6.1 Project Area

This section describes the environment in which the proposed Central Plains Water Enhancement Scheme will be developed. Aspects to be covered include the natural and physical resources; ecosystems; communities; amenity values; and social, economic, aesthetic, and cultural conditions to the extent that these are likely to be affected by the proposed activities.

Taking a very broad view, the area affected by the project covers some 2,500 km^2 of central Canterbury, stretching from the foothills and inner margin of the plains southeast to the coast, and bounded to the north by the Waimakariri River, and to the southwest by the Rakaia River. Direct effects of the project will occur in the western half of this area in the parts of the rivers where the intakes are sited, where the reservoir is to be located in the Malvern Hills, and on the plains where irrigation will occur. This total direct scheme area covers about 1,200 km^2. Downgradient of this core area, parts of the surface and subsurface environments may be affected. These are the channels of the Rakaia and Waimakariri Rivers, the Selwyn River, Irwell River and other springfed streams that drain into Lake Ellesmere/Te Waihora, and linked to these surface features, the groundwater systems below the surface.

6.2 The Physical Environment

A number of discrete physical and natural environments are affected, and these are described below. The Rakaia and Waimakariri river environments will be affected by the water takes, and intake structures. Their immediate floodplