely to be a major problem in the Waianiwaniwa Reservoir. Based on wind records from 1978-1993, the predominant winds at the Hororata Recording Station are north-westerlies and north-easterlies, with the strongest winds (>20 m/s) coming from the north-west. The Waianiwaniwa Reservoir would be fairly sheltered from north-westerly winds and the fetch in this direction would not be great (≈2 km), particularly at lower water levels (<75% full). Because of the reservoir's orientation, the greatest exposure would be to north-easterly and south-westerly winds. Moderately strong winds (10-20 m/s) can come from the south-west and north-east. South-westerlies would likely have the greatest effect on sediment re-suspension, mainly in the northern portion of the reservoir where it would be shallower.

Table 8-4 shows a NARFET analysis (Smith, 1991) of wave base-depth assuming a 20 m/s wind for one hour at 10 m above the ground for winds from the south-west, north and north-east and for the reservoir at 100 % and 25 % full. The wave base-depth gives the depth of the orbital motion of surface wind-waves. The mean depths of the reservoir at 100 % and 25 % full would be 25 and 21 m, respectively. The maximum wave base-depths for a 20 m/s wind from either the north or north-west with the reservoir at 100 % and 25 % full are estimated to be 9.4 m and 8.2 m, respectively. Since the maximum wave base-depth is less than the mean depth of the reservoir in either case, re-suspension of sediment by wind-generated waves is not expected to be significant in the deeper areas of the reservoir. In the shallower north-east end of the reservoir, re-suspension of sediment by wind-generating waves is not expected to occur when the reservoir is 100 % full, as the water depth at the north-east end exceeds the wave base-depth (Table 2-4), but it is expected to occur at this end when the reservoir is 25 % full. Some re-suspension of deposited sediments in littoral areas by wind generated waves is expected.

Table 8-4: Wave base-depth for a 20 m/s wind for 1 hour duration at 10 m above the ground for the Waianiwaniwa Reservoir.

Location	Fetch (km)	Wind direction	Wave base depth (m)	Water depth (m)
Reservoir 100 % full (WL=280 m)				
Southern shore, west of dam	4.4	NE	9.4	45
Southern shore, west of dam	4.6	N	9.3	45
North-east shore	4.6	SW	8.9	20
Reservoir 25 % full (WL=253 m)				
Southern shore, west of dam	3.7	NE	8.1	25
Southern shore, west of dam	3.6	N	8.2	20
North-east shore	3.7	SW	8.1	0

Eutrophication and Weed Growth

Eutrophication is expected to be an issue during the initial period (3-4 years) of the Waianiwaniwa Reservoir. Inundated sediments and vegetation in lakes are likely to yield large quantities of nitrogen and phosphorus and promote phytoplankton growth (Viner and White 1987).

Water quality problems in reservoirs are frequently associated with high phytoplankton production (Hoare et al. 1987). However, in the Wainiwaniwa Reservoir, it is likely that phytoplankton production would be largely limited by low light penetration. Moderately high concentrations of suspended sediments in the reservoir would scatter down-welling irradiance and reduce light penetration (Davies-Colley 1989). Based on optical properties of glacial fed lakes in South Canterbury, light extinction coefficients for the reservoirs would probably be between those of Lake Pukaki (1.56 m^{-1}) and Lake Tekapo (0.63 m^{-1}), depending on the amount of time since the last freshet. This would likely correspond to a euphotic zone (depth of phytoplankton growth, or 1% irradiance) of 3-8 m. The relatively short water residence time of the reservoir would tend to reduce eutrophication problems because of the mass export of nutrients from decomposition of vegetation and soils. Over time, nutrient levels in the Waianiwaniwa Reservoir should approach those of the source (i.e., the Waimakariri River), which would be relatively low and not support algal blooms.

It is unlikely that large rooted aquatic plants would develop to any great extent in the littoral areas because of the combined effects of low water clarity and considerable fluctuation in water levels (>5 m) seasonally. Large areas of shallow littoral habitat, such as in the sub-basins of the Waianiwaniwa Reservoir, would regularly be exposed to air from water draw-downs.

Stratification and Anoxia

The occurrence of hypolimnetic oxygen-depression in newly formed reservoirs has been well documented (Godshalk and Barko 1985; Henriques 1987), and principally it occurs because of high biological oxygen demand from decomposing flooded terrestrial vegetation and organic soils (Gunnison et al. 1985). During periods of thermal stratification, oxygen-consuming processes in bottom water can lead to oxygen depletion because stratification prevents mixing with oxygen-rich surface water. Typically, New Zealand lakes are monomictic (i.e., they mix from top to bottom once per year) and usually stratified during summer and mixed during winter (Jolly and Irwin 1975).

Hypolimnetic oxygen-depression would be expected to occur in the Waianiwaniwa Reservoir during the first few years of operation, particularly during summer. The duration of thermal stratification would be the main determinant of the extent of oxygen depression. Winds are the main force in mixing between surface and bottom layers in lakes (Green et al. 1987). The duration and severity of stratification and hypolimnetic oxygen depression are likely to be less because of the shallower depths and greater fetch. Stratification and anoxia are more likely to occur in the initial period of inundation of the valley.

Oxygen depletion is unfavourable for most aquatic organisms, and can have significant effects on water chemistry, particularly at the sediment-water interface. The extent of such effects would largely depend on the duration of summer stratification. However, given the relatively short residence time of water in the proposed reservoir, these conditions would be expected to improve with time (say after five years of operation). In the Opuha Reservoir in South Canterbury, such conditions persisted from January-April 1999, one year after the reservoir was filled (Meredith 1999), and still occur (in 2002 at the time of writing) to some extent when stratified in summer (B. Spigel, NIWA, pers. comm.).

Drying of Reservoir

It is very likely that there would be insufficient water available from the rivers in dry years, so large portions of the Waianiwaniwa Reservoir would go dry. When the reservoir would be drawn down to less than half full, greater than 5 km^2 of marginal area would be exposed (Figure 8-1). Most of these exposed areas would be in the shallow sub-basins of the reservoir, particularly the north-west corner. This may result in dust storms during strong winds, which would be a nuisance to local residents and lessen the recreational values of the reservoir. Dust storms have been reported to be a nuisance to local residents around reservoirs (e.g., Lake Tekapo) during strong northwesterlies in dry years (Kirk 1989).

Water quality for irrigation

It is recommended that water for irrigation be drawn from the epilimnion (surface layer) of the reservoir, as this would have the highest water quality during potential anoxic periods. It is likely that when stratified, hypolimnetic water, at least in the early years of the reservoir, would not be of sufficient quality for stockwater water due to relatively high concentrations of ammonia and trace metals. Should prolonged periods of stratification result in hypolimnetic anoxia, mitigation procedures such as water column destabilisation or hypolimnetic oxygenation may be required. The occurrence of anoxia can be expected to decline as water quality improves over time.

Fish populations

Sampling

A survey of the fish populations present in the Waianiwaniwa catchment was conducted in October 2002 during moderate flows and good weather conditions. From the headwaters to within the vicinity of Glentunnel, a total of 11 sites (Figure 8-2) were sampled qualitatively with the use of a backpack electric fishing machine, dipnet, and stopnet. At each of the sites, the species and numbers of fish caught were recorded. In addition, the general features of the river channel, substrates, bank conditions, habitats and relative abundance of benthic invertebrates were noted for each of the sites.

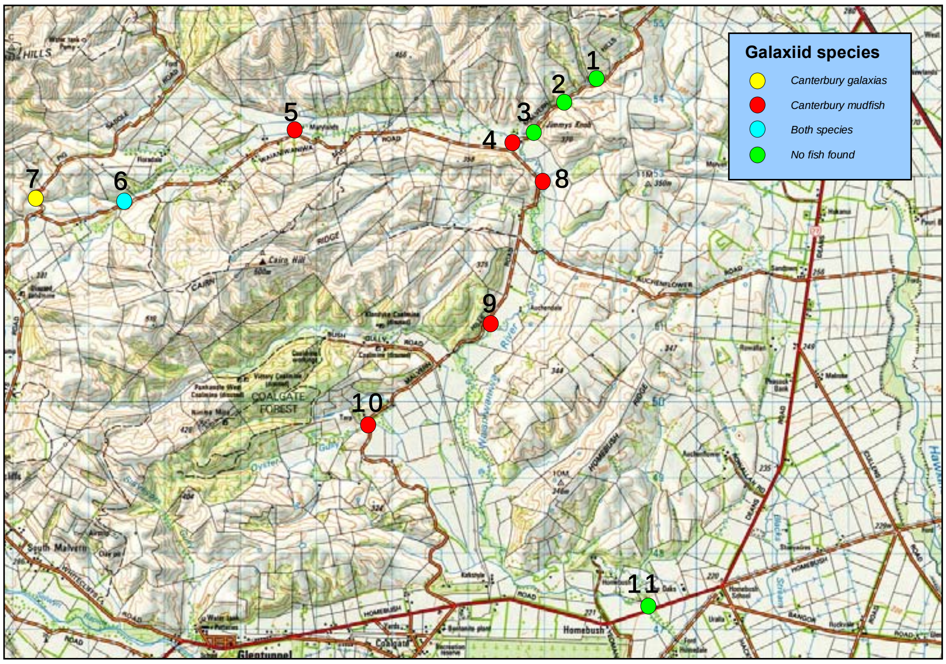


Figure 8-2: Waianiwaniwa Valley fish sampling sites, October 2002.

Results

Only three species of fish were found in the Waianiwaniwa catchment, with all of them being wholly freshwater resident – they comprised the Canterbury mudfish (*Neochanna burrowsius*), Canterbury galaxias (*G. vulgaris*) and the upland bully (*Gobiomorphus breviceps*). The upland bully was the most abundant fish, followed by the Canterbury mudfish, which was present at all but four of the headwater sites – at the uppermost site in the headwaters, only the Canterbury galaxias was found. No fish were found at the lowermost site sampled (Site 11), where the river flows onto the plains.

At three of the sites (1-3) in a headwater tributary, no fish were found. A minor population of the Canterbury galaxias was present in the headwaters (Sites 6 & 7). With the exception of Site 7, the Canterbury mudfish was found at all sites between numbers 4-10. The upland bully was present at all sites where galaxiids were found. No fish were found at Site 11 where the river enters the cobble/bouldery bed of the plains, most likely because surface flow is highly ephemeral (only during major floods).

The most significant aspect of the fish populations in the Waianiwaniwa River was the rather abundant and widespread nature of the Canterbury mudfish, a species that is on the rare and endangered list of freshwater fish in New Zealand. The species was found in all major habitats (runs, pools, riffles), although its numbers were generally greater in slow-flowing runs and pools. This widespread occurrence of the species within a catchment has not been recorded elsewhere– hitherto, the species has been recorded to occupy swampy habitats not usually occupied by other species of fish (McDowall 1990).

In order of preference the habitats were: *upper* – slow-flowing run with cobble bed and lush riparian cover; *middle* – pool ~0.6 m deep with gravel and fines on the bed and riparian grasses overhanging the banks; *lower* – shallow (0.1-0.2 m deep) and tumbling flows (~0.3-0.5 m/s) in a cobble-bedded riffle with some slack water pockets along the banks covered with a moderate growth of riparian grasses.

The Canterbury mudfish caught in the Waianiwaniwa River ranged in body length from 60-136 mm, with the larger fish found mainly in runs and pools, with some of them from riffles in which some slackwater was present along the banks or amongst the cobbles. Upland bullies of all sizes were captured with some darkly coloured males in spawning condition being around 100 mm in length. A total of four Canterbury galaxias (70-125 mm long) was found in the headwaters (Site 7) in a slow-flowing run ~0.4 m wide and 0.3 m deep, with a silt-covered bottom and an abundance of riparian grasses overhanging the banks; also, a single specimen was found further downstream in the headwaters (Site 6) – these were the only specimens collected of this species in the Waianiwaniwa catchment.

Implications of fish findings

The presence of a major population of the Canterbury mudfish in the Waianiwaniwa catchment has significant conservation value, as the species has been considered to be rare and endangered for some time (McDowall 1990). Flooding of the valley with the reservoir for the Central Plains irrigation scheme would render the habitat in the area unsuitable for Canterbury mudfish. Moreover, with inflow of water from the Waimakariri River into the reservoir, the riverine habitat upstream of the reservoir would become invaded with eels, which are a predator of the Canterbury mudfish. According to Darfield resident, Phil Deans (*pers. comm.*), a few large eels were caught in the Waianiwaniwa River a couple of years ago, indicating that a minor population exists in the catchment. To date, the only population of Canterbury mudfish that has been found to co-occur in reasonable numbers with eels is in Tutaepatu Lagoon, a water body of a few hectares in size and some 2 m maximum depth situated near the coast between Waikuku and Woodend. The reason for this unlikely co-existence appears to be due to the occasional drying out of the lagoon during severe droughts, resulting in the complete dying out of the eel population. Consequently, no large eels are present in the lagoon to be a significant threat to the mudfish population – the onset of piscivory (fish-eating) occurs at about 650 mm body length in shortfin eels (Jellyman 1989), the species most likely to be found in the lagoon. The mudfish survives drought periods by aestivating in moist, shaded microenvironments (McDowall 1990). This lagoon dried up in 1998, during which the entire population of some 2000 eels was wiped out (Glova & Hulley 1998). The lagoon also dried up in 1972 with devastating effects on the eel population (Mr R. Tau, *pers. comm.*). The findings in Tutaepatu Lagoon suggest that mudfish can co-occur with eels that have not reached the piscivorous size-threshold (i.e., ~450 mm long for longfins and 650 mm for shortfins (Jellyman 1989)) – eels that are likely to get into the Waianiwaniwa catchment are longfins because of their greater inland distribution (McDowall 1990). However, while mudfish may co-occur with eels that have not reached the piscivorous size-threshold, juvenile eels would compete for food with mudfish and as a result the abundance and condition of the mudfish population are likely to decline.

The presence of a major population of the Canterbury mudfish in the Waianiwaniwa catchment has ramifications for the Central Plains irrigation scheme. While the proposed reservoir would eliminate riverine habitat in the lower reaches of the valley, there would still be considerable riverine habitat upstream of the reservoir. Screening migrating eels from entering the intakes of the Rakaia and Waimakariri Rivers would be impractical because of the small mesh (~2 mm) required for the small elvers. Excluding eels from entering the habitat upstream of the reservoir would be very difficult, as elvers are known to get out of the water and crawl up through the vegetation and amongst the substrates along the banks during rains.

8.4.3 Social Effects

There are a number of direct and indirect social effects that would arise should a reservoir be constructed in the Waianiwaniwa Valley. These include the inundation of residences, farm properties, loss of access to properties, as well as potential loss of amenity and recreational values, and perceived risks. There will be positive effects that will arise from the reservoir and the CPWE scheme as a whole. These effects are discussed in this section.

Land Ownership and Use

Figure 8-3 shows land parcel boundaries taken from the Selwyn District Council GIS (geographic information system) cadastral database, with an overlay of the Dam and Reservoir footprints. Some 1,200 ha of land will be flooded, or included within a 20 m riparian buffer around the Reservoir. Thirty-nine land parcels will be affected, as listed in Table 8-5.

Table 8-5: Land Ownership of Waianiwaniwa Valley Properties

Map Code	Land parcel number	Land area lost to reservoir* (ha)	Road access
6	Lot 1 DP 72161	7.5	maintained
8	RS 31795	75.4	lost
9	Lot 1 DP 74641	2.6	lost
10	Lot 1 DP 16593	total	lost
11	Pt Lot 3 DP 18018	49	lost
12	RS 31795, RS 31795	12.7	lost
13	Lot 1 DP 5922	134.4	lost
14	Pt RS 19044, Section 1 SO 17477	total	lost
15	Lot 1 DP 53818, Lot 3 DP 16550	total	lost
16	Pt Lot 1 DP 16113	total	lost
18	Pt Lot 1 DP 5092	13.5	maintained
22	Pt Lot 1 DP 2898, Lot 1 DP 5426	27.7	maintained
24	Pt Lot 3 DP 16113, Lot 2 DP 16113	304	lost
25	Pt Lot 3 DP 18018	total	lost
26	Pt Lot 3 DP 18018, Lot 2 DP 18018	28.5	lost
27	Lot 1 DP 70704, RS 32347	92.5	lost
28	Lot 2 DP 23418	3.9	lost
29	Pt Lot 2 DP 16550	211.2	lost
30	RES 1872, RES 1871	total	lost
31	RS 21079, RS 21078, RS 16826, Pt RS 16825	51.4	maintained
106	Pt RS 23565	2.1	maintained
116	Lot 2 DP 43008	30.7	lost
117	Lot 2 DP 44310	20.8	lost
118	Lot 1 DP 44310	13.1	lost
119	Pt Lot 2 DP 5478	2.7	maintained
122	Lot 1 DP 83516	13	maintained
299	Lot 2 DP 354663	125	maintained
300	Lot 1 DP 354663	7.9	maintained

* Includes a 20 m riparian strip around the Reservoir margin

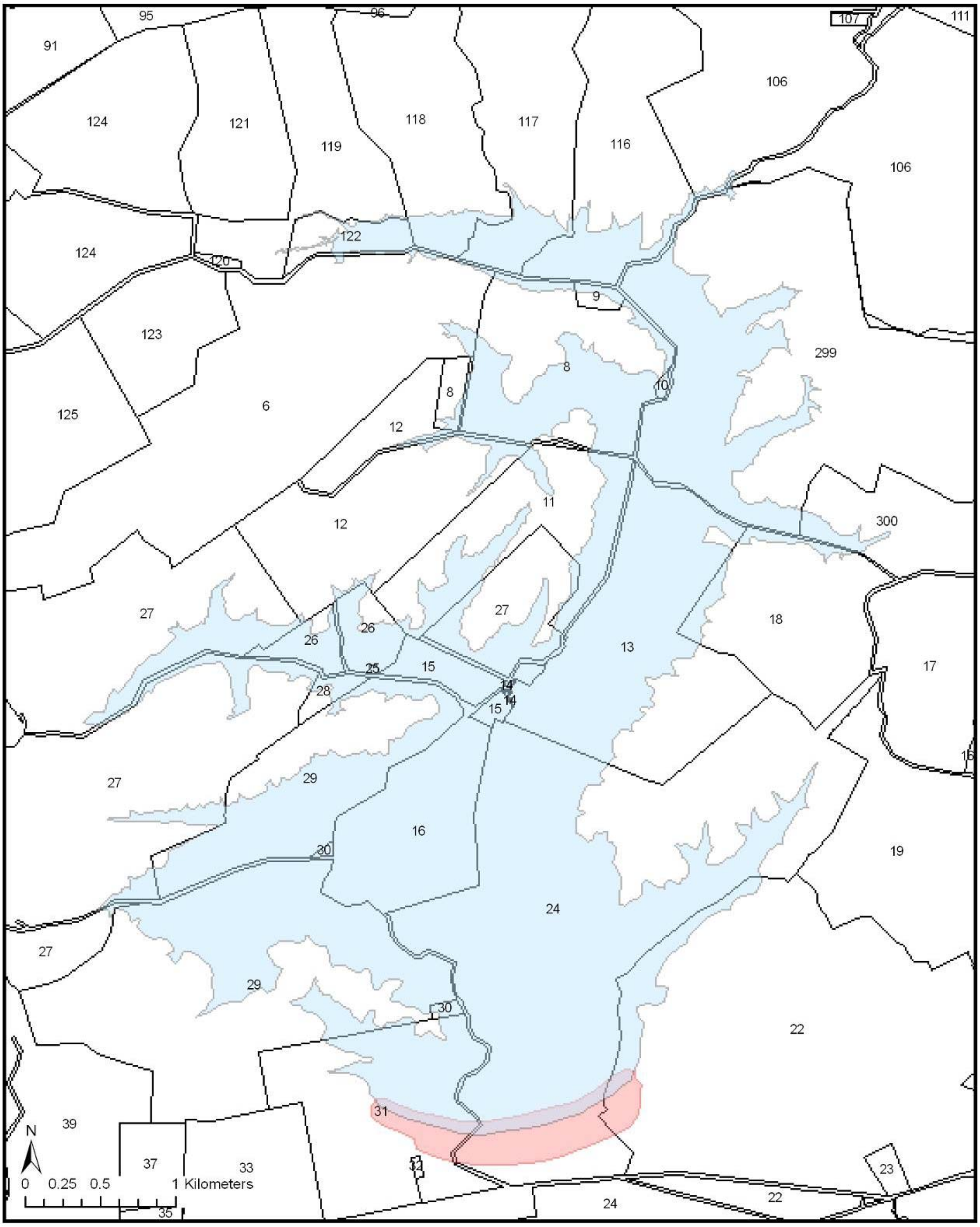


Figure 8-3: Land parcels affected by the Waianiwaniwa Reservoir

Flooded Residences

There are 12 residential buildings that will be inundated by the Reservoir, and 2 that will be ~ 300 m away from the water's edge. The location of the inundated residences is shown on Figure 8-4. The impact on the owners and occupiers will be large as there are no on-site mitigation measures available. Should the project go ahead, the only recourse would be for these residents to relocate outside of the area, and this process would involve proper compensation by the Scheme.

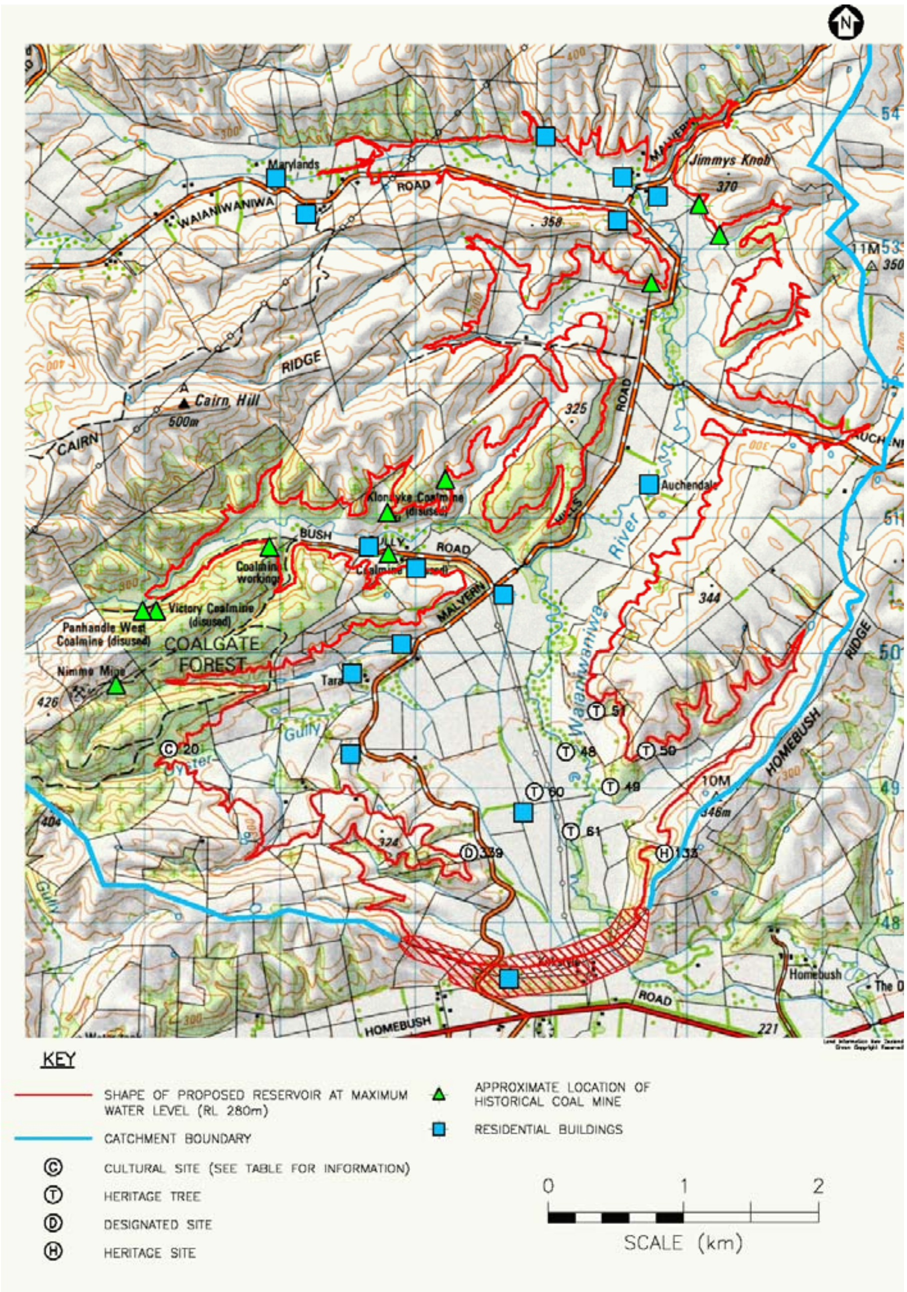


Figure 8-4: Residences, Coal Mines and Heritage Sites in the Waianiwaniwa Valley

Loss of Productive Land

With the flooding of the valley, there will be the loss of approximately 1,200 ha of agricultural land. This would be offset by the increased productivity from the land to be irrigated, such that while there is a loss of productive land, on balance the productive capacity of the Central Plains would be considerably enhanced.

Coal Mines

Coal mines were operated in the Malvern Hills throughout the late 1800's and early 1900's. The majority of mines were located in Bush Gully and in Surveyors Gully, though other mines were located where coal seams were found to outcrop. Figure 8-4 shows the locations of coal mines throughout the Waianiwaniwa Valley. The underground mining was extensive in places, particularly in the case of the Klondyke mine, which followed seams up to "1500 feet down dip" (approximately 300 m below ground level), and up to about 600 m along strike (personal communication, Ken Shearer, Canterbury Coal Ltd). Klondyke Mine was unusually extensive, and many mines were discontinued because they were overwhelmed by groundwater or because the coal seams were faulted out. In some circumstances the coal seam was found again, and mining continued. The faults responsible for displacing the coal do not have large throws as the coal seams generally follow a line of strike that is not radically offset.

The proposed dam is outside the area of coal measures outcrop and it is therefore extremely unlikely that underground mining has been carried out in the dam footprint, however coal mining has been undertaken within the reservoir footprint.

Two disused coalmines on Bush Gully Road are shown on the topographic map as being within the area that will be flooded by the reservoir. These are the Klondyke Mine at map reference NZMS 260 L35: 258-510 at 280 m asl, and an unnamed mine at NZMS 260 L35: 258-507 at ~ 270 m asl. In addition, Canterbury Coal Ltd mines coal in this area, and has a stockpile site at map reference NZMS 260 L35: 250-509 at 275 m asl. All of these sites will be flooded by the reservoir, and the operating mine facilities will need to be relocated, and alternative road access provided. Acid mine drainage from these areas could affect water quality in the reservoir, although given the likely dilution, this is not expected to cause a significant adverse effect. Fieldwork will be carried out to determine the full extent of mine flooding, and the likelihood of contamination of reservoir waters. Appropriate mitigation may need to be proposed.

Designations, Heritage and Cultural Sites

Designations are provisions within the District Plan to give effect to a specific purpose, and are provided for under the Resource Management Act 1991. Designations can be considered as an alternative to a resource consent. The designation usually relates to public works or utilities such as roads, airports, sewage treatment plants, quarries etc. Activities on the sites that have designations on them become permitted activities, provided the purpose of the activity meets with the scheduled activities for that designated site. Within the inundated area of the Waianiwaniwa Valley there is only one designated site, and that is for a quarry on Malvern Hills Road – reference D339. The location of this site is shown on Figure 8-4.

A designation may be removed by the requiring authority (Selwyn District Council) that established the designation if it no longer wants that designation under section 182 of the RMA. Removal of a designation does not require public input, and can only be removed by the requiring authority. It is important in such administrative procedures, that this process is transparent and a proper purpose is used for the removal of the designation.

A Heritage Site is one for which a Heritage Order as defined by section 187 of the RMA has been obtained, or alternately is a site defined as having special heritage values in the District Plan. A Heritage Order is a provision in a district plan that gives effect to a requirement made by a heritage protection authority. Heritage protection authorities include the Minister of Conservation, a local authority, the New Zealand Historic Places Trust in addition to a number of other bodies. Where a heritage order has been obtained, then no person may undertake any activity that would wholly or partly nullify the effect of the heritage order without prior written consent of the relevant heritage protection authority. Flooding such a site would clearly contravene the order.

There is one heritage site potentially affected by the Waianiwaniwa reservoir, and that is a bridge on the Homebush Station - reference H133. In addition to the heritage site mentioned, there are approximately 6 trees with heritage status. These heritage sites are shown on Figure 8-4.

A cultural site is scheduled within the District Plan as a site of Waahi Taonga. There is one scheduled cultural site within the inundated area of the valley, an oven – reference C20. This is listed as near Auchenflower Rd, however the planning map location of this site is not "near Auchenflower Rd". This site is shown on Figure 8-4.

The designations, heritage and cultural sites are listed in Table 8-6.

Table 8-6: Schedule of Heritage Sites affected by the Reservoir

Site No.	Description	Location & Legal Description
	Designations	
D339	Gravel Reserve (SDC)	Malvern Hills Rd, Coalgate Res 1872
	Heritage Sites	
H133	Bridge Homebush Station	Homebush Rd Lot 1 DP 2898
	Heritage Trees	
T48	*Pinus Radiata* Largest in Canterbury	Homebush Station – Lot 2 DP 16113
T49	Hemlock *Psuedohetrophylla*	Homebush Station – Lot 2 DP 16113
T50	Indian Pine *Pinus walliciana*	Homebush Station – Pt Lot 3 DP 16113
T51	*Cupressus macrocarpa* planted c. 1860 39m tall	Homebush Station – Lot 2 DP 16113
T60	Atlas Cedar *Cedrus atlantica*	Homebush Station – Lot 2 DP 16113
T61	*Cupressus macrocarpa* 52.4m tall	Homebush Station – Pt Lot 3 DP 16113
	Cultural Sites	
C20	Oven	Near Auchenflower RdLot 1 DP23595

Note: shaded rows are features that may not be affected depending on their exact location and elevation.

A Heritage Order may be removed by the heritage protection authority, in much the same manner that a designating authority can remove a designation. It is not clear however from the Plan, which of these sites have heritage orders, and which are just noted as heritage sites in the Plan as part of the Council's duties under section 7 of the RMA. This has implications in relation to their removal from the Plan. If the site is protected for heritage reasons under the Plan, then either a variation to the Plan (instigated by the Council) or a Plan change would be required, both of which would involve notification and public involvement. If the site has a heritage order, then only the relevant heritage protection authority may remove the order.

These sites do not in themselves become fatal flaws to the establishment of a reservoir in the valley. Under the District Plan, activities which impact upon such sites are not likely to comply with the permitted activity status. In general, within the rural section of the plan, activities such as earthworks, removing heritage trees, buildings, roading and utilities that impact adversely upon such sites, would become limited discretionary activities, provided no other rules are contravened within the Plan which would require a different status. Therefore in so far as these sites are concerned, the construction of the reservoir would have little significance in relation to the status of the activity under the plan.

Roading

Access to the Selwyn Plantation Board forests is at present from Bush Gully Road within the valley. Similarly access to the proposed coal mine of Kenroll Services is also from this road. An alternate route will be needed to each of these areas. There is an area of plantation approximately opposite Auchenflower Rd that also belongs to the Selwyn Plantation Board. Access through the valley will not be possible once flooded, but access into the reservoir will be available from Auchenflower Rd, Malvern Hills Rd, and Waianiwaniwa Rd from the west.

Farm properties to the north of the valley at present gain access through the valley from the south. Alternate road access would need to be provided from the west off Waianiwaniwa Rd or from the East off Malvern Hills Rd. These routes would be less direct and may result in additional transportation costs to the local farmers. See Section 8.14 for more information on transportation impacts and mitigations.

Recreation

Recreational opportunities exist for use of the reservoir as a contact recreation venue, (sailing, windsurfing, power boating, skiing, jet skiing, swimming etc.) and possibly fishing, although the filling and emptying regime will mean that access for recreational purposes will be limited during the latter part of the irrigation season, predominantly from January through to May.

There will be opportunities to provide recreational water bodies that are constantly full of water for the above activities through the careful consideration of the construction activities. The dam construction will require bulk excavation to obtain material for the dam shoulders. This provides the opportunity to take this material from downstream of the dam face, leaving behind an extensive excavation that could be developed for recreational use. A suitable location would be to the south of Homebush Road, where haul distances to the construction site and access to water from the headrace could easily be provided.

Risks to Residents

There is concern within the community in relation to dam collapse, triggered by an event such as upland flooding or an earthquake. The catchment of the Waianiwaniwa Valley is small (5,600 ha) compared to the surface area of the reservoir (1,200 ha) and the outlet capacity of the dam. The maximum probable rainfall event is able to be contained within the reservoir with a controlled outlet of up to 60 m^3/s (the capacity of the outlet for peak irrigation demand) to the Waianiwaniwa River. The outlet structure would therefore also be the overflow structure for these events. Therefore the risk of dam failure from flooding and overtopping will be negligible.

Dams in New Zealand are required to be designed to withstand severe earthquakes without breaching. In a severe earthquake, damage to the core of the dam can be controlled such that while leakage may occur, requiring the dam to be emptied quickly, a dam breach is avoided. The risks associated with any dam, while negligible, will remain a concern of any downstream residents.

See Central Plains Water Enhancement Scheme – Dam Safety Assurance Report (URS, 2006) for a fuller discussion of dam safety.

8.5 Effects on Groundwater Systems

Assessment of the effects on groundwater quantity and quality within and downgradient of the scheme area have been provided by Aqualinc Research Ltd (2005b). This is based on their Canterbury Groundwater Model (Aqualinc, 2005a) adjusted to take account of the most up-to-date information, and the specific characteristics of the Central Plains Water Enhancement Scheme. The Canterbury Groundwater Model allows both dynamic and steady-state modelling of groundwater systems, based on a comprehensive set of input data (described below). For the purposes of this assessment, outputs of a steady state model run have been used. This uses approximately 30 years of historical data on rainfall and river flows, to generate a snap-shot of how the groundwater environment would have looked had the Central Plains Water Enhancement Scheme been in operation over this time period. In this way a robust description can be developed, based on model parameters and functioning that very accurately represent the actual environmental conditions that prevail across the Canterbury Plains.

8.5.1 Overview of Data Sources

The following list summarises the data collated and transformed for developing the groundwater model.

- Topographical data
- Climate data
- Agricultural soil characteristics
- Land use
- Central Plains Water Enhancement Scheme
- Surface water data
- Geological data
- Groundwater level data

- Aquifer tests and material properties
- Groundwater abstraction data
- Hydrogeology
- Groundwater quality

Topographical Data

The land surface profile was developed from a digital elevation model (DEM) of Canterbury supplied by the National Institute for Water & Atmospheric Research (NIWA). The DEM was supplied at 30 m grid spacings and was originally generated from the 1:50,000 scale topographical maps (NZMS 260 series). Elevations of stream and stream channels were audited by NIWA, such that they were consistent with surface water flow directions.

Climate Data

For the purposes of this project, the term 'climate data' encompasses rainfall data and potential evapotranspiration data.

Rainfall Data

Annual rainfall isohyets were obtained from the Canterbury Strategic Water Study (Morgan *et al*, 2002). A map of the isohyet zones was reproduced avobe in Section 6. The discontinuity between the 650 mm and 750 mm isohyet zones along the Selwyn River was removed before the isohyets were used in developing the groundwater model.

Rainfall time series data was obtained from NIWA's climate database. There is good coverage of rainfall sites across the model domain, and individual stations were selected to represent each rainfall isohyet zone between each of the major rivers. Stations were selected for their long length of record and minimal missing data. The rainfall time series recorded at a station has been used as the time series for the isohyet zone within which it falls.

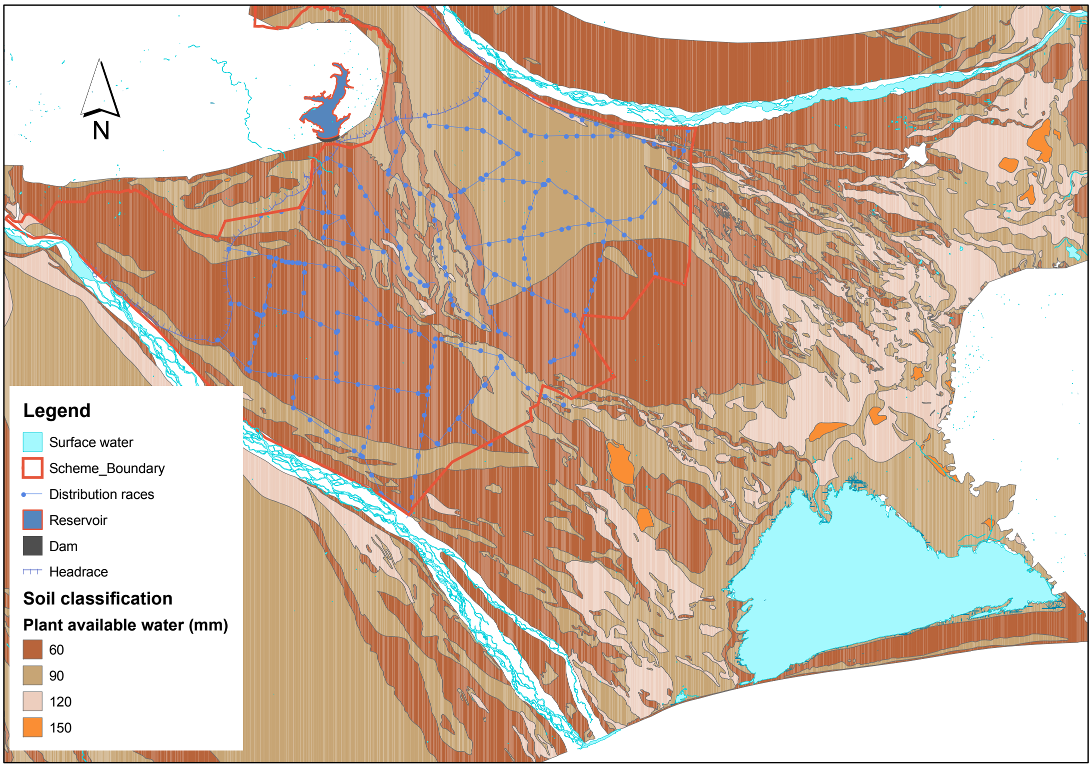
The locations of rainfall stations, and the rainfall distribution pattern across the plains were shown in Section 6.

Potential Evapotranspiration

Local meteorological data from Winchmore and Lincoln has been used to calculate PET using the Penman-Monteith equations.

Agricultural Soil Characteristics

The characteristics of agricultural soils on the Canterbury Plains are a required input for the model, and soil maps of the Canterbury Plains area were obtained from ECan. The soils database classifies all agricultural soil types into various water holding classes based on the plant available water (PAW) classification. The PAW classification was adjusted to a rooting depth of 600 mm (Morgan *et al.* (2002).The equivalent PAW classifications were further grouped into four classes, with the representative agricultural soil water holding capacities being 60 mm, 90 mm, 120 mm, and 150 mm for the mid-points



of each class. A map showing these soil water holding capacities is shown Figure 8-5.

Figure 8-5: Agricultural soil water holding capacities

Land Use

Land use is an important aspect of any groundwater model, as it is the land use and corresponding irrigation regime (if any) that determines how much land surface drainage enters the subsoils and may eventually recharge groundwater. Land use for the model has been defined for two scenarios: current (status quo) development and land use given that the Central Plains Water Enhancement Scheme is developed over 60,000 ha.

Status Quo

The status quo level of development was based on the land use as of 30 June 2002. This information was provided by Statistics New Zealand via the 2002 Agriculture Production Census (AgCensus), and supplemented by data collected from the farmer surveys. This is fully documented by Aqualinc, 2005a.

Future Development

Future development is based on Morgan *et al.*, (2002) and is the land use resulting from the proposed development, given that 60,000 ha are developed and that the available water for irrigation is in accordance with the prospectus for the Central Plains Irrigation issue (CPW, 2004).

The areas for the various land uses under the status quo situation with Central Plains Irrigation water are shown in Table 8-7. Crop land use has following rotation (equal portions of each crop type are assigned within each hydrological zone):

- Wheat
- Barley
- Peas
- Clover
- Rye grass

Table 8-7: Land uses for the Central Plains Irrigation Scheme

Land use	Status Quo areas (ha)	CPWE Scheme areas (ha)	Description
Pasture	11,000	37,000	Includes dairying and dairy support/intensive livestock.
Crop	1,500	23,000	Arable
Other	500	0	Includes lifestyle and horticulture
Dryland	47,000	0	Assumed to be dryland pasture

Irrigation water supply has been restricted for the scheme portion by a seasonal maximum take of 625 mm/year. When seasonal demand maximum is reached, demand is set to zero and land surface drainage is assigned to a dryland equivalent. There is incorporated a 10-day lag between restriction start and assigning the dryland drainage conditions in the analysis (i.e. 10 days of irrigated drainage before the dryland drainage kicks in). This is to make some allowance that the increased moisture content in the irrigated soil will increase drainage if there is a precipitation event. A 10-day period was chosen as this is the return period for the zones modelled.

Central Plains Water Enhancement Scheme

The parts of the Central Plains Irrigation scheme that have been included in the model analysis are the main headrace, the distribution races, the by-wash discharges and on-farm losses. The surface water flows are reduced at their inflow to the groundwater model to account for the takes from the Rakaia and Waimakariri Rivers.

On-farm system losses between the farm supply point and the paddock surface has been set at 5%. Irrigation uniformity coefficient has been set at 80%. Average application depths represent good practice and generate about a 17% loss to sub-surface drainage. Total on-farm irrigation losses are therefore about 22%

Main Head Race

It has been assumed that the headrace leakage rate will be 1 m^3/s distributed evenly along its length. This water has been added to the model elements that the headrace passes over, and added this to the irrigation/rainfall time series for each of these elements.

Distribution Races

An average leakage rate of 1.87 m^3/s has been assumed for the distribution network races, evenly distributed over the scheme area. This has been added to the groundwater recharge resulting from the calculated irrigation/rainfall drainage under the scheme areas.

Dam Leakage

Groundwater recharge from dam leakage has not been included as this is expected to be effectively zero.

By-wash Discharge

Constant by-wash discharge of 2 m^3/s is assumed. This was partially distributed between 6 discharge points (six discharges, 1/6 of 1 m^3/s) along the Selwyn River. The discharges of 1 m^3/s near the Waimakariri and Rakaia rivers have been ignored due to their small size in relation to the flow in the rivers at these points.

Changes in Surface Water Flows

In the groundwater model, the surface water flows in the Rakaia and Waimakariri Rivers need to be reduced to account for the takes supplying the CPWE Scheme. This was done by subtracting the time series of proposed takes from the inflows to the groundwater model. The locations are so close to the proposed sites for the takes that it is not expected to affect the accuracy of the model simulations. The time series of takes were supplied by URS for the period supplied from 1967 to 2001, and extended to cover 2002-2005 by assigning the average for a particular day calculated from that particular day's take from the 5-year period 1996-2000.

Surface Water Data

For the purposes of this study, surface water data refers to measurements of flows in rivers, streams, drains and springs. An overview of the data sources used in building the groundwater model will be given. Daily average stream flow data was obtained from Canterbury Regional Council and NIWA. Data has been collected from a number of sites, including automatic recorder sites (14) and manual stream gaugings (30). These data are used to calibrate the model (ie demonstrate that it simulates accurately). However, some of it is also used as inputs where surface water flows into the area modelled.

Streambed Invert Levels

One of most influential factors in determining the interaction of surface water features with groundwater is the elevation of the invert of the stream bed. Bed invert elevations (above mean sea level) for most of the streams in the model domain have been taken from the DEM. There are only a few actual measurements of bed invert elevations available for Canterbury streams. This data, obtained by Canterbury Regional Council from the Ashburton River (89 readings), and Waimakariri River (63 readings)

Bed Roughness

The stream package uses Manning's formula to calculate stream stage height and resulting flows. A bed roughness factor of 0.035 has been used for all streams, which is the roughness factor for earth with stones or weeds presented in Table 5.2 of Streeter and Wylie (1983).

Stockwater Distribution Schemes

Groundwater recharge from stockwater has been incorporated into the analysis of the effects on the groundwater system. The main stockwater takes between each major river have been summed and distributed evenly over the land surface. The total stockwater take has been reduced by 10 % to allow for the water consumed by stock and evaporation losses as suggested by Taylor (1996). The remaining stockwater take has been assumed to drain to groundwater evenly over the zones, within which it is taken and distributed. This recharge has been assumed to be continuous all year round and as such has been converted to a depth per unit area per unit time and directly added to the land surface recharge calculated under rainfall, irrigation and Central Plains Water recharge. Table 8-8 summarises the stockwater portion of the takes and the calculated groundwater recharge rates. Some of these takes have an irrigation component, which is accounted for in the analysis when irrigation is applied and percolation to groundwater is calculated.

Groundwater Abstraction Data

To simulate transient groundwater levels, groundwater abstraction (pumping) must be included in the model. There are various uses for groundwater. The two greatest abstractive uses of groundwater in Canterbury are irrigation and municipal supply. However for completeness, stockwater and other consented non-irrigation takes as well as permitted takes are included in the model, and hence in the analysis of effects on the groundwater environment. However, compared to the volume of water abstracted for irrigation and for the Christchurch city, rural domestic and stockwater takes are small and sparsely distributed.

Irrigation Takes

Irrigation is the largest abstractive use of groundwater in Canterbury and is likely to remain so. Irrigation demand in the model has been calculated using a crop-soil water balance model. The irrigation takes are for consents granted up to 30 June 2002.

Table 8-8: Stockwater takes and resulting groundwater recharge

Scheme or river	Intake	Take rate (ℓ/s)	Comment on source of data
Waimakariri-Selwyn zones			
Paparua	Waimakariri	1,300	1,300 ℓ/s for stock only; (Kerry Harrison, Selwyn District Council, *pers. comm.*).
Malvern	Kowai Upper	500	500 ℓ/s from LE (1999) and Neal Borrie (Aqualinc, *pers. comm*.); max rate of 900 ℓ/s consented, but estimate of actual take used.
	Kowai Lower	130	130 ℓ/s from LE (1999) and Borrie (*pers. comm*.); max rate of 300 ℓ/s consented, but estimate of actual take used.
	Bishops Creek	50	50 ℓ/s from LE (1999) and Borrie (*pers. comm*.); max rate of 500 ℓ/s consented, but estimate of actual take used.
	Waimakariri	374	374 ℓ/s from LE (1999) and Borrie (*pers. comm*.); max rate of 700 ℓ/s consented, but estimate of actual take used.
	Spring source	60	60 ℓ/s from LE (1999) and Borrie (*pers. comm*.)
	Selwyn River	156	156 ℓ/s from LE (1999) and Borrie (*pers. comm*.); max rate of 250 ℓ/s consented, but estimate of actual take used.
	Total	**2,570**	**Resulting recharge rate = 0.117 mm/day**
Selwyn-Rakaia zones			
Ellesmere	Rakaia at Te Pirita	732	732 ℓ/s for stockwater component (Borrie, pers. comm.).
	Rakaia at SH1	500	Old take of 566 ℓ/s LE (1999) not utilised fully (Borrie, pers. comm.); hence adjusted to 500 ℓ/s to approximate actual take.
	Hororata	283	283 ℓ/s from LE (1999) and Borrie (pers. comm.); max rate of 500 ℓ/s consented, but estimate of actual take used.
Selwyn	Selwyn	93	93 ℓ/s from LE (1999) and Borrie (pers. comm.); max rate of 95 ℓ/s consented, but estimate of actual take used.
Total		**1,608**	**Resulting recharge rate = 0.102 mm/day**

Municipal Takes

Compared to irrigation takes, rural domestic takes are considered small and sparsely distributed. However, the Christchurch city abstracts a considerable amount of water for domestic, commercial and industrial use. All consented municipal takes are included in the analysis for completeness.

Specific water use data was obtained by Morgan *et al.*(2002), and included an approximation of the seasonal demand for Christchurch City. A minor amount is abstracted by other users within Christchurch, which has not been considered.

Hydrogeology and Groundwater Water Quality

The hydrogeological and groundwater quality characteristics employed in the groundwater model have been described above in Section 6. The groundwater model is not used to simulate water quality.

8.5.2 Assessment of Effects on the Groundwater from Changed land Use

The effects from the scheme on groundwater can be divided into 2 categories: affects on the amount of groundwater (quantity) and affects on the quality of the groundwater (quality).

The primary concerns with respect to groundwater quantity are due to changes in water levels due to the altered hydrologic regime, this includes both decreases and increases in groundwater levels.

The primary concerns with respect to groundwater quality are due to changes in concentrations of substances and microorganisms due to the altered behavior on the land surface (changes in land use).

Groundwater Quantity

The impact on groundwater quantity needs to be divided up into categories. There are impacts on:

- Groundwater levels for shallow and deep aquifers; and
- Base flow discharges to surface water bodies (i.e. Selwyn River).

The effects on Groundwater quantity are based upon groundwater model simulations with the Canterbury Groundwater Model (Aqualinc, 2005a). The model inputs are modified to account for the operation of the proposed Central Plains Water Enhancement Scheme. The analyses are steady-state in nature, where all inputs are based on average conditions for the period from 1967 to 2004. This includes irrigation demand that is averaged across the year.

The Canterbury Groundwater Model is calibrated as documented in Aqualinc (2005a), and Figures 8-6 and 8-7 show the robustness of the calibration. It is interesting to note that the groundwater model is reasonably accurate in predicting the amount of variability or change in the system under different stresses, although there is under estimation of variability for large (greater than 10m) variations in head. Figure 8-7 shows a fair amount of scatter, however this is reasonably evenly distributed on both sides of the 100% regression line. Furthermore one would expect the groundwater model to slightly underestimate variability as the model does not include quickflow and other direct runoff mechanisms. These calibrations are important as they show that the model can accurately simulate the amount of change that may occur if the Central Plains Water Enhancement Scheme is established.

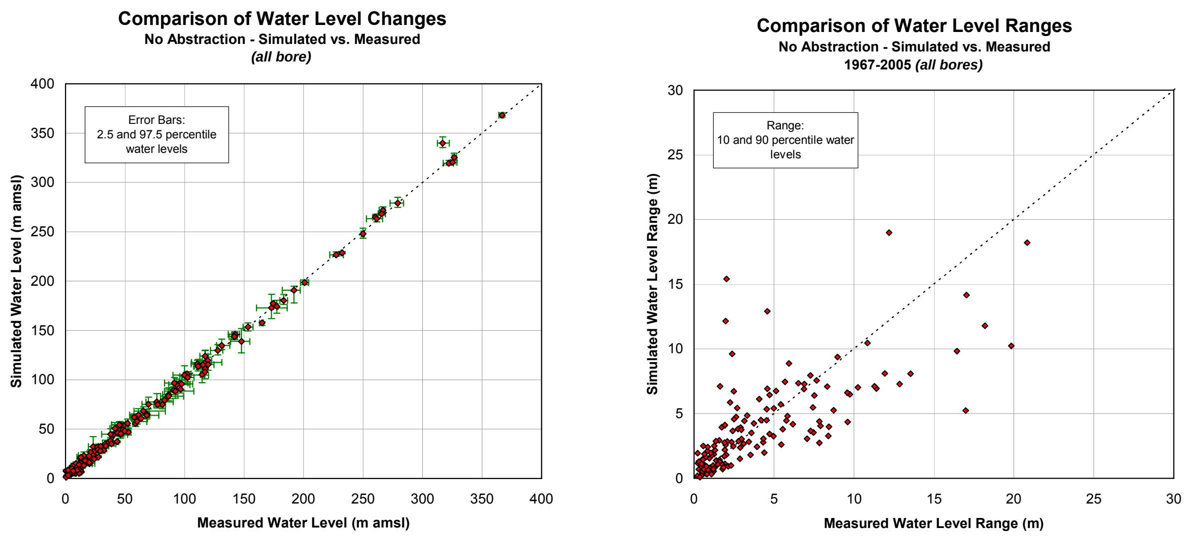


Figure 8-6: Observed versus simulated head in the groundwater model, as well as the range of variation for simulated and observed.

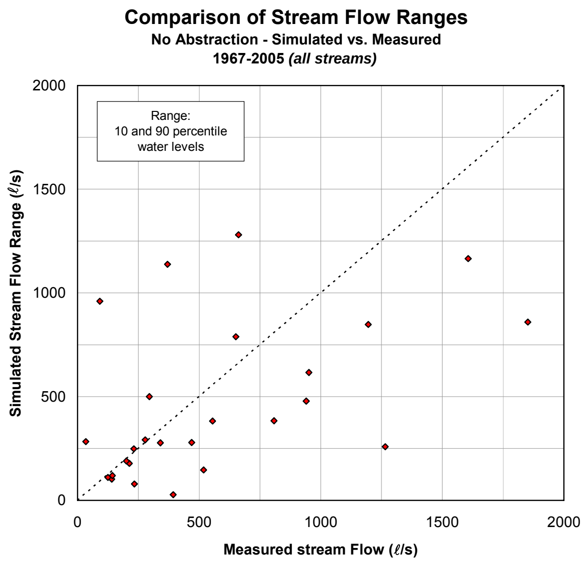


Figure 8-7: Observed versus simulated variation in stream flow in the groundwater model

Groundwater Levels

The change in groundwater levels is determined via a steady-state simulation with the Canterbury Groundwater Model. This calculated the average state of the environment where the system inputs are averaged over the entire period of interest, and a constant land use is assumed. The assumed land use was taken to be the status quo land use as at 1st July 2002, except for the CPWE Scheme area which was assumed to have land use as shown in Table 8-7.

Groundwater levels are modelled to increase substantially in the areas where CPWE Scheme water is applied. Figure 8-8 shows the increase in groundwater levels based on the steady state conditions, and indicates an increase of up to 20 m in upper aquifers. This is a significant increase, although most of it is in areas where the depth to the water table is large.

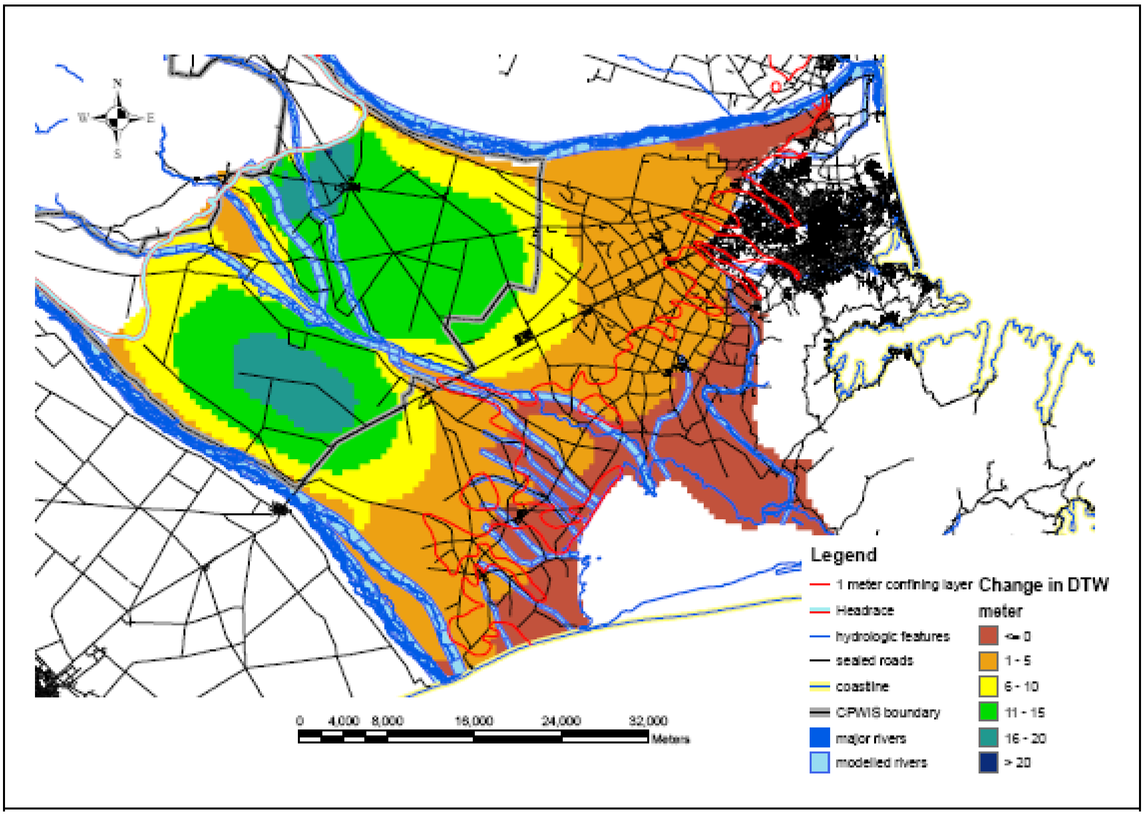


Figure 8-8: Change in groundwater levels resulting from the Central Plains Water Enhancement Scheme

Figure 8-9 shows the steady-state piezometric contours resulting from the CPWE Scheme. This can be compared to the status quo situation described above in Section 6 (see Figure 6-5). Along the Waimakariri River and Waimakariri Plains the CPWE Scheme simulation is little different from the present status quo simulation aside from the general increase in groundwater level. However, the Rakaia Plains, and Rakaia River areas are different under the CWPE Scheme, as this area will experience greater increase in groundwater levels (Figure 8-8). There is a smaller fall in water table level away from the Rakaia River indicating decreased loss of water from the river to groundwater flow. The notches in the piezometric contours along the lower Selwyn River are more marked under the CWPE Scheme simulation, indicating increased baseflow to the Selwyn River. Further details on baseflow changes in the Selwyn River and other streams are given below.

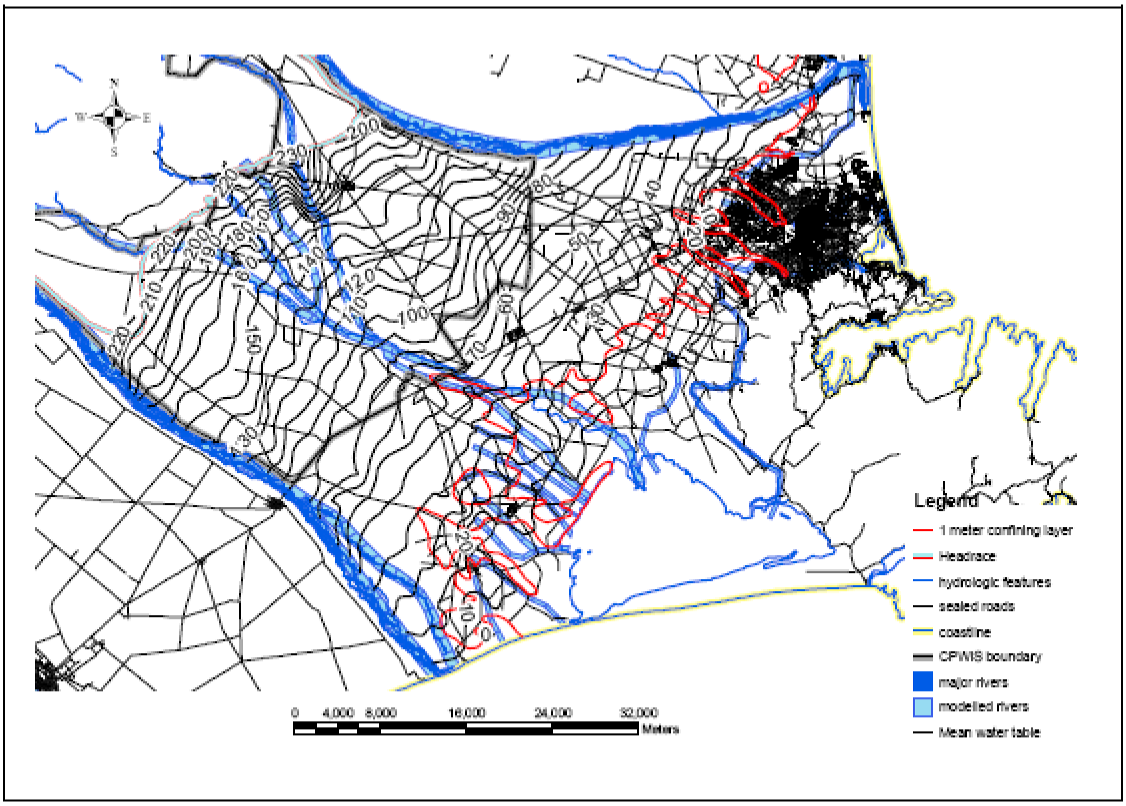


Figure 8-9: Mean piezometric surface (water table) with the CPWES averaged over all time. (Compare with Figure 6-5)

Base Flow Discharges

There is a substantial increase in groundwater inflow to the lower plains streams and rivers (Table 8-9). The Selwyn and Irwell Rivers and the Hamner Drain all have significant increases in base flow. Birdlings Brook and Wakauni Creek show moderate increases in baseflow.

Table 8-9: Changes in average base flow for selected rivers

River and location	Increase or decrease	Qualitative change*
Hinds River @ Boundary Rd (12 km from Mouth)	Increase	About zero
South Ashburton River @ Valetta (23 km from Confluence)	Increase	About zero
Ashburton River @ SH1 (18 km from Mouth)	Increase	About zero
Selwyn River @ Coes Ford (6 km from Mouth)	Increase	Significant
Wakanui Creek @ Elgin/Innes Rds (10 km from Mouth)	Increase	Moderate
Wakanui Creek @ Christys Rd (7 km from Mouth)	Increase	Small
Wakanui Creek @ Chertsey Rd (3 km from Mouth)	Increase	Small
Wakanui Creek @ Mouth	Increase	About zero
Waianiwaniwa River @ Confluence	No change	About zero
Tent Burn @ Brooklands Farm (2 km from Mouth)	Increase	Small
Waikekewai Creek @ Mouth	Increase	Small

River and location	Increase or decrease	Qualitative change*
Birdlings Brook @ Feredays Rd (Near Top)	Increase	Moderate
Birdlings Brook @ Clarks Rd (4 km from Mouth)	Increase	Small
Harts Creek @ Clarks Rd (5 km from Mouth)	Increase	Small
Harts Creek @ Timberyard Rd (1 km from Mouth)	Increase	Small
Doyleston Drain @ Weir (1 km from Coast)	No change	About zero
Boggy Creek @ Irwell/Rakaia Rd & Rountrees (Near Top)	Increase	Small
Boggy Creek @ Caldwells Rd (7 km from Mouth)	Increase	Small
Boggy Creek @ Leeston-Christchurch Rd (4 km from Mouth)	Increase	Small
Boggy Creek @ The Lake Rd (1 km from Mouth)	Increase	Small
Hanmer Drain @ Stewarts & Caldwells Rds (Top)	Increase	Significant
Hanmer Drain @ Leeston-Christchurch Rd (4 km from Mouth)	Increase	Significant
Hanmer Drain @ The Lake Rd (1 km from Mouth)	Increase	Moderate
Irwell River @ Rakaia-Selwyn Rd (14 km from Mouth)	Increase	Significant
Irwell River @ Brookside-Burnham Rd (9 km from Mouth)	Increase	Significant
Irwell River @ Leeston-Christchurch Rd (4 km from Mouth)	Increase	Significant
Irwell River @ The Lake Rd (1 km from Mouth)	Increase	Significant
LII @ Moirs (Near Top)	Increase	Small
LII @ English Bridge (6 km from Mouth)	Increase	Small
LII @ Pannetts Rd (3 km from Mouth)	Increase	Small
LII @ Wolfes Rd (1 km from Mouth)	Increase	Small
Halswell River @ Ryans Bridge (9 km from Mouth)	Increase	Small
Heathcote River @ Buxton Tce (6 km from Coast)	Increase	Small
Avon River @ Gloucester St Bridge (12 km from Mouth)	Increase	Small
Styx River @ Radcliffe Rd (9 km from Mouth)	Increase	About zero

*Classes defined as: <5 % change = about zero; 5-50 % = small; 50-100 % = moderate; >100% = significant

Summary

This analysis of effects on steady state groundwater quantity conditions from the changed land uses due to the operation of the Central Plains Water Enhancement Scheme may be summarised as follows.

- Groundwater levels will increase West of State Highway 1; and
- Base flow discharges to surface water features within the scheme area as well as down gradient of the scheme will increase.

Groundwater Quality

The loading of the groundwater system with NO_3-N will increase with the development of the Central Plains Water Enhancement Scheme. This is to be expected given the change from low intensity to high intensity agricultural land uses. At the same time the water quantity that is carrying this increased loading will also increase. However, for the purpose of the groundwater modeling done for this assessment, it has been assumed that no mitigation measures will be put in place and this will provide a conservative basis for interested parties to determine their position on this issue.

Groundwater quality concerns focus on 3 primary areas:

- Increased nutrient leaching of NO_3-N and phosphorus (P)
- Increased leaching of pesticides (*sic* insecticides, pesticides and fungicides)
- Increased concentrations of microbes migrating to the groundwater table

Nutrients

Nutrients (N and P) are leached in different quantities from the two main types of land uses expected under the change in land use if the Central Plains Water Enhancement scheme is developed. Table 8-10 shows a summary of leachate concentrations for four different land uses. Cropping generally has a substantially higher leachate concentration for NO_3-N than grazing (MAF, 2000).

Previous work shows that leachate concentrations under grazed pasture is on the order of 12 g/m^3 (Monaghan *et al.*, 2000; MAF, 2000). The leachate concentration is more or less independent of leachate volume for a fixed application practice. In this report a leachate concentration of 12 g/m^3 is assumed for land with cattle (V Bidwell, Lincoln Environmental, *pers. comm.*).

In Table 8-10 dryland land use is assumed to be grazed pasture. If solely sheep were used for dryland agriculture the NO_3-N concentration would be lower. Other land uses (such as lifestyle blocks) are assumed to be driven at a lower intensity than standard commercial agricultural ventures. Aqualinc does not consider effects from septic tanks etc. associated with lifestyle blocks. Note that the "other" land use category is a very small percentage of the total land in question.

Table 8-10 NO_3-N concentrations in leachate from different land uses as used in determining present and future average nitrate concentrations in the aquifer system

Land use	Nitrate-N leachate concentrations non-irrigate (g/m^3 or mg/ℓ)	Data source	Nitrate-N leachate concentrations for CPWES (CFR, 2005) (kg/ha/y)
Pasture	12	Monaghan *et al.* (2000), MAF (2000)	Average 5 Range 3-12
Arable	28	MAF (2000)	Average 44 Range 17-81
Other	6	Half of pasture and roughly the same as sheep	
Dairy	12	Monaghan *et al.* (2000)	Average 32 Range 20-45

In the analysis for the effects on groundwater, a status quo land use ratio has been assumed (e.g. dairy versus arable) similar to what is expected under the CPWES, though only on 24,000 ha, which is the approximate irrigated area as of July 2005.

For the remaining approximately 36,000 ha, grazing with sheep has been assumed (leachate concentration of 6 g/m^3). The analysis for the effects from nitrates is based a 60:40 (dairy:arable) mix of land uses. The amount of nitrates leached from the soil profile is based on CFR (2005) analysis. The analysis shows approximately a doubling in the amount of nitrates that are leached to the groundwater system – 1.4 to 1.9 million kg nitrate-N per year prior to the CPWES versus 3.7 to 3.9 million kg nitrate-N per year with the CPWES. At the same time, there is an increase in land surface drainage as well as an increase in groundwater table; both of which help to dilute the concentration of the nitrates.

The average yearly concentration of nitrate-N that will be in the land surface drainage across the entire 82,000 ha within the scheme boundary (60,000 ha plus 22,000 ha) after the CPWES is developed is on the order of 6.5 to 7 g/m^3. The estimate of the status quo land surface concentration is on the order of 5 to 5.5 g/m^3.

A key factor in determining the future concentration is the mix of arable and pastoral land uses. Figure 8-10 shows a sensitivity analysis for the land surface drainage concentration as a function of the percentage of land that is in arable cultivation; for comparison, the figure shows our estimate of the current drainage concentration, the MAV for nitrate-N, as well as the design case for CPWES.

Naturally, it is more important to determine what the resulting concentration of nitrate-N is in the groundwater. It is assumed that all the nitrate-N remains in the upper aquifer. This will be the case, as model simulations do not show a change in direction for the hydraulic gradient between the upper and second aquifers when comparing the status quo versus the CPWES developed scenarios.

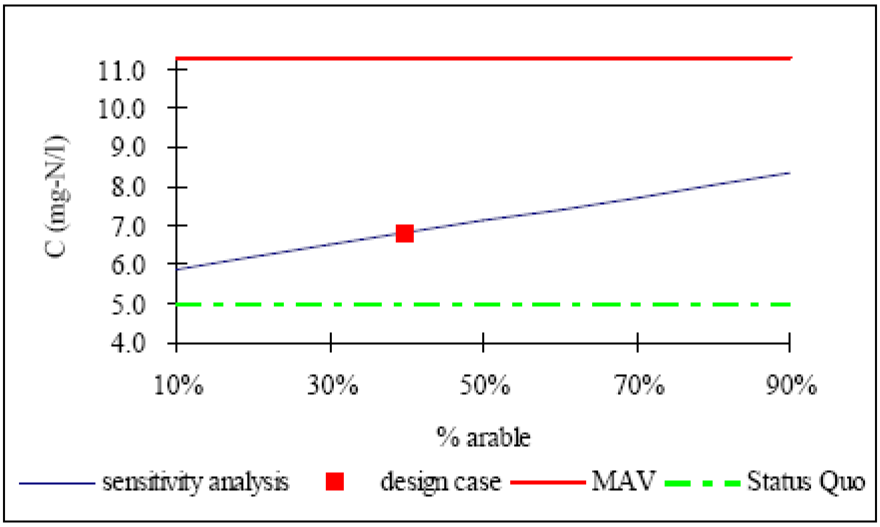


Figure 8-10: Sensitivity analysis of the leachate concentration of nitrate-N as a function of the amount of arable land within the CPWES 60,000 ha

The predicted estimate for the mean groundwater concentration of nitrate-N after the development of the CPWES is 2½ g/m^3 higher than the observed mean (6.8 g/m^3 versus the observed 4.3 g/m^3). This is in uppermost aquifer, as no effects are expected to reach the deeper aquifers.

The Scheme may also result in an increase in phosphorus leached to groundwater. However, phosphorus is not a known problem associated with cropping or diffuse dairy activities in New Zealand. Monoghan *et al* (2000) found very low concentrations of phosphorus leaching from paddocks associated with agriculture in New Zealand, and the concentrations of phosphorous observed in groundwaters in Canterbury support this thesis. Therefore, there are not expected any adverse affects on the groundwater associated with phosphorous.

Pesticides

The observation for Canterbury is that pesticides are generally not a significant problem for groundwater quality. The highly aerated groundwater system is ideal for the decay of most modern pesticides.

Microbes/Pathogens

Microbes and pathogens have a relatively short lifetime in the groundwater system. Given the travel times from the irrigated land under the Central Plains Water Enhancement Scheme to significant potable water extraction sites, it is highly unlikely that microbes or pathogens will be a significant risk for water quality.

Given the relatively rapid die-off rates of pathogens in groundwater, and the relatively slow rate of groundwater movement, it is unlikely that viable micro-organisms will travel more than a few hundred metres downgradient from their sources.

8.5.3 Conclusions

There will be a substantial change in land use associated with the shift from dry land farming to agricultural practices when irrigation water is available under the Central Plains Water Enhancement Scheme, and this will impact on the groundwater system. In this work the irrigation practice assumes the use of current best practice based on spray irrigation. The impacts on the system are primarily in the form of increased groundwater levels and increased nitrate loading.

The analyses presented here build upon assumptions regarding changing land use outlined in the Canterbury Strategic Water Study (Morgan *et al.*, 2002). The analyses are steady state; that is, represent the average change in state of the system, given that the climate is similar to what is observed for the period from 1967 to 2005 inclusive.

Groundwater levels will increase by up to 20 m in some areas. Significant increases in groundwater levels are limited to northwest from State Highway 1. The increased groundwater levels will cause an increase in the baseflow component of a number of rivers and streams. The Selwyn (Waikirikiri) and Irwell rivers have significant increases in baseflow.

Groundwater quality will be affected as a result of implementing the Central Plains Water Enhancement Scheme due to the predicted increase in the amount and concentration of nitrates in the groundwater system. There is not expected to be a significant effect on groundwater quality due to other potential pollutants.

The basis for the determined increases in nitrate-N are derived from MAF (2000). Nitrate-N loading of the system is expected to increase roughly 70 % which will result in an increase of approximately 2 g/m^3 in the average groundwater concentration. The increase in water table produces an increased dilution of the nitrate-N that is leached from the agricultural soils. Some of the high observed concentration of nitrate-N are in areas that may not be significantly affected by the proposed scheme and others may be a result of local impacts not attributable to broad-acre farming practices. But, lacking contaminant transport analyses the most robust analysis is to assume a uniform increase.

It is important to note that these analyses are based on an assumption of a continuation of present irrigated farming practices and make no allowance for available mitigations, should they be required. See Section 9.5.8.

8.6 Christchurch City Groundwater

Christchurch City draws its water supply from aquifers beneath the city, and the Proposed Natural Resources Regional Plan has a number of provisions designed to protect this resource. It is necessary to assess whether the CPWE Scheme will affect the City's groundwater supplies.

Hayward (2002) shows that the flow direction of groundwater beneath Christchurch is east-southeast to southeast, with recharge from Waimakariri River drainage and rainfall on the plains. The draft Christchurch Groundwater Recharge Zone Map (http://www.ecan.govt.nz/NR/rdonlyres/AD1CD5C9-5DF3-4AB7-B73D-C6A16D6C34E6/0/GroundwaterRechargeZonesAmendments050527.pdf) shows that there is a small area of overlap between the Scheme area and the Christchurch Groundwater Recharge Zone. This ~9.5 km^2 area is bounded to the north and south by the Waimakariri River and Halkett Road respectively; and to the west and east by Intake/Station Roads and Calders/Thompsons Roads. Races D1 and D3 will traverse this area, and there will be a bywash wetland and emergency discharge point to the Waimakariri River. In addition, there are two shareholders in the Scheme here, whose land occupies ~ 50 % of the area, although it is not known whether they will actually irrigate this. The bywash discharges and water use on the land have the potential to affect the Christchurch Groundwater Recharge Zone.

From the flow lines and sources of groundwater shown by Hayward (2002, Figure 1-3), groundwater sourced from this part of the recharge zone flows southeast towards West Melton, Templeton, and Halswell. It rises back to the surface in springs that feed the headwaters of the Heathcote River. The dominant source for this groundwater is the Waimakariri River, with some rainfall contribution. This area falls along the boundary between the Christchurch-West Melton groundwater zone, and the Central Plains groundwater zone (see Figure 52a in Brown and Webber, 2002), and water here does not flow beneath the City.

The modelling study of Aqualinc (2005b) showed that the CPWE Scheme will result in a small increase in flow in the spring-fed rivers that drain through Christchurch (The Avon and Heathcote Rivers, see Table 8-9 above). From the groundwater flow lines shown by Hayward (2002) the Avon River is unlikely to receive any water directly from the Scheme area, and the increased flow will be due to a pressure effect related to the increase in groundwater level. The small increase in Heathcote River flow may in part be Scheme water, although this will be a very small proportion given the peak irrigation rate on all the affected land will be only 200 L/s, and much of this will be used by plants and not contribute to groundwater. The bywash water from Race D3 would contribute 0.8 m^3/s in this area, via soakage through a wetland.

The selection of aquifers used to supply the city's water provides a further safeguard for the quality of Christchurch's drinking water. The city draws its water from either areas east of the zone potentially affected by the scheme's water, or in areas where the scheme could potentially affect the water, predominantly from deeper aquifers below the level that could be impacted by the scheme.

It can be seen that the CPWE Scheme will have a small positive effect on Christchurch groundwater by increasing flow through this system, and water quality is unlikely to be affected as groundwater flow paths only touch the fringes and the shallow aquifers in areas where the city draws its water.

If as a direct consequence of the Scheme, any drinking water supply wells are affected such that they fail to meet the New Zealand Drinking Water Standards, CPWL will provide an alternative supply that meets that standard.

8.7 Effects on Biological Environments

This section assessing effects on the biological environment has been provided by Kingett Mitchell Ltd, and is based on information available prior to the final collation of the AEE. It is therefore of an indicative nature at this stage, and may be refined as more information becomes available.

8.7.1 Terrestrial Ecology

Overall the effects on the Central Plains terrestrial environment, in relation to the inherent habitat values and sensitivities, are considered to be low and with positive outcomes for wetland and riparian habitats in association with appropriate mitigation.

The effects of construction and use of intake and discharge structures, and canals and races is expected to be minor and temporary, as affected habitats are already highly modified and have low sensitivities to disturbance. Localised riparian and wetland vegetation losses along the Waimakariri and Rakaia Rivers, and existing water races are considered minor, and can be mitigated and the habitat enhanced with site restoration. Bird breeding habitats have the potential to be disturbed during construction by vehicle movements, and will be surveyed prior to construction and mitigation options (e.g., translocation, and consideration of timing of works in relation to breeding seasons) considered.

Inundation and use of the Waianiwaniwa Valley storage reservoir will cause permanent loss of riverine and riparian ecosystems of low natural value, and loss of some cultural and heritage sites. Large areas of exposed lake bed, susceptible to animal and plant pest populations, will develop in response to seasonally fluctuating lake levels. Riparian and wetland habitat creation and enhancement would reduce the level of those effects and provide wetland habitat for birds and other terrestrial animals.

Increased surface flows and groundwater availability due to greater irrigation of the Scheme area will enhance both indigenous and exotic plant growth in riparian and wetland habitats within the Scheme area and lower plains waterbodies provided stock are excluded and invasive weeds (especially willows) are controlled. This enhancement effect is expected to be minor in the Scheme area and lower plains waterbodies towards the Waimakariri and Rakaia Rivers but more significant in the wetland and riparian ecosystems associated with the lower Selwyn and Irwell Rivers. Sites of natural significance, avifauna habitats and other terrestrial ecosystems will either be unaffected or will benefit from increased water availability effects.

Nutrient increases in surface flows and groundwater will have a neutral or minor positive effect on riparian and wetland vegetation growth. Controls on weed species may be necessary and some smaller channels may clog with excessive vegetation; although given the current high nutrient levels in most waterbodies in the area, this effect is considered minor.

The effects of increased freshwater and nutrient inputs on Lake Ellesmere are considered minor in relation to the existing pressures on the lake environment (e.g. intensive agriculture adjacent to the lake, and artificially regulated lake levels). Riparian and wetland plant community distributions may vary initially in response to local salinity fluctuations but vegetation extent is not expected to change.

8.7.2 Instream Habitats

The operation of the scheme has the potential to affect instream and aquatic habitat through the diversion, damming and discharging of water and through landuse intensification.

The operation of the Waianiwaniwa Reservoir will have a significant effect on the habitat quality provided within the reservoir. The proposed operating range (up to 11 m in a typical year) will result in the exposure of large areas of the reservoir bed, which will reduce the quality and availability of littoral (edge) habitat.

The existing flow of the Waianiwaniwa River may be maintained by releasing water from the reservoir. If this does occur then any effect of the damming of the Waianiwaniwa River on the quantity of instream habitat downstream of the dam is expected to be minor.

Water from the Rakaia and Waimakariri Rivers, and the new reservoir will result in the creation of instream habitat within the canals and water races. It is expected that the instream habitat that will develop in the canals and water races will be similar to that of the Rangitata Diversion Race and existing water races respectively; which is generally a suitable habitat for healthy aquatic ecosystems. The creation of the canal and water race network is regarded as a positive affect in terms of creation of new aquatic habitat within the Scheme area.

Operational bywash discharges have the potential to be used to create or enhance the existing riparian wetland aquatic habitat within the Scheme area. The creation or enhancement of wetland habitat is regarded as a positive effect. Infrequent emergency bywash discharges are not expected to have significant adverse effects on instream habitat within the receiving environment (Rakaia, Waimakariri and Selwyn Rivers) and any effects (e.g., scour or sedimentation) will be short-lived. Any effects on habitat would be greater in the Selwyn River than in the two braided rivers, due to their relative size.

Effects associated with the use of water on instream habitat are largely related to potential increases in sediment inputs caused by landuse identification. Many of the streams within the Scheme area are ephemeral and therefore the existing instream habitat values of these waterbodies is limited. The proposed on-farm management requirements for land owners that receive water from the scheme are aimed at reducing sediment inputs into streams. The successful implementation and monitoring of these on-farm management practices (such as fencing and planting of riparian strips) should help ensure that any effects of land intensification on instream habitat of streams within the Scheme area are minor.

It is considered unlikely that the scheme will result in an increase in the sediment inputs to lowland coastal and Lake Ellesmere streams. One possible exception to this is the Selwyn River. The successful implementation and monitoring of farm management practices aimed at reducing sediment runoff (such as fencing and planting of riparian strips) should help ensure that any effects of land intensification on instream habitat values within the Selwyn River are minor.

Increased irrigation has the potential to increase baseflows in some streams within the potential effects area (PEA). Streams in which there is likely to be a significant increase in baseflows and increase in the amount of instream habitat are the Selwyn and Irwell Rivers, and upper Hanmer Road Drain. Less significant increases in baseflow are expected in the Avon, Heathcote, Halswell, and LII Rivers; Boggy, Waikewai, and Harts Creeks; and Tent Burn.. Any increase in baseflows and corresponding increase in the amount of instream habitat within these streams is regarded as a positive effect. The increase in flow rates in Lake Ellesmere streams is expected to increase the amount of habitat within Lake Ellesmere although the extent of this increase is unclear due to the lake level management regime.

8.7.3 Water Quality

The water quality of the Waianiwaniwa Reservoir is expected to be elevated in nutrients, particularly during the first 5-10 years of operation, and during dry periods when the lake level is likely to be drawn down. The water quality is expected to be acceptable for the purpose of water storage for irrigation purposes. If it is decided that the reservoir should be used for other purposes, such as aquatic ecosystems or recreation, then a range of options are available to enhance the lake water quality to meet this purpose. These options include vegetation clearance and planting and harvest of nutrient stripping crops prior to valley inundation.

Operational effects of the CPWE Scheme mainly comprise effects related to discharge of irrigation bywash and effects associated with landuse intensification. In some years when the Reservoir is drawn down to very low levels, operational bywash water could be of lower quality, although discharging this through the bywash wetlands would mitigate any potential effects on water quality downstream. Effects of infrequent emergency bywash discharges are likely to be minor and short-lived in the Rakaia or

Waimakariri Rivers, but would have greater impacts on water quality in the smaller and relatively sensitive Selwyn River.

Effects of landuse intensification mainly include increased runoff of sediment, phosphorus and faecal material, which could adversely affect downstream water quality and may result in an increase in biomass of algae and plants. However, use of appropriate mitigation measures, including fencing of waterways, will reduce any effects.

Increased irrigation will increase groundwater levels and stream flows downgradient of the Scheme area, and water level increases will be most pronounced directly downgradient, in the Irwell and Selwyn Rivers. Increased baseflow concentrations of nitrate-N are expected in streams downgradient of the Scheme area due to increased concentrations in groundwater. There is increased potential of nitrate-N concentrations to exceed ANZECC trigger levels in Doyleston Drain, Boggy Creek and Selwyn River. However, following the ANZECC guidelines, this would not indicate an adverse effect, rather that further assessment may be necessary.

Increased freshwater inflows into Lake Ellesmere will reduce the salinity and increase total nitrogen concentrations, but effects are expected to be minor and are unlikely to have any effect on water quality.

8.7.4 Algae, Macrophytes, and Invertebrates

Operational effects of the CPWS on algae, macrophytes, and inverebrates will relate to discharge of irrigation bywash and effects associated with landuse intensification. Bywash discharges will be opassed through wetlands, and this will mitigate any potential adverse effects on periphyton, macrophyte or invertebrate communities arising from the occasional release of lower quality bywash during occasional periods of low Reservoir water level. Effects of infrequent emergency bywash discharges are likely to be minor and short-lived in the Rakaia or Waimakariri Rivers, but should probably be avoided in the smaller and ecologically sensitive Selwyn River.

Physical effects of landuse intensification mainly include increased sediment and phosphorus runoff, which could adversely affect aquatic biological communities. Wetlands, and the Hororata and Selwyn Rivers are considered the most sensitive to these effects. However, use of appropriate mitigation measures, including fencing of waterways, will ensure any effects are largely mitigated.

Increased irrigation will increase groundwater levels and stream flows downgradient of the Scheme area, and water level increases will be most pronounced directly downgradient, in the Irwell and Selwyn Rivers. Any increases in groundwater levels are likely to result in positive or nil effects on aquatic habitat for streams and wetlands, and is unlikely to affect periphyton, macrophyte and invertebrate communities within Lake Ellesmere.

Increased baseflow concentrations of nitrate-N are expected in streams downgradient of the Scheme area. Nutrient enrichment effects of nitrate (e.g. increased proliferations of periphyton) are considered unlikely, as nitrate-N is already unlimiting in most streams. As noted above, nitrate concentrations in the lower Selwyn River could exceed ANZECC trigger levels. However, the ANZECC (2000) guidelines note that trigger levels are not to be treated as environmental standards, rather that an exceedence indicates further assessment may be required at the time. The Selwyn River does have existing high-quality aquatic ecosystems present, and it is appropriate that the ANZECC (2000) guidelines should be followed should nitrate trigger levels be persistently exceeded.

8.7.5 Fish and Recreation

The principal potential effect of diverting water from the Waimakariri and Rakaia Rivers is on the upstream migration of native fish and adult salmonids and the entrainment of juvenile salmonids and native fish migrating downstream. The potential effect of the structures on salmonid migration will be mitigated through the construction and operation of an appropriately designed fish screen, which will use best practice design guidelines recommended by the Canterbury Regional Council.

As a result of the expected high level of performance of the fish screens it is expected that very few salmonids will become entrained into the inlet canal, head race canal and water race net work. However, those fish that do become entrained will not necessarily be 'lost to the system', as it is likely that these fish will make it back to either the Rakaia, Waimakariri or Selwyn River as a result of operational or emergency bywash discharges.

Because of their small size, it is inevitable that some adult and juvenile native fish will pass through the fish screens and into the inlet canal, reservoir, head race canal and water race network. These fish will either establish populations within the waterbodies associated with the storage or transfer of water, will be returned to the Rakaia, Waimakariri or Selwyn Rivers via bywash discharges or will not survive.

The fish community values that develop within the reservoir will be largely dependent on the water quality, habitat quality, reservoir operating regime and diversity and abundance of native fish that become entrained into the system at the upper Waimakariri River intake. The wide operating range of the lake, and high levels of natural turbidity within the reservoir will probably limit the value of the Waianiwaniwa reservoir as native fish or salmonid habitat.

Options for mitigating the potential effects of the loss of Canterbury mudfish habitat within the Waianiwaniwa Valley and possible increased predation pressure on Canterbury mudfish within the upper Waianiwaniwa River will be evaluated following consultation with the Department of Conservation.

The fishery values that develop within the Waianiwaniwa reservoir will be largely dependent on the water quality, habitat quality, reservoir operating regime the diversity and abundance of native fish that become entrained into the system. The creation of the reservoir offers the potential for the eel and trout fishery values of the Waianiwaniwa Valley to be enhanced, although this effect is not considered to be large.

The use of irrigation water has the potential to affect water quality and instream habitat quality and quantity within various waterbodies within the PEA, and as a result affect fish, fishery and recreational values. The amount of instream habitat for various fish species is predicted to significantly increase in the Selwyn and Irwell Rivers, the upper reaches of Boggy Creek and the Hanmer Road Drain. This in turn expected to result in a positive effect on the existing fish, fishery and recreational values of these water bodies. The predicted size of the increase in flow in other Lake Ellesmere and coastal springfed streams is lower and its resultant increase in instream habitat and the potential positive effects of this on fish, fishery and recreational values is also lower than for the Selwyn and other nearby rivers.

8.8 Effects of Water Use on Soils

There is potential for irrigation water to have a number of effects on soil physical characteristics. Potential adverse effects include pugging in poorly drained soils, runoff erosion from bare soil surfaces, reduction in infiltration capacity from sealing of the soil surface, and breakdown in soil particle sizes. These effects are considered unlikely in the Central Plains Water Enhancement Scheme area. Soils are well drained and not conducive to pugging. Soil erosion is only likely with flood irrigation techniques, and these are not proposed for this Scheme. Soil surface sealing and breakdown of particles occurs is spray irrigation water is applied at very intense rates. This would be a very inefficient and uneconomic use of water. Given farmers must purchase water from the scheme, it is unlikely they will persist with such practices.

A number of beneficial soil effects are likely to occur under the proposed scheme. Increased soil moisture levels will allow greater pasture grass growth, which in turn will increase the organic matter content of the soils. This will improve the soils' water holding capacity, and increase biological activity, both of which will have beneficial effects on soil productivity.

8.9 Effects on Landscape and Visual Amenity Values

8.9.1 Potential Effects

An assessment of the landscape and visual effects was provided by Chris Glasson Landscape Architects Ltd. (*Central Canterbury Plains Water Enhancement Scheme Landscape Assessment*). The following material is taken from this report.

When dealing with the sustainability of the scheme in this location, the issues to be concerned with are the detailed effects on the landscape. If applied to the RMA, these landscape issues relate to Natural Character (S6a), Outstanding Natural Features and Landscapes (S6b) and Amenity Values (S7c).

Natural Character

Natural (S6a) includes *"the preservation of the natural character of the coastal environment, including the coastal marine area, wetlands, lakes and rivers and their margins, and the protection of them from inappropriate subdivision, use or development."*

Natural character occurs in greater to lesser degrees in a continuum form the pristine to modified environments. This is a reflection of the modified nature of landform, water surface, and vegatative cover. The natural character of the landform is dependent on the natural elements, patterns and processes.

The foothill area, in which some of the scheme's components are located in, is generally an area where there is medium to high natural character with the dominant elements being landforms, pastoral grassland and exotic vegetation.

The built environment is limited to farm dwellings and roads and fences for the majority of the scheme. The settlement of Colgate which will be in close proximity to the reservoir and lakes structure is obviously a location of low natural character.

Due to its lack of landform diversity, the Plains landscape on the other hand has a dominant land cover and land use character. The landscape is seen as less natural than the foothills because it is more modified by human intervention. There are limited remnant natural features such as wetlands, forest, shrubland, and grassland. The braided rivers of the Waimakariri, Selwyn and Rakaia are the most natural features within the scheme's location.

The developed Plains are very important to the region's landscape image, even if the degree of natural character is medium to low. Both the Waimakariri and Rakaia Rivers are two of New Zealand's outstanding braided rivers. The former is used more for recreation than the Rakaia but the latter is a better fishing river. Both rivers are dramatic, and unpredictable even though they are partly contained, there are discharges and irrigation draw off occurs. The gravel bed provides habitat for several rare and endangered endemic birds and the rivers are a focus for reflection, relaxation, fishing and jet boating.

The Waimakariri River is of great significance to the tangata whenua while both rivers are a link between the mountains and sea. The issues of sustainability and inappropriate development apply on both rivers. It is therefore important that any development has regard for the naturalness and simplicity of the river landscape especially at the gorges, where there is a sequence of grassed terrace flats and bush clad cliff faces. These structures must be integrated into the environment so as to minimise the impact on the natural dominance of the landscape.

The value of the scheme in terms of natural character will be enhanced by creating places for recreation and ecological enhancement especially along the main canal and at the lake. The planting of native species adjacent to the lake edge could provide a high degree of quality to this environment thus enhancing the natural character.

During the construction process and for several years after the scheme is operable, many of the scheme's components will be raw looking and have high impact, thus affecting the degree of natural character. This will be especially true of the intake and canal as it bisects the terrace and for the dam structure. With appropriate enhancement measures in place these components will soften and become integrated so that the natural character is retained.

Outstanding Natural Features and Landscapes

It is accepted that section 6(a) matters comprise the key issues, but for completeness and acknowledging a degree of interrelationship between 6(a) and 6(b), an assessment of the Scheme in terms of section 6(b) has also been carried out. Section 6(b) requires *"the protection of outstanding natural features and landscapes."* Under S6(b) the scale of an outstanding natural feature or landscape needs to be identified.

That is, in assessing what is an outstanding feature or landscape with regard to an application, the feature or landscape is that which is identified at the regional scale.

For the landscape which falls within this scheme, Environment Canterbury in their Canterbury Regional Landscape Study (1995) recognised the lower Waimakariri River and Gorge and the lower Rakaia River and Gorge as being regionally outstanding natural features and landscapes. These outstanding qualities have been discussed already in the previous section of "Natural Character" but the important point is that the braided river is a unique feature of the New Zealand landscape. It is therefore important that this element remains intact. At the intake points on both rivers it is a meandering river over a shingle bed, and the braided river begins more downstream.

Both intake locations are memorable places for the legibility of the landscape of the well defined and linear terraces and the steep batters, the geometry of the paddocks and shelter belts on the river flats offset by the randomness of the rivers and the clarity of the colour, (grey shingle, dark green trees, light green pasture and the gold of the gorse). The naturalness is punctuated by the Highbank power station and pylons, isolated buildings, roads and fencelines. The Environment Court (WESI vs QLDC c180.99) defined relevant criteria for assessing outstanding landscapes as being: The natural science factors – geology, topography, ecological and dynamic components of the landscape; its aesthetic values including memorability and naturalness; its expressiveness (legibility); how obviously the landscape demonstrates the formative processes leading to it; transient values; occasional presence of wildlife; or its values at certain times of the day or of the year; whether the values are shared and recognised; its value to tangata whenua and its historic associations. This criteria clearly shows that landscape is not restricted to the visual and is not merely the picturesque and scenic. The perception of landscape and the effects of aspects such as noise, culture and history on appreciation of the landscape are relevant. The landscape may thus be considered both as a biophysical entity and as a cultural resource. In considering the various landscape criteria, *"natural science criteria and legibility landscape criteria should be given weight over all other criteria."* When considering a natural feature, a feature can be identified as a *"distinctive or characteristic part of the landscape."* (WESI vs QLDC c180).

The remainder of the landscape for the affected area has some high values in and around the foothills but this cannot be classified as of outstanding value. Overall the attraction of the high and low plains is as a pleasant and partly modified environment as well as a frontispiece to the hills and mountains beyond.

Amenity Value

Under section 7(c) of the RMA regard must be shown for *"the maintenance and enhancement of amenity values".* Many of the issues discussed under natural character and natural features can also affect amenity values. In relation to this proposal, amenity values include remoteness, tranquillity and seclusion. Such qualities can be retained if the built structures are integrated into the landscape with an element of separation between each dwelling. To retain the amenity values the overall appearance of the development should not be dominated by the built environment. To assess the potential effects on amenity values it is important to know about the visibility of the proposal, who will be affected and how significant any adverse effects will be.

8.9.2 Visibility

Visibility is a determination of how easily and regularly a landscape is seen by people. This can contribute to the importance of a particular landscape. The Environment Court has recognised that it is not just a numbers game, Steffan Browning v Marlborough DC and NZ Marine Farming Assoc w 20/97 (Annie Bay). The Court has decreed that it is not about how many see a landscape but the significance of seeing that landscape.

The visibility of an object can determine the visual effect. This need not necessarily be a negative effect but new objects in the landscape can influence the amenity value of an area. It is often how well a new object can be integrated to a landscape as to whether a negative effect is created.

Many of the components of the scheme will be visible elements in the landscape, especially the intakes, the main canal and storage reservoir. The tributary canals are less visual and impacting but the results of the presence of water to the plains could create an effect with a change in land use as well as the type of objects added to the landscape.

The visual effects are as follows.

Rakaia Intake

This is a very visible structure on the northern side of the river at the toe of the embankment, and can be viewed from a lookout point on the edge of the northern river terrace, from the Gorge Bridge and Rakaia River Road on the south side.

Waimakariri Intake

This intake and the and the adjacent canal is less visible than the Rakaia River one. From Rubicon Road (south side) and Woodstock Road (north side) views of the structure can be seen, but these are well off the main roads and used infrequently by the farming community. It is at the gorge bridge where the canal could have more impact as it bisects the terrace slope. The canal will be piped for a distance of 150m through the rock under the bridge.

Main Canal

This component could create a visual impact on the landscape especially during the years prior to the effectiveness of the enhancement measures. However, much depends on how well the structure can be integrated into the landscape. As the canal crosses the plains the canal embankments will be at eye level so the horizontal line continues the same linear effect of the hedgerows, shelter belts and plains themselves. When viewed from above, such as Maffeys Road, the canal is an incongruous element cutting across the grain of the landscape. When viewed from below, such as from the Hororata to Colgate road, the canal is a horizontal element set against the undulating and incised foothills.

Enhancement measures will partly ameliorate the incongruity of the canal from Glenroy to the Selwyn River. As the canal crosses over the smaller waterways an aqueduct will be constructed, something which will have, in some places, little effect while in others it will be noticeable.

The design of the aqueduct could assist its integration, such as a greywacke rock faced structure, which could make the object more recessive than a pipe.

The Waianiwaniwa Reservoir

During construction and before the enhancement measures gain maturity the reservoir will be a very visible structure from the main road (SH 77) between Colgate and Glentunnel and from Colgate itself. Because the neck of the Wainiwaniwa Valley is narrow the visibility of the dam structure is of a short duration when passing by. However, for Colgate residents the effect is more severe and the loss of a pastoral landscape of grassland and a thicket of mature trees will change the existing amenity. The reservoir will change the character of the Waianiwaniwa Valley with the addition of a large water body.

Canals & Water Races

There will be a diverse range of water channels across the plains. These will vary in width and there will be little difference as to what currently exists on the plains except for construction techniques. Generally, the channels will be less visible than existing ones because there will be fewer weirs and abutments. However, some may be wider, e.g. 5 to 10m with more gently sloping sides.

There will be little adverse visual effect with these other than creating a more diverse environment, as the structures are lineal, follow roads and fence lines and have a low height.

Bywash Canals & Settling Ponds

The bywash canals are the end point for the whole system and there will be a number of these throughout, so the same visual effect will apply to these as to other channels. In some instances such as the Selwyn River it is possible that the bywash canals could utilise small streams like the Irwell Stream which discharges into the Selwyn River. The visual effect of adding more water into these existing streams will be a positive visual effect. At present there is little water in these streams during normal flows.

In most instances the bywash races will empty into settling ponds before discharging underground to the main rivers. With the addition of wetland planting, such components will add to the ecological diversity of the river terraces. This will create a positive visual effect.

Overall visual effect

The water enhancement scheme will alter the visual character of the landscape it is located in, just as it has for existing irrigation schemes. The downs and plains grassland colour will become green rather than ochre in summertime. The use of land could become more intensive with cropping and dairying than for sheep farming or, as has happened with the large central pivot dairy irrigation schemes, existing shelter belts and fence lines have been removed to create a more open landscape. There will be an advent of more pump sheds and tanks within the landscape.

It is therefore hard to predict the exact change of the land use, but it will change, just as the plains landscape has been evolving for the past 100 years with changing land uses. This is not necessarily a negative effect but a changed one.

8.9.3 Enhancement Measures

Taking into account the areas of moderate to high naturalness and the outstanding quality of the Rakaia and Waimakariri gorge landscapes it is important that great care is undertaken when aligning the intake canal and races, that they are integrated, and an amenity/ecological value is included with the enhancement measures. Even though much of the landscape a modified one, it is an open and highly visible one, meaning that the correct placement of scheme components is paramount in maintaining a harmonious landscape.

The following are recommended mitigation and enhancement measures for the main components of the water enhancement scheme:

Rakaia and Waimakariri Intakes

- Leave the concrete structure to weather naturally
- Any timber and iron components of the structure should be painted in recessive colours
- The batter slope of the terrace across which the canal route is made should first be grassed and then planted with colonising native plants such as kohuhu, coprosma, totitoi, NZ broadleaf and manuka.

The Headrace

- A sinuously aligned canal especially at the base of the foothills.
- Grassed batter slopes to the canal batter slopes.
- In several places along the alignment, create larger free form areas as part of the canal as local amenity and ecological places which integrate to the existing land form and are near road access points (see plan).
- To increase the plant material diversity with native plants and amenity shade trees. The latter will link to existing trees throughout the foothills and river systems.

The Waianiwaniwa Reservoir

This component of the scheme offers the greatest opportunity for amenity, recreational and ecological values. The lake edge is the key area where the enhancement measures can take place.

- Grassed dam batter slopes.
- Significant areas of exotic tree planting to relate to the existing situation

- Lake edge to be accessible in places (beaches, board walk/jetties, grassed areas) and to be ecologically diverse (range of native plants, gradients, and habitats).
- Picnicking, boat launching and camping areas to be developed.
- Shade trees and sheltered areas.

Headrace & Water Races

- Grassed batter slopes

Bywash Canals & Settling Ponds

- Gentle batter slopes
- Soft edges with native planting
- Removal of some willow growth and weed

Appurtenances

- Painting the small pump sheds in recessive colours
- Locating appropriately coloured storage tanks in the landscape. White ones have high impact
- Grading off excess excavated material and grading the batter slopes

Vegetation Enhancement

Contouring and enlarging of water bodies for recreation and ecological values are important enhancement measures, but it is the plantings which can link areas together, screen, shelter, shade and provide wildlife habitats and amenity areas for people to enjoy.

Planting types can include:

Exotic deciduous tree suitable for Canterbury conditions:

- ash
- birch
- box elder
- elm
- oak
- plane
- poplar
- willow

Native vegetation (colonising species):

- Aristotelia
- beech
- cabbage tree

- coprosma
- Griselinia
- kanuka
- kohuhu
- kowhai
- lacebark
- lemonwood
- manuka
- Phormium
- Pittosporum
- Pseudopanax
- ribbonwood
- rush
- sedge
- Totara

8.9.4 Conclusion

The water enhancement scheme will result in some change to the landscape of the area and high plains. This change will be most noticeable at the outset, especially during construction. Like all large schemes they mellow with time due to appropriate enhancement measures which integrate the components into the landscape and the fact they become an accepted part of the landscape. We have been aware of irrigation canals on the plains for over 100 years and more latterly with centre pivot and pump stations. Where the greatest change will take place, the main canal and storage reservoir, is where the greatest opportunities exist for recreation, for increasing ecological diversity and for amenity values. In time these areas could become a real asset to those who frequent the high plains.

8.10 Effects on Tangata Whenua Values

A Cultural Impact Assessment Report (CIA) was prepared as part of consulting with Ngāi Tahu with regards to assessing the environmental (including cultural) effects of the proposed Central Plains Water Enhancement Scheme (refer Central Plains Water Enhancement Scheme: An assessment of impacts on Ngāi Tahu values, Prepared by Dyanna Jolly Consulting on behalf of Te Taumutu Rūnanga, Te Ngāi Tūāhuriri Rūnanga and Te Rūnanga o Ngāi Tahu October 2005.) The CIA was regarded as a starting point in the process of providing the Central Plains Water Trust with good information that would enable meaningful discussion between parties about how to address Ngāi Tahu concerns.

The CIA assessed the effects of the Base Scheme on Ngāi Tahu cultural values and interests, and identified the ways that any adverse effects may be avoided, remedied or mitigated. It was provided in order that an Assessment of Environmental Effects report could be prepared that helps satisfy Canterbury

Regional Council requirements to assess consent applications against Resource Management Act (RMA) 1991 sections 6(e) *relationship of Māori with ancestral lands, waters and sites,* 6 (f) *protection of historic (including cultural) heritage from inappropriate use and development,* 7 (a) *Kaitiakitanga* and 8 *Treaty of Waitangi.*

The CIA was prepared on behalf of Te Taumutu Rūnanga and Te Ngāi Tūāhuriri Rūnanga, as kaitiaki rūnanga for the project area, and Te Rūnanga o Ngāi Tahu, as iwi authority. As kaitiaki, Ngāi Tahu has a responsibility for the sustainable use and management of the environment in the takiwā - *mō tātou, ā, mō kā uri ā muri ake nei* (for us and our children after us). This means ensuring that Ngāi Tahu values associated with the central plains are protected, and in many cases, enhanced, for future generations.

The consultation process with ngā rūnanga for the purposes of this report identified five areas of concern regarding potential or actual effects on cultural values:

1. Effects related to water abstractions
2. Effects related to mixing of waters
3. Effects related to the Waianiwaniwa Storage Reservoir
4. Effects related to the construction and use of canals
5. Effects related to the use of water on the Central Plains

The process of identifying cultural impacts, and providing recommendations to avoid, remedy or mitigate such impacts, was guided by cultural thresholds: desired states or levels of acceptability that are determined through the need to protect, maintain, and in some cases enhance, values at levels that are acceptable to tangata whenua.

Thirty-eight recommendations were provided in the body of the CIA, as measures to address adverse effects on Ngāi Tahu values. The recommendations highlighted a number of important kaupapa/themes:

- That values associated with the Waimakariri River in particular will be adversely affected if the proposal proceeds. Ngāi Tahu was not convinced that the proposed abstraction, or the flow regime in the WRRP, are consistent with protecting of the relationship of tangata whenua with this river and the wāhi tapu and wāhi taonga values associated with it.
- There was a lack of faith that the Scheme provides certainty for instream life and users in the same way that it is provided for out-of-stream users (irrigators).
- Any discharge of mixed Waimakariri-Rakaia water to water (e.g. the flows of the Waimakariri, Rakaia, Waikirikiri or other natural surface waterbody) within the Scheme must be avoided.
- Ngāi Tahu did not believe that there is any practical way to keep tuna/eels out of the system, and thus recommended that the Scheme design incorporate the creation and management of longfin eel habitat.

- There are registered archaeological sites that will be directly affected by the Scheme, and others that are considered at risk. Further, several areas in the project boundaries were considered high risk in terms of the potential for adverse effects on unknown sites of cultural significance (e.g. confluence of the Kōwai – Waimakariri rivers). A range of mechanisms, including archaeological surveys, cultural monitoring and ADPs is required to manage the protection of archaeological sites.

- The Scheme has the potential to influence the presence, influence and abundance of native biodiversity (and the valuable ecosystem services that they provide) on the central plains landscape; and this potential should be realised to the highest degree possible.

- Appropriate farm management and environmental monitoring must be the basis of this Scheme if good environmental outcomes are to be realised. Any farm accords must be proven to be implementable, effective and enforceable.

- Ngāi Tahu would not accept any adverse effects on Te Waihora and the lowland streams as a consequence of this Scheme. The Scheme must be compatible with the vision and management objectives that Ngāi Tahu has set out for Te Waihora and its catchment.

What was most clear during the hui, interviews and group discussions that led to the CIA was that Central Plains Water Ltd (CPWL) needs to provide Ngāi Tahu with the same degree of certainty regarding environmental sustainability and protection of the relationship between tangata whenua and their ancestral lands and waters, as it is striving to provide for shareholders in terms of irrigation supply. Rūnanga representatives were seeking assurance that the Scheme was not being driven by economic forces at the expense of the land, water, biodiversity and cultural heritage of the central plains.

The focus of Ngāi Tahu at this time was not about whether to support or oppose the Central Plains Water Enhancement Scheme. Rather, it was about finding a balance between enabling sustainable use while avoiding adverse effects on Ngāi Tahu values and the environment.

Since preparation of the CIA, Central Plains Water representatives have held three hui with Ngai Tahu representatives between March and May 2006 to seek to resolve concerns as far as possible, to agree on mitigations where necessary and on a way forward where any concerns are not resolved.

8.11 Social Effects

This assessment of the social effects of the Scheme has been provided by Taylor Baines and Associates Ltd.

Four scenarios projected by Butcher Partners Ltd (2000) indicate that should Central Canterbury become fully irrigated there will be a major shift to dairy farming through the conversion of existing properties from livestock and arable production. Two of the scenarios also project that land suitable for crops will be used to expand horticultural and process crop production.

Experience in other parts of New Zealand indicates that land use change following irrigation commonly leads to changes in farm ownership. The link between changes in land use and ownership has impacts not only on farm families, but also on the social structure of rural communities. Different land uses require different skills, and may attract farmers with different values. While social division may arise between newcomers and established members of the community, a stabilised or increased population can have benefits for schools, sports clubs and social services. Irrigation and associated land uses demand a wider skills base among farmers, farm workers, farming service providers and contractors, rural service providers and small business people. Often local skills and resources are not congruent with the new production systems and rural towns can miss out on the full economic and social potential of the new irrigation-based production systems.

Four scenarios of land use change in Mid Canterbury and the Central Canterbury Plains

Studies of the irrigation potential of Mid Canterbury and the Central Canterbury Plains indicate that there is a total area of 192,427 hectares in these regions which would benefit from the provision of water through community irrigation schemes. The area on the Central Canterbury Plains estimated to benefit from irrigation was estimated to be 84,729 hectares, with 71,885 hectares identified as suitable for intensive livestock production, and 12,394 for arable or intensive cropping production (Butcher Partners Ltd, 2000: 6).

Based on the present land use of these 192,427 hectares in Mid Canterbury and Central Canterbury, Butcher Partners Ltd (2000: 15-21) devised four scenarios of land use change that may occur in these areas as a result of irrigation development. These four scenarios were:

- *Likely Short Term*: changes in the near future based on current economic conditions and the capacity for cultural and ownership change
- *Dairy*: an extrapolation of current trends
- *Fruit and Vegetable Bowl*: a future in which the geopolitical climate has changed
- *Biological Enterprises*: a future using a high level of new technology.

Butcher Partners Ltd then projected the patterns of land use associated with each of these four scenarios. The projections of land use patterns they developed are presented in Table 8-12 below. Butcher Partners Ltd point out that the "Likely Short Term" scenario is the "most likely mix" based on the economics of different land uses, and realistic expectations of ownership change that is likely to occur over the short term. The other three scenarios are illustrative rather than predictive.

Table 8-11: Land use (ha) for four scenarios arising from irrigation development

Land Use	Present	Likely Short Term	Dairy	Fruit & Vegetable Bowl	Biological Enterprises
Dairy	0	76089	148939	76089	76089
Dairy Support	0	0	37235	0	0

Sheep	118126	41218	0	41218	41218
Beef	17908	15638	0	15638	15638
Deer	7093	19232	0	19232	19232
Arable	45086	32819	0	0	15083
Process Crop	4214	6253	6253	14087	12583
Horticulture	0	1177	0	26161	12583
TOTAL	192427	192427	192427	192427	192427

Source: Butcher Partners Ltd (2000: 21).

All four scenarios project a major shift to dairy farming (of between 76, 000 to 149,000 hectares) should these 192,427 hectares of land in Mid Canterbury and Central Canterbury become irrigated. This shift to dairy farming is expected to result from the conversion of existing properties from sheep, beef and arable production. Two scenarios (*Fruit and Vegetable Bowl* and *Biological Enterprises*) project that land with suitable soil for crops will be used to expand the level of horticultural and process crop production by about 21,000 to 36,000 hectares. Although all four scenarios are for land in both Mid Canterbury and Central Canterbury that would benefit from irrigation development, it is likely that the smaller area to be supplied with water from the proposed Central Plains irrigation scheme will experience land use changes of a similar nature.

Irrigation encourages livestock farmers to adopt different farming systems with much higher levels of production. It enables arable farmers to double their revenue because of the increased reliability of production and, more importantly, the wider range of crop options (e.g process vegetables) which are available to them. Moreover, irrigation provides existing farmers with the option of switching to horticultural production (Butcher Partners Ltd, 2000: 23). These changes of land use will, however, require significant on-farm development expenditure for irrigation systems and conversion to other forms of production.

Present and projected land use of the scheme area after commissioning

MacFarlane Rural Business Ltd has examined the present land use of the target area of the scheme, and projected the possible pattern of land use in the area after its commissioning. Their assessment of the hectares devoted to each land use pre and post the introduction of the scheme are presented in Table 8-13 below. Under this projection the total effective area within the boundary of the scheme is assumed to be 85,000 hectares (although it is expected that only 60,000 ha will be irrigated from Scheme water), and there is a further 10,250 hectares outside the scheme boundary whose economic return is expected to be enhanced by irrigation on land within the boundary. As with the wider Butcher partner scenarios, the major land use changes in the scheme area according to this projection are a switch from dry land pastoral farming to dairying and intensive crop (arable and process) production. Between them these two major forms of agricultural activity are expected to use 70 per cent of land in the scheme area.

Table 8-12: Present land use and post land use of the scheme area

Land use	Current land use of scheme area		Post land use of scheme area	
	Hectares	Per cent	Hectares	Per cent
Livestock	45000	53	0	0
Mixed	8000	9	10250	12

Finishing	0	0	5000	6
Arable & Process	0	0	15250	18
Dairy	22000	26	44500	52
Non effective	10000	12	10000	12
TOTAL	85000	100	85000	100

Source: MacFarlane Rural Business Ltd

Previous experience with land use and social change following irrigation

Case studies of other irrigation areas show that irrigation can transform the land and landscape. It can also transform society. Nevertheless, several generations of New Zealand farmers viewed irrigation primarily as an 'insurance' against a perverse climate rather than as a tool to manage their production. It was not until sophisticated irrigation technology developed with spray and sprinkler systems that the full potential of water application was realised. Previous research[1] compiled and reviewed as a background study for this social assessment has traced the development and social impacts of community irrigation schemes, attitudes and adaptations of farm families and subsequent ownership changes.

Early irrigation schemes were developed on the Waitaki River and in the Ashburton District. But irrigation and farm technology in the early days were insufficient to realise the full potential of the water. By the 1950's, however, advances in border dyke and spray irrigation prompted some groups to run what became 'experimental schemes'. In the 1960's the central government's policies for national development lead it to sponsor a number of schemes throughout the country and these occurred in the 1970's. Despite considerable support from government agencies, most community schemes have involved long, frustrating periods of gestation requiring strong advocacy and leadership.

In the past, when water finally reached pastoral farmers they tended to hold few expectations of radically changing their farming techniques through irrigation. Their overwhelming desire was to improve the quality of their stock. This view of land use change was a common pattern of response when on farm irrigation first becomes available.

Farmers and rural communities soon learnt that their substantial investment in water resources is more than simply an 'insurance' against perverse climate. The application of water becomes a new daily function with associated new irrigation and farming technology. It can mean unremitting work. Therefore irrigation is often linked to youth and enthusiasm and to new types of farmers, particularly dairy farmers, who view irrigation very much as a management tool. With the advent of centre pivot

[1] This research includes community case studies of the Waitaki Plains, Otautau and Clandeboye and a social assessment of land use change under irrigation undertaken by Taylor Baines and Associates as part of the FRST funded project "Resource Community Formation and Change" (Contracts TBA801 and TBAX0001); a review report, "Social Impact of Irrigation", Appendix 4 in Butcher Partners (2000); and a MAF technical paper (no. 2002/13), "Economic and Social Assessment of Community Irrigation Projects", prepared by Stuart Ford with contributions by Geoff Butcher and Taylor Baines and Associates.

irrigators, however, the labour requirements for irrigation have reduced significantly and therefore this barrier to the uptake of spray irrigation is decreasing.

Experience shows irrigation commonly leads to changes in farm ownership. On the Waitaki Plains, for instance, many established, dry-land, sheep farming families sold their farms and were replaced by younger families. These new farmers modified traditional farming systems with the support of an accessible and regular water supply. They invested heavily in farm improvements, upgrading pasture for cropping and sheep, and constructing bigger and better homes and farm buildings. The Amuri replicates the Waitaki experience with 60 per cent of farms there changing ownership after the advent of irrigation (Hunt, 1998).

Furthermore, the available research shows successive ownership and land use changes coming in waves after the introduction of irrigation.

A general model of land-use and ownership change

Social research on previous irrigation schemes has identified a generalised pattern of successive land use and ownership changes (McCrostie Little and Taylor, 2001).

First wave

The existing pastoral farmers primarily want to improve their traditional base - stock breeding, meat and wool growing. On-farm irrigation is labour intensive and initially capital expensive. Older farmers are reluctant to incur more or new debt and can find the work too physically demanding so they retire in favour of the next generation.

Second wave

The second wave of farmers enter into major irrigation investment. They increase stock numbers and productivity but generally stay with the same production base. These farmers learn that pastoral farming and irrigation are not always compatible and, sometimes suffering from the results of over-capitalisation, make the decision to sell, prompting the next 'wave' of irrigation farmers.

Should these farmers stay, they radically change their production base to incorporate intensive arable farming, dairying or horticulture, realising the future lies in these sorts of new land uses. The shift to dairying is often achieved via a series of interim changes, such as running a small herd alongside the main farm or bull beef raising. It is, however, more likely that these farmers do not make the total change from pastoral to new forms of farming such as dairying themselves but elect to sell, retire or farm elsewhere.

Third wave

Widespread changes in land use and farm ownership occur during the third wave. Newcomers buy into converted farms or directly convert them on change of ownership. They are usually dairy farmers by choice and experience and they frequently come into the district from an established dairying district. As the third 'wave' of irrigation farmers they create a 'new' dairy economy in the host district.

Likely scenario of social effects following changes in land-use and ownership

The link between ownership and land use change is a fundamental dynamic of irrigation development. It impacts not only on farm families but also on the social structure of the host community, its settlements and small service towns.

In a generational farming community, such as the Central Plains area, there has been considerable continuity for farm families through the process of farm succession, and this continuity flows through to the rural communities as well. Irrigation therefore will pose a potential risk and some challenges to these traditional farming areas and to community stability, because different land uses demand different farming skills and frequently attract farmers with different outlooks. On the other hand, newcomers to the community have the potential to boost demand for struggling rural services provided by schools and health professionals.

Changes in land use can spark a local perception that the population base has 'exploded' through diversified land use and the commercial and employment opportunities offered by irrigation - when in fact growth has been more modest. For example, over the 10 years from 1986 to 1996 the population of the Waitaki Plains area grew by 5 per cent, below the overall New Zealand growth of 7.2 per cent. The growth in population of irrigated areas does become significant, however, when compared with the fall in population evident in many non-irrigated rural communities. For the Central Plains, however, there has already been population growth in the Te Pirita and Rural Darfield areas in particular since the mid 1980's. So further irrigation development in the form of the proposed scheme will most likely contribute to steady growth in these areas compared to reversal of a decline..

Population change will also be evident in the composition of the population as dairy farming impacts on the age structure of the community. In the Amuri, Hunt (1998) found that there was an overall rise in the number of younger to mid-life males and that conversely in the same district there was a decline in the 60 years cohort. Dairy farming families are often in their lower to middle life cycle and sharemilkers frequently have young children in their families. As a consequence, school rolls will increase, especially in the junior classes. These increased school rolls can revitalise a community, where the school is at the centre of the district's identity. An increased roll expands staff numbers and helps the school to operate as a hub for educational, recreational and social activities.

Communities undergoing irrigation development experience considerable social change as the 'old' families move out and are replaced by 'new' families. Potential social divisions are created as the first dairy families move in from outside. Dairy farming is often regarded as a lower status occupation than traditional sheep and beef farming, one with very different work patterns and with a comparatively high level of farm workers. The continual movement of dairy farm workers in and out of the district each season can create feelings of dislocation among members of the more established community who remain.

While the average age of the community becomes younger with irrigation, the expectation that youth and enthusiasm will have a greater involvement in the provision of community services and facilities may not be fulfilled. The transient nature of sharemilking means that some families take little part in community activities and organisations, and this is often a cause of criticism from more established community members.

Another issue is the ability of the district to take full advantage of the flow-on effects from new land use activity and changes in population. Opportunities will be created for irrigation contractors and suppliers, building contractors and suppliers, dairy equipment, veterinary services, transport operators, etc. Increased horticultural production will bring a demand for seasonal workers. If they are not available locally, then labour and farm services will be sought outside the district.

Some farm workers and local contractors will have to change their skills base if they are to take advantage of these opportunities, or in some cases to survive where demands for previous occupations such as shearing are reduced.

Businesses in small towns such as Darfield will have to adapt their skills in response to the changes in land use and business opportunities in their surrounding area. Otherwise benefits are likely to flow mainly to Christchurch. New business opportunities will not be restricted to land based production either, as newcomers with new entrepreneurial skills take initiatives in other sectors such as rural tourism.

Overall, based on the projection of the pattern of land use after the scheme's commissioning described above, the following can be predicted as likely changes for the Central Plains area:

- ownership of land will be transferred to newcomers, although some established farmers will adapt by converting their properties to other forms of production
- local labour and businesses will expand their base of skills to take advantage of the new opportunities offered by dairying and intensive crop production (arable & process), however some opportunities will drift to outside the district
- rolls of schools will increase from the arrival of young families attracted by the expansion of dairying
- demand for social services will increase due to the population growth associated with the changes in land use.

The actual land use changes and social consequences of those changes, however, depend on many factors that are difficult to predict, including the extent to which the community manages the rapid transformation of its economic base and social organisation.

The social effects arising from this scenario of land use change are identified and discussed in more detail below, with specific points that describe anticipated effects for each theme.

The local business sector

Construction of the infrastructure for the scheme, and changes in land use of the area serviced by the scheme are likely to have flow-on effects for local business enterprises as well as firms in Christchurch and other centres in the region. The additional turnover for local firms providing goods and services for construction firms and their workers is likely to be limited in value and duration. More important are the additional sales that firms in Darfield, and other smaller townships, can derive from the increased productivity of the agricultural sector.

Those additional sales will allow local firms to expand their activities and employ more staff. A study of the intra-regional expenditure of Canterbury farmers (Agriculture New Zealand Ltd, 2001) found that about half of overall farm expenditure (working, capital and personal) in Central Canterbury[2] is disbursed in small towns in the region. Farmers commonly purchase the majority of direct inputs as close to the farm as possible, while services (both professional and semi-skilled) and capital items are purchased in Christchurch and Ashburton. Although dairy farmers incur a lower proportion of their expenditure in small towns than both arable and livestock farmers, they still have a major throughput on the local economy as their expenditure per hectare is much greater than their arable and livestock counterparts. The specific points raised about the local business sector include:

- the firm's present relationship with local farmers and their loyalty to that firm (this will not hold for newcomer farmers)
- the extent the local firm is dependent on the custom of local farmers for its financial viability
- type(s) of farm system (e.g. arable, dairy) the local firm provides goods or services to
- the availability of skilled labour to provide specialised goods and services (transport operators are reporting a loss of highly skilled drivers to the dairy industry)
- opportunities for firms not directly linked to the agricultural sector (e.g. hotels, food stores, service stations) to generate additional turnover in both the construction and operational phases of the scheme.

Employment

More intensive uses of existing land will provide increased employment both on farm and off-farm in the area of the proposed scheme. Cropping and dairying farms will require additional labour, and in the latter case many of the sharemilkers and other workers are likely to come from outside the district. There will also be some loss of employment, however, for shearers and other contractors who provide services to dryland livestock farms. The specific points raised about impacts on employment include:

- people resident in the area may lack the skills required by employers and may need to receive appropriate training, for example in dairy fam work, irrigation maintenance and building
- the type of employment provided to local residents should shift from casual to include more permanent jobs

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2 Between the Waimakariri and Rakaia rivers and including Banks Peninsula.

- on farm jobs such as farm maintenance, fencing, spraying etc will provide employment for local contractors
- the creation of jobs through the establishment of additional plants to process the expansion in farm production
- people attracted by employment opportunities in the area may choose to reside in Darfield and other rural townships.

The local economy

As mentioned under the section discussing the local business sector, the local economy is likely to share the benefits of an expansion in agricultural production. More extensive irrigation will allow farmers to reduce the fluctuations in their expenditure, and thus provide greater certainty for local firms that may wish to expand/change their activities to match the new requirements.

A specific negative impact could arise from the closure of Bush Gully Road within the Waianiwaniwa Valley which provides access to the forests of the Selwyn Plantation Board.

Access to the proposed coal mine of Kenroll Services is also from this road. The specific points raised about the local economy include:

- a consistent supply of water to more of the area’s farmers will enable them to achieve consistent levels of production and allow them to diversify into horticulture, different types of crops and seeds, and dairying
- consistent levels of agriculture production will stabilise the turnover of other rural businesses and enable them to create more jobs
- the more intensive use of irrigated land will increase the value of farm properties and reduce the amount of land available for subdivision into lifestyle blocks
- real estate sales face uncertainties associated with the siting of the reservoir and the route of the canals
- an expansion of dairy production in the area may drive up wage rates in other parts of the local economy (e.g. truck drivers)
- dairy farms require winter feed (e.g. barley) and dairy grazing which can be supplied by arable farms, allowing them to diversify
- the scheme could lead to heavy dependence of the local economy on dairy farming
- an inflow of sharemilkers and workers on dairy farms will generate extra expenditure in the rural townships of the area.

Community organisations

Community organisations often struggle to find sufficient volunteers to ensure their activities continue at a sustainable level. Since the agricultural reforms of the 1980's there have been greater demands on the time of farm women, who formerly provided much of the voluntary labour for community organisations. The increasing number of commuter, or lifestyle families, in much of the area of the scheme, has further restricted the activities of community organisations as these people often have a different sense of place from that of farming families. The specific points raised about impacts on community organisations include:

- the view of some residents that dairy farmers, sharemilkers and itinerant farm labourers are less likely to participate in community organisations than other people with agricultural occupations
- the increased population attracted by the scheme would provide more volunteers to serve in community organisations (e.g. the Fire Brigade, School Committees)
- the potential rejuvenation of sports clubs by newer arrivals belonging to a younger age group
- the potential conflict of values between incoming dairy farmers and pastoral/cropping farmers.

Services and schools

This theme is closely related to community organisations. It addresses the effects of the scheme on delivery of community and health services, school rolls and other aspects of educational activities and infrastructure. Changes in rolls between 1996 and 2005 for the nine schools in the scheme area show that while six of them have had increases in the number of their pupils, the remainder have experienced declines in their rolls. Furthermore, two other schools (Glenroy and Homebush) in the area closed during this ten year period. The specific points raised about impacts on services and schools include:

- school children from new families resident in the area will result in a growth in school rolls with a consequent increase in staff and funding
- an opportunity to create special roles for some of the area’s schools (e.g. develop a speciality for children from a rural background)
- an increased population attracting additional funding for the Malvern Health and Community Trust to improve district nursing services
- the facilities and services at Darfield Hospital would be better utilised by an expanded population
- the growth of Darfield’s population to 1,800 people will require an increase in the township’s water supply.

Scheme costs

This theme addresses issues concerning the affordability of the scheme (including the cost at the farm gate) and funding, management and shareholding arrangements. The specific points raised about costs include:

- whether the scheme should be operated and funded by a local authority trading enterprise or by a private irrigation company
- the savings of major reticulation and energy costs through a gravity feed system
- a concern that estimated costs for the development of the scheme may rise beyond its threshold of economic viability
- the scheme's economic viability may be dependent on high returns then available from current commodity prices
- the water from the scheme will be less expensive than from deep wells because of the electricity cost of the latter
- the need for financial support to meet the cost of the scheme for young farmers who are setting up their first farm.

Management of change

New land uses, newcomers and demographic change could initially destabilise the rural communities. The leadership role of families who remain, changing their own skills base and upgrading their existing production to effectively utilise irrigation, is critical during this interim period. They help to validate new land uses and maintain some sense of stability in the community, and are 'social anchors' for the emerging community. Furthermore, as noted, a stabilised or even increased population can have a positive impact on health services, local schools, sports and recreation facilities, and other social services, thereby strengthening the rural communities.

As the local labour supply, skills and businesses are not necessarily congruent with the new farming systems, the community and rural towns can miss out on the full economic and social potential of the new irrigation-based farming system. Irrigation and associated land uses will require a wider set of skills among farmers, farm workers, farming service providers and contractors, rural service providers and small business people. The wider community of Central Canterbury will therefore need to take specific steps to maximise the benefits of irrigation. These include:

- establishing where and how new labour demands will be met
- considering where and how accessible training and technological expertise are available to farmers, contractors and farm workers to adapt to the skill demands of new technologies and land use changes

- ensuring businesses such as building and irrigation contracting industries are prepared to take part in the on-farm construction stages of irrigation and dairy conversion, to maximise local employment and expenditure
- considering the wider entrepreneurial and business opportunities offered by irrigation
- establishing community mechanisms and partnerships for managing social change, such as a community trust.

8.11.1 Other effects

In addition to the social and economic effects of land use changes arising from accessing water from the scheme, there are a number of other direct and indirect effects that are anticipated. These effects, which were identified from our analysis of consultation records, meetings and interviews with key informants, and comparative cases have been organised into a number of themes below. Under several of these themes there is a list of specific points that describes the nature of the anticipated effects.

Canal Systems

The irrigation system will involve a large number of races crossing the plains. In particular the main headrace canal, gravity canal into Waianiwaniwa Valley and the outlet canal have only minor scope for relocating their position. It may be practicable to move the alignment east and west by up to 100 metres to avoid significant features, but this will not be sufficient for some properties to prevent them becoming divided by the canal. Allowances have been made in the cost estimates for bridge and culvert crossing of these canals.

There will be some people who will directly benefit from having the canal cross their property, due to the easy access to irrigation water. However, there are also likely to be other people with the canal on their property who do not receive such a benefit.

The distribution canals below the headrace have a much greater degree of flexibility as to their location. It would be likely that the existing routes of stock water races could be utilised in an expanded form. Some distribution races may be able to be located within the road reserve.

There will be a significant safety issue with major canals, in particular the outlet canal from the reservoir. At times this canal will have no water in it, and therefore appear safe. Shortly thereafter there could be 60 m^3/s flowing down it, which would be extremely dangerous for people and animals caught in it.

Works in River Beds

The river intakes will involve low level groynes to be constructed in the river bed to divert water into the intakes. The intakes themselves will have control gates within concrete structures. These may be seen not to fit in with the natural character of the braided rivers. The works away from the intakes will be across the flood terrace of the rivers and will not be conspicuous from within the river bed, but will be obvious from the top of the river terraces.

Archaeological sites

It is possible during the construction of the scheme that archaeological sites may be discovered. It will be essential to have in place protocols to deal with such finds. This is particularly so for Maori cultural sites. Tangata whenua have separately identified the need for protocols to be established in advance of any physical works undertaken.

Construction

There will be impacts from construction activities at the dam site and along the routes of the scheme on the environment, and the people and communities nearby. Experience with other dam construction projects shows that they can require considerable workforces, possibly requiring a construction camp or other temporary accommodation. The specific points raised about construction activities include:

- the construction of the discharge canal will have potential negative effects including noise and dust on the everyday activities of the residents of Coalgate
- stress from construction activities on near neighbours can be alleviated by a phased approach and keeping people informed
- there will be potential disruption of farm management and operations by construction activities
- increased demand for workers' accommodation will affect local communities
- increased heavy traffic volumes on local roads will have associated amenity and safety concerns.

Risks to residents

Some residents perceive risks from future natural phenomena to the operation of the irrigation scheme, and the safety of the dam and residents downstream of the outlet. The specific points raised about risks include:

- the options of tunnels through the Harper Hills, or culverts near townships, provide an opportunity to balance the reduced risk of canals failing against the increased cost of these alternatives
- the risk of an earthquake breaching the reservoir in the Waianiwaniwa Valley, or main outlet, and flooding the townships
- the low incidence of dam collapse in New Zealand
- the negligible risk of dam failure from flooding and overtopping due to the maximum probable rain event being able to be contained within the scheme's reservoir
- risk analysis will be undertaken as appropriate during the detailed design phase.

Site

There are concerns about the scheme and its operations, and its impact on local ecology near the storage dam or distribution channels. The specific points raised about the site include:

- the merits (or otherwise) of alternative sites for the reservoir
- flooding of the scheme's reservoir in the Waianiwaniwa catchment would render the habitat unsuitable for a major population of Canterbury mudfish
- dust blown by NW winds from the mudflats of the reservoir when it is drawn down in summer could affect residents of Whitecliffs, Glentunnel and Coalgate
- the route of the discharge canal and its effects on properties there.

Visual

The visual impacts of the irrigation scheme and the associated land use change on neighbours, recreational users and others include:

- the potential planting of trees around the reservoir
- the bed of the reservoir will not be clear of vegetation so it will not be a clean lake
- the loss of shelter belts on farms to accommodate central pivot irrigation, which can to some extent be mitigated with the planting of new varieties of trees that are quick growing.

Disadvantaged groups

Some groups of people in the area may be particularly disadvantaged by the scheme, and there are possible effects on their welfare. The specific points raised about disadvantaged groups include:

- the potential loss of amenity values for residents of the townships of Sheffield, Glentunnel, Coalgate and Hororata who have chosen to live there for lifestyle reasons
- concern that the costs of the scheme will be borne by residents of the townships and farms around the reservoir and canals while its benefits will accrue elsewhere
- the uncertainty associated with the scheme could influence the farm management practices of farm families with properties in the Waianiwaniwa Valley that will be inundated by the reservoir
- a possible increase in transport costs for farm families located to the north of the Waianiwaniwa Valley and the Selwyn Plantation Board whose present access to their properties is by roads that will be flooded by the reservoir.

Compensation

The theme of compensation is directly related to the groups of people identified as potentially disadvantaged by the scheme. There is a concern that compensation measures not only address issues concerning the market value of a farm property, but also recognise that other factors, such as changes in lifestyle and disruption to future plans and the effects on amenity values, need to be considered. The specific points raised about compensation include:

- the need to develop a fair mechanism to buy farm properties in the Waianiwaniwa Valley that will enable families to relocate;
- many residents of Sheffield, Glentunnel, Coalgate and Hororata are retired and could not afford to move to another settlement without some financial support if their property values fell unreasonably
- the issue of compensation must be settled without coercion or force being applied to those whose properties are required for the scheme
- the availability of insurance cover for a breech of the reservoir to the residents of the above three townships
- the guidelines for compensation should recognise that the level of financial reimbursement to property owners should be based on a range of factors not just property values
- the effect of the scheme in increasing a sense of uncertainty for farmers in the Waianiwaniwa Valley and residents of the townships.

Recreation

There are concerns about the effects of the scheme on recreational activities in the rivers from which the water is drawn. The storage reservoir has some potential as a site for recreational activity. The specific points raised about recreational activities include:

- the opportunities for recreational use (e.g. windsurfing) on the reservoir in the Waianiwaniwa Valley
- the limitations of the reservoir as a recreational space due to the seasonal fluctuations in water levels, particularly in the late summer
- the impact of water extraction from the Rakaia and Waimakariri Rivers and the concern of anglers that their recreational use of these rivers will be restricted by further reductions in water levels
- nitrification of surface water, effects on aquatic populations and the need to better manage the multiple use of surface water
- any restrictions on recreational during construction.

Recreational opportunities

Recreational opportunities exist for use of the reservoir as a contact recreation venue (sailing, rowing, kayaking, windsurfing, power boating, skiing, jet skiing, swimming) and possibly fishing, although the filling and emptying regime will mean that access for recreational purposes will be limited during the irrigation season, predominantly from December through to August. There is also an opportunity for white water kayaking on a purpose-built course on the reservoir outlet. Other recreational activities that could occur around the reservoir, head race and feeder canals are walking, running, tramping, cycling and mountain biking.

Existing canals in Mid Canterbury are used for swimming, canoeing, kayaking, multi-sports events and shooting of wild fowl. Non water based recreational activities include tramping along the canal banks, picnicking and photography. The canals are also an important source for fire fighting purposes.

There will be opportunities to provide recreational water bodies that are constantly full of water for the many of the above activities through the careful consideration of construction activities. The dam construction will require bulk excavation to obtain material for the dam shoulders. This provides an opportunity to take this material from down stream of the dam face, leaving behind a large hole that could be flooded for recreational use. A suitable location would be to the south of Homebush Road, where haul distances to the construction site and access to water from the headrace canal could easily be provided.

The system of canals will not be able to have vegetated sides as this may compromise the flow of water and the water tightness of the embankments. There will be opportunities for areas adjacent to existing streams to be developed as wetlands where bypass flows from the scheme could be discharged. Any direct augmentation of stream flows will require passing through land based systems such as wetland areas. Such areas provide habitat for a variety of bird species (including game birds) and an opportunity to enhance native plant species.

Water

Some stakeholders have concerns about the drawing of more water from the Rakaia and Waimakariri Rivers for use by the scheme, and the consequent effects on other users of the resource. These concerns include the effects of the scheme on drainage, and nutrient contamination of ground water and surface water both within the scheme's area and near Lake Ellesmere.

The specific points raised about water include:

- concern that the scheme may promote intensive farming methods that will impose an increased environmental burden on streams, aquifers and downstream properties, and particularly the effect on waterways and ground water of increased nitrate levels associated with dairying
- the potential effects on the quality (i.e. nutrients) and quantity of ground water available for farms near Lake Ellesmere

- the extent that nitrate leaching will be manageable and whether future environmental controls over pollution could limit the expansion of dairying
- the possibility that greater flows of water in the Selwyn River and other streams on the level of Lake Ellesmere may require more frequent openings to the sea which would impose an additional rate burden on about 50 lakeside properties
- concern that continued reliance on wells for irrigation may deplete the resource of ground water whereas the scheme could recharge the existing deep wells in the area
- the possible use of Lake Coleridge to provide an additional reserve of water for the scheme
- the effect of large scale extraction of water, and use for dairy farms, on the quality and quantity of the ground water source of the Kirwee township supply
- debate about whether Christchurch's water supply should be an issue for the scheme.

8.11.2 Conclusions

A major irrigation project such as proposed for the Central Plains involves several strands of direct and indirect social effects and broader social change. The nature of these social effects and changes will vary over the life cycle of the project, including the planning, construction and operational phases. The social effects include the longer-term changes associated with new forms of land use and economic activity, the effects of water extraction, effects of headworks such as the reservoir and canals, and effects of changes in water quality and quantity. However, the positive and negative social effects will not be evenly distributed. While there will be many potential benefits for the farming community, district and region, there are potentially a much smaller number of people who will experience most of the negative social effects.

Monitoring the social-economic outcomes of the scheme, from the point of view of farmers and their families, communities and other affected parties, will require the development of a more detailed profile of farmers and families in the area of the scheme. Additional information about water based recreation and effects may also be required once the water sources and scheme configuration put forward for consent applications have been confirmed. Further work is needed on mitigation strategies, especially for people and households directly affected by headworks, and local and stakeholder input should be sought to develop strategies as the design details evolve.

Managing the social effects of the scheme should enhance its contribution to social and economic wellbeing. It would therefore be useful to establish early on a system to manage the social effects of the scheme from a community perspective. This approach would recognise that the positive and negative effects will fall unequally. One option to investigate in this regard is formation of a community trust fund based on the capital value of the scheme and an ongoing contribution from scheme income. The fund would be targeted at community-level enhancement projects and developments.

Further public consultation is also vital. The Steering Committee and Consultative Working Party could be used as the basis for an ongoing community liaison forum once the project is under way.

8.12 Economic Effects

8.12.1 Introduction

An economic analysis of the proposed irrigation development was undertaken to assess the potential overall economic impacts of the project on the regional economy. Three measures were used in this respect, namely, output, added value and job. Output is more or less the equivalent of an industry's turnover or sales. Added value, on the other hand, excludes intermediate inputs (i.e. the products and services purchased from other industries) from the value of an industry's output and, thereby, it avoids double counting of economic activity. For example, in measuring the activity of the agricultural sector, it excludes the goods and services purchased from other industries such as road transport, fertiliser manufacture, business services. Added value is conceptually the same as Gross Domestic Product (GDP) which is the universally accepted measure of economic activity. It is noteworthy that added value includes salary and wage payments and profits before payment of interest and taxes. Therefore, the added value measure is relevant to an assessment of whether the proposed scheme will help improve the socio-economic well-being of society as distinct from determining whether the proposed resource allocation is economically efficient. While labour is a cost in economic terms employment is generally considered socially desirable and, therefore, it is also a useful measure in assessing socio-economic impacts. The analysis had regard to the backward and forward linkage effects of the scheme (I.e. the multiplier effects) in assessing the total impact on regional economic activity.

The scheme's intent is to irrigate about 60,000 ha of land. To assess the economic impacts of this, a number of assumptions were made. First, it was assumed that the total effective catchment within the scheme boundary is 85,000ha while there is a further 10,250ha outside this area whose economic return will be enhanced by irrigation of the land within the scheme boundary. This land will remain in dryland farming after the scheme is commissioned but at enhanced profit levels. Second, with respect to the 60,000ha target area, it was considered that as at the present date 22,000ha is in dairy units and hence already irrigated. Likewise, it is assumed that another 8,000 ha is running mixed farming systems of dairy support, arable sheep and beef and some deer and is also irrigated. Hence, in total it was assumed that approximately 50 percent of the direct target area (i.e. 30,000 ha) is currently under irrigation and therefore the scheme is replacing well water with surface water with respect to this land. Third, it is assumed that as a consequence of replacement of well with surface water that an additional 15,000 ha of irrigated land, within the scheme's catchment, will be irrigated. Hence, as a direct and indirect consequence of the scheme, the irrigated catchment area (well and surface) will increase to 75,000 ha. Thus, Including the 10,250 ha of associated dryland, it is assumed that around 85,000 ha of land will benefit from the scheme.

Fourth, it is assumed that the 75,000 ha of irrigated land will result in:

- 44,500ha in dairy

- 15, 250ha of intensive crop
- 10,250 ha mixed livestock dairy support and crop with a further 10,250 ha of dryland
- 5,000 ha of intensive stock finishing.

Fifth, it is assumed that new irrigated land will operate at the top end of performance levels reflecting the need for farmers to perform efficiently so as to service the debt levels that will incur as a consequence of the scheme's development. This assumption also allows for technological improvements and other profit enhancing factors that can reasonably be expected to occur following the scheme coming into effect.

The schemes capital costs are estimated as follows:

- Off farm works $6,200/ha
- On farm irrigation development $ 2,650/ha
- On farm associated development $ 550/ha
- Dairy specific $3,624/ha

The $6,200/ha is the April 2004 estimate of the initial cost to get water to the farm gate while $2,650/ha represents a typical cost for a Rotorainer or centre pivot system with surface water pumps. The allowance of $550/ha for on farm development costs is a typical costing after allowing for re-fencing, shelter (in and out), digger work, tracks and fertility enhancement. Other major on farm costs that are allowed for include additional livestock/working capital (particularly for arable) and plant and equipment (again for arable). For dairy conversion, dairy specific capital costs include the cowshed tracks, waste-water and housing.

An allowance of $112/ha is assumed for running costs and $150/ha for electricity costs.

Farm budgets were prepared for the farms within the scheme boundary pre and post irrigation and from this the incremental change in output, added value and jobs resulting from the irrigation scheme was derived. The flow-on impacts were assessed using regional multipliers derived from Statistics New Zealand's 1996 inter-industry study. It is likely that part of the increased output resulting from the proposed scheme will be processed resulting in additional impacts on the regional economy, i.e. over and above that generated by the expansion of agriculture. In this respect, conservative estimates (based on analysis of the 1996 inter-industry study) of the farm gate outputs that are likely to be processed were made. The inter-industry study was also used to derive regional processing multipliers.

8.12.2 Agriculture and associated processing impacts

Table 8-14 shows the annual estimated direct and indirect agricultural and processing impacts generated by the scheme once it is fully developed and operational.

Regional direct and indirect agricultural output is expected to increase by $357M per annum once the scheme is at full production. A proportion of this additional agricultural output will be processes and this is conservatively estimated to generate an additional $485M per annum. This is a combined increase of about $842M per annum. As a consequence of those output increases, direct plus indirect regional added value is estimated to rise by $353M per annum with agriculture contributing about $201M and processing $152M of that amount. Direct plus indirect employment is estimated to increase by around 2,500 jobs with around 1,100 of this increase being created by the expansion in agricultural output and about 1,400 from processing.

Table 8-13: Annual regional impacts of scheme at full production

Activity	Direct & indirect $M	Direct & indirect Added Value $M	Direct + indirect jobs
Agriculture	357	201	1078
Processing	485	152	1421
Total	842	353	2499

Table 8-15 shows the direct plus indirect output, added value and employment impact of the increased production created by the scheme over 38 years.

This period is made up of a three-year off-farm construction period followed by a 35 year water permit consent period, the maximum permitted under the RMA. The analysis assumed that on-farm construction would commence in project year three and continue for project years four and five. It was also assumed that agricultural output resulting from the scheme's capital expenditure would accrue one year after the completion of on-farm construction activity to which it related. Hence, it was assumed that full

Table 8-14: Accumulated direct indirect and added value

Year	Direct & indirect $M	Direct & indirect Added Value $M	Direct + indirect jobs
1 – 3			
4	281	118	833
5	562	235	1,666
6	842	353	2,499
7	842	353	2,499
8	842	353	2,499
9	842	353	2,499
10	842	353	2,499
11	842	353	2,499
12	842	353	2,499
13	842	353	2,499

Year	Direct & indirect $M	Direct & indirect Added Value $M	Direct + indirect jobs
14	842	353	2,499
15	842	353	2,499
16	842	353	2,499
17	842	353	2,499
18	842	353	2,499
19	842	353	2,499
20	842	353	2,499
21	842	353	2,499
22	842	353	2,499
23	842	353	2,499
24	842	353	2,499
25	842	353	2,499
26	842	353	2,499
27	842	353	2,499
28	842	353	2,499
29	842	353	2,499
30	842	353	2,499
31	842	353	2,499
32	842	353	2,499
33	842	353	2,499
34	842	353	2,499
35	842	353	2,499
36	842	353	2,499
37	842	353	2,499
38	842	353	2,499
Total undiscounted	**28,638**	**12,009**	**84,968**
NPV	**7,381**	**3,095**	

agricultural development would be reached in project year six. The results of those assumptions are shown in undiscounted and discounted values.

Discounting enables costs and benefits occurring at different points in time to be compared as it recognises the time value of money and, therefore, the fact that the value of money in the future is not the same as the equivalent sum of money now. For example, at 10 percent discount rate $1,000 in year 20 and year 30 is the equivalent of $164 and $63, respectively, in year 1. The effect of discounting is to give more weight to current rather than future financial flows. The sum of discounted costs and benefits is referred to as net present value (NPV). Selection of the discount rate tends to be problematic, but for the purpose of analysis of the scheme, 10 percent is used as this rate is commonly used in New Zealand with respect to public sector project evaluation. A lower discount rate increases NPV while a higher percentage reduces it.

Over the total analysis period, direct plus indirect agriculture and processed output increases by almost $29B ($7B NPV) and added value by $12B ($3B NPV). The incremental employment created by agriculture and associated processing is estimated at 85,000 job years over the total analysis period.

8.12.3 Scheme construction impacts

The scheme's off-farm and on-farm construction activities will also generate economic activity in the region. Table 8-16 shows the activity that the scheme's construction is estimated to directly plus indirectly sustain in undiscounted and discounted (NPV) values.

The scheme's total off-farm, on-farm (including associated) development expenditure is estimated at $699M. This estimate excludes capital expenditure on plant and equipment, livestock and purchase of Fonterra shares. The direct and indirect regional output generated by this expenditure is estimated at about $1.56B ($1.33B NPV) while the added value is estimated at $562M ($482M NPV). The regional activity created by construction is estimated to sustain about 6,100 job years of work.

Table 8-15: Construction impacts of proposed scheme

Year	Direct output $M	**Dir+ind $M**	**Added value**	**Dir+ind added value $M**	**Dir+ind jobs**
1	155	340	42	124	1342
2	155	340	42	124	1342
3	233	518	62	187	2031
4	78	178	20	63	690
5	78	178	20	63	690
6 – 35					
Total undiscounted	699	1555	185	562	6094
NPV	$600	$1,333	$159	$482	

8.12.4 Combined construction, agriculture and processing impacts

Table 8-17 combines the construction, irrigation and processing impacts for the analysis period.

The three year off-farm construction period and the following 35 year (maximum consent) period is estimated to directly and indirectly increase regional output by $30B ($7.4B NPV), added value by around $13B ($3B NPV) and to create 91,000 job years of work.

Table 8-16: Combined agriculture processing and construction impacts

Project year	Direct+indirect output $M	Direct+indirect added value $M	Direct+indirect jobs
-3	340	124	1,342

Project year	Direct+indirect output $M	Direct+indirect added value $M	Direct+indirect jobs
-2	340	124	1,342
-1	518	187	2,031
1	459	181	1,523
2	740	299	2,356
3	842	353	2,499
4	842	353	2,499
5	842	353	2,499
6	842	353	2,499
7	842	353	2,499
8	842	353	2,499
9	842	353	2,499
10	842	353	2,499
11	842	353	2,499
12	842	353	2,499
13	842	353	2,499
14	842	353	2,499
15	842	353	2,499
16	842	353	2,499
17	842	353	2,499
18	842	353	2,499
19	842	353	2,499
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24	842	353	2,499
25	842	353	2,499
26	842	353	2,499
27	842	353	2,499
28	842	353	2,499
29	842	353	2,499
30	842	353	2,499
31	842	353	2,499
32	842	353	2,499
33	842	353	2,499
34	842	353	2,499
35	842	353	2,499
Total undiscounted	30,193	12,570	91,062
NPV	7,433	3,040	

8.13 Transportation Effects

Transport issues relate to the Waianiwaniwa Dam and Reservoir footprints; the severance effects this causes to surrounding land; and issues relating to the headrace and the network of water distribution races.

8.13.1 Roading and Railway Hierarchy

Selwyn District Council identifies a roading hierarchy in the District, with the State Highways (SH 1, SH 73, SH 77) being managed as *Strategic Roads* managed primarily ensure safe and efficient flow of through traffic to its destination. Other roads, including *Arterial Roads*, and *Collector Roads*, are managed to provide the equally important functions of carrying 'through' traffic; providing access to properties; and providing pedestrian, cycle and stock access to properties.

8.13.2 Dam Area

Roads affected within the dam and reservoir area are:

- Malvern Hills Road from approximately 0.4km from SH 77 to approximately 1.7 km beyond the Malvern Hills Road/ Waianiwaniwa Road Intersection;
- All of Bush Gully Road;
- Approximately 1.9 km of Auchenflower Road from Malvern Hills Road; and
- Approximately 3.3km of Waianiwaniwa Road beyond the Malvern Hills Road/ Waianiwaniwa Road Intersection.

The dam and reservoir will reduce the access to the upper part of the Waianiwaniwa Valley and eliminate access to a number of properties bounding the shore of the proposed reservoir.

8.13.3 Midland Railway Line

The Midland line is the only rail link between Canterbury and Westland. Canal crossings are proposed near "The Oaks" southeast of Racecourse Hill and in Sheffield.

8.13.4 General Roading Network

State Highways consist of SH 73 as the link to the West Coast particularly between Darfield and Arthur's Pass, and SH 77 that links Darfield and Ashburton via the Rakaia Gorge. The headrace will cross SH 77 near the dam site, while SH 73 is crossed near "The Oaks' southeast of Racecourse Hill, and in Sheffield.

State Highways and Selwyn District Council Roads affected by the main canals include:

Table 8-17: Roads affected by the Scheme

Road Name	Road Hierarchy where defined in the District plan	Alternative link available	Comment
Steels Road	-	No. It provides access to Rakaia River	Road could be realigned parallel to the headrace
Rakaia Terrace Road	-	Yes	Headrace should be bridged to maintain network
Leaches Road	Arterial Road	Yes	Road is important link between Horarata and Rakaia Gorge particularly during Ski season.
Rockford Road	-	Yes	Headrace should be bridged to maintain network
Downs Road (1)	-	Yes, but would rely on Leaches Road or SH 77	Headrace should be bridged to maintain network
Downs Road (2)	-	Not close by	Road is an essential link between Horarata and Coalgate
Coal Track Road	-	Yes but only via unsealed roads	Road is an essential link
SH 77 Home Bush Road	Strategic Road	No. Not with lowering significantly level of service	Headrace must be bridged to maintain network
Rowallen Road	-	No	Road could possibly be realigned parallel to the headrace, but would also need to cross the Blacks Creek.
Deans Road	Collector Road	Yes but only via unsealed roads	Headrace must be bridged to maintain network
Cullens Road	-	Yes but partly via unsealed roads	Headrace could be bridged to maintain network
Clintons Road	-	Yes	Headrace may not need to be bridged but subject to tenure review
SH 73 West Coast Road	Strategic Road	Not a convenient alternative	Headrace must be bridged to maintain network
Loes Road	Status of road to be		

Road Name	Road Hierarchy where defined in the District plan	Alternative link available	Comment
	reviewed		
Auchenflower Road	Status of road to be reviewed		
Tramway Road	-		Headrace could be bridged to maintain network
Beak House Road	-		Headrace could be bridged to maintain network
Old West Coast Road	Arterial Road		Headrace must be bridged to maintain network
Un-named Road near Westwood	Status of road to be reviewed		This provides access to the Waimakariri River bed. Some access is needed
Malvern Hills Road (Sheffield)	-	Yes, but access is via ford on Bulls Road	Headrace should be bridged to maintain network
SH 73 West Coast Road	Strategic Road	Yes, but would not meet acceptable level of service	Headrace must be bridged to maintain network
Woodlands Road	-	Yes via unsealed road	Headrace could be bridged to maintain network
Keens Road	-	No	Headrace must be bridged to maintain access to farm
Hubicon Road	-	No	Headrace must be bridged to maintain access to farm
Un-named Road	Status of road to be reviewed	No	Access to Waimakariri River needed: Jet Boat facility

Lesser effects will result where the distribution network races need to cross roads in the district.

8.13.5 Traffic Safety

Traffic safety issues within Selwyn District can be assessed from the "Land Transport NZ Road Safety Issues Selwyn District" Report which contains Road Casualties details for 5years 2000 -2004. The major issues in Selwyn District were "poor observation", "rural intersections" and "loss of control on rural roads". Factors relating to crashes due to "poor observation" in order of frequency are crossing/turning, miscellaneous, bend-loss of control, straight-loss of control, overtaking, and head-on. Two fatal crashes occurred on roads that will be under pressure to take more traffic due to traffic being unable to exit from the lower part of Waianiwaniwa Valley.

8.13.6 Land Impacts at the Dam Site and Reservoir

The Scheme will affect land and roads in the Waianiwaniwa catchment and this will mean some upgrading of upper section of Waianiwaniwa Road and major works on Hartleys Road linking Whitecliffs and possibly Pig Saddle Road linking to Springfield. Both these roads are unsealed and in parts little more than single lane with steep sections of road and tight curves. The latter route is to a lower standard. Farms in the upper section of Waianiwaniwa Road will need these improvements to ensure stock trucks and school bus service can operate safely, or a road link around the new reservoir provided.

8.13.7 Land Take and Revised Access Requirements

Table 8-18 lists the properties affected by the land take and access requirements in the Waianiwaniwa Valley. For each affected land parcel, land will be flooded by the reservoir, and lost to a 20 m riparian strip around the maximum water level shoreline. In addition, some land parcels will lose their road access (known as severance) and new roads may need to be provided. This would result in an additional loss of land area for some land parcels. At this stage the exact locations of the new road accesses have not been determined, however an indicative location is provided in Figure 8-11.

Table 8-18: Land owners affected by land take and access requirements in the Waianiwaniwa Valley

	Ratepayer 1	Ratepayer 2	Land Parcel Number
1	Bennett William Lee		LOT 2 DP 23418 PT RURAL SECS 14669 16926
2	Broughton Gordon James	Broughton Barbara Jean	LOT 2 DP 83516 BLK IV HORORATA SD
3	Cant Alister Robert	Cant Dianne Katherine	LOT 1 DP 53640 BLK IV HORORATA SD
4	Couper Christian Lewis	Couper Mitchell Delves & Anr	LOT 1 D P 16593 BLK I HAWKINS SD
5	Deans James		LOTS 1-2 DP 27256 LOT 4 DP 16113 PT LOT
6	Deans Philip Russell & Jocelyn Lee	Saunders Geoffrey Childers	LOT 1 DP 354663

7	Duncan Forestry Ltd		PT LOT 2 DP 5478 BLK IV HORORATA SD -TNA
8	Edwards Feliciana Bonggo	Edwards Gefhel Bonggo	LOT 1 DP 23418 BLK IV HORORATA SD
9	Friedman Richard Henry	Friedman Anita Cheryl	LOT 2 DP 53818 LOT 1 DP 5922 BLKS I V HA PT LOT 1 DP 5092 BLK I HAWKINS SD LOT 1 DP 44223 BLKS I V HAWKINS SD
10	Gartery Winston John Arthur		PT LOT 3 DP 18019 BLKS IV HORORATA SD I
11	Gilmour Sandra Elizabeth		LOT 1 DP 44310 BLK IV HORORATA SD
12	Heddell Pastoral Ltd		LOT 2 DP 354663
13	Hidden Valley Timber Ltd		RURAL SEC 31493 PT RURAL SEC 31795 BLK I
14	Kirkstyle Farm Ltd		LOTS 2 5 PT 3 DP 16113 LOTS 1-3 RES 1600
15	Lucas Martin Freer	Lucas Annette Gay Lucas	LOT 2 DP 44310 BLK IV HORORATA SD BLK I
16	North Nelson Roland	North Suzanne Mary	LOT 2 DP 18018 PT LOT 3 DP 18019 BLK IV
17	Phillips Alfred William	Phillips Ina Mary	LOT 1 DP 83516 BLK IV HORORATA SD
18	Robertson James Murray	Robertson Maureen Ruth	LOT 2 DP 43008 BLK IV HORORATA SD BLK I
19	Robertson James Murray	Robertson Maureen Ruth & Craig M	PT LOT 2 DP 10959 SEC 1 SO 10809 LOT 1 D
20	Scott David Edward Hunter	Stanley Stewart Allan	RS 16824 16826 21078/9 PT RS 15017 15152
21	Selwyn District Council		LOTS 3-4 DP 53818 BLK IV HORORATA SD
22	Selwyn Plantation Board Ltd		PT LOTS 2-3 DP 6591 LOT 3 DP 8898 PT LOT

23	Slattery Anthony D, Shaun J & Peter F	Slattery Maria J, Christopher R & Botting A	LOT 1 DP 74641 BLK IV HORORATA SD BLK I
24	Tara Farm Ltd		PT LOT 2 DP 16550 PT LOT 1 DP 16113 BLKS RES 1871-1872 BLK VIII HORORATA SD
25	Thompson Brian Ivan		LOT 1 DP 72161 BLK IV HORORATA SD
26	Thornton Carol		LOT 1 DP 33885 BLK VIII HORORATA SD
27	Thwaites John Hugh Joseph		LOT 1 DP 53818 LOT 3 DP 16550 BLKS IV VI
28	Various		LOT 64 DP 1104 PT LOT 1 DP 3103 RURAL
29	Bennett William Lee		LOT 2 DP 23418 PT RURAL SECS 14669 16926

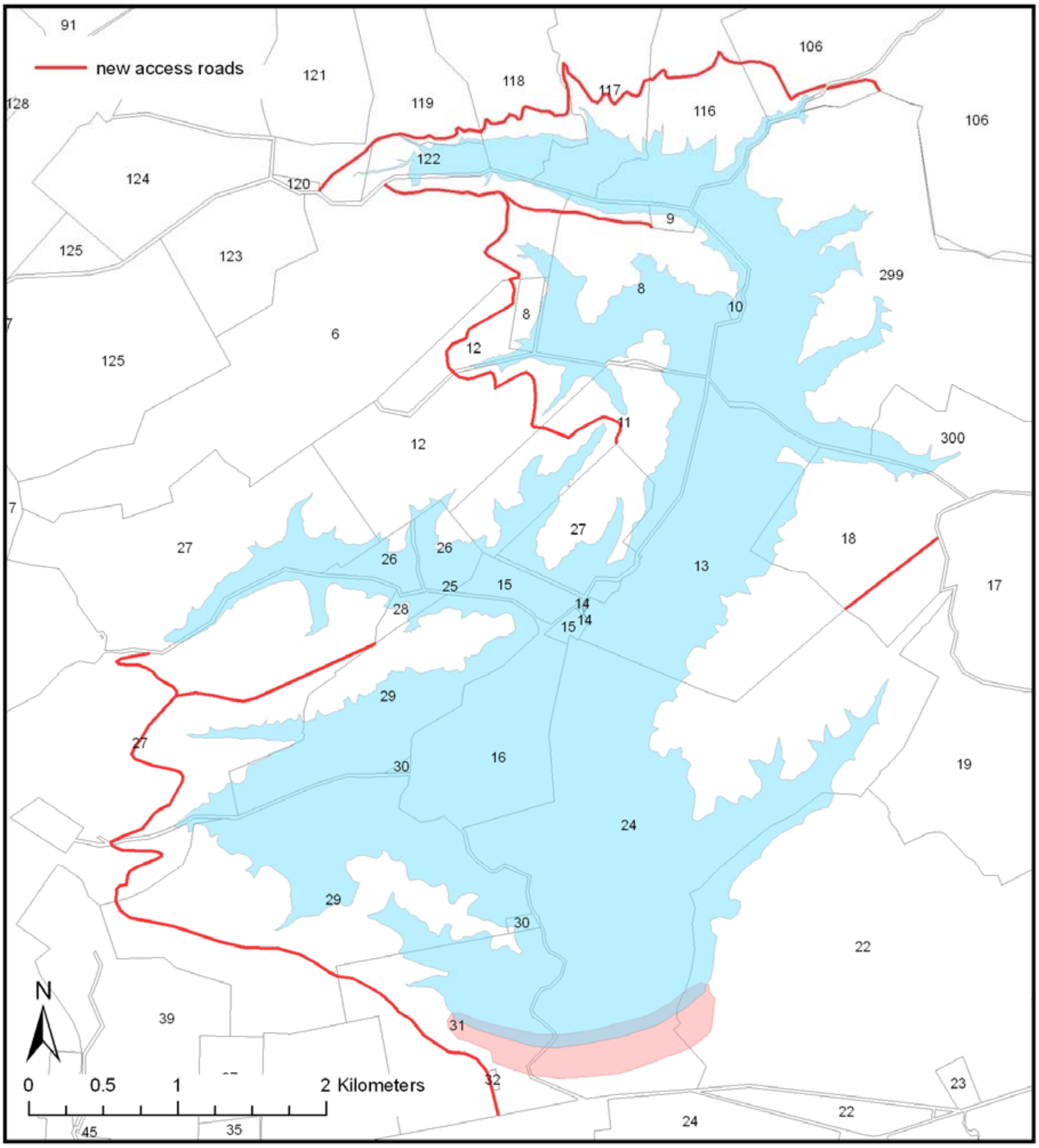

Figure 8-11: Land parcels affected by the Waianiwaniwa Dam and Reservoir (New access roads are shown for indicative purposes only.)

Table 8-19 below lists the roads that will be flooded by the Reservoir.

Table 8-19: Roads to be stopped or closed

Road Name	Length of road to be stopped or closed (km)	Comment
Malvern Hills Rd	9.9	Remaining 3 km of the road can be upgraded to provide access to Id 106 and further connect via Id 116, 117, 118 and 119 to Waianiwaniwa Road.
Auchenflower Rd	1.7	Remaining parts of the road can be upgraded to provide access to Id 18, 13 and 24 from Deans Road.
Bush Gully Rd	1.5	Road completely vested by reservoir.
Waianiwaniwa Rd	2.0	Road could be realigned along the northern shoreline across Id 119, 118, 117, 116 and 106 to provide connection to Malvern Hills Road.

8.13.8 Specific Roading/Rail Issues

- Headrace crossing at SH 73 and the Midland Rail Line by the “The Oaks’ southeast of Racecourse Hill and in Sheffield. The former site is located at a slight kink in SH 73, and is close to Clintons Road, the railway and a historic cottage, while the latter site is located within Sheffield close to buildings, an intersection and the railway. It will be essential that neither SH 73 nor the Midland Line is raised significantly at these crossings, as there is a need to maintain Safe Stopping Sight Distance (SSSD), Safe Passing Sight Distance (SPSD), intersection Entry Sight Distance (ESD) and clear zone distances to hazards. Specific criteria to be met are outlined in Selwyn District Rural Volume of Proposed District Plan: Notified September 2001 and in Transit New Zealand’s Standards and Guidelines Manual (SP/M/021), Planning and Policy Manual (SP/M001) and State Highway Geometric Design Manual (SP/M024).

- Construction activities will require encroachment agreements to occupy the highway, which will detail issues such as liability, cost contributions, construction and maintenance responsibilities. All temporary traffic control will be to the Code of Practice for Temporary Traffic Management and the expectations will be that traffic delays be kept to a minimum.

- Similarly Toll and NZ Rail Corporation will require deed of grant to occupy the railway reserve. They will have specific traffic control requirements and have strict criteria to minimise the track closures as the Midland line only occasionally can be closed due to the high freight cartage that is transported.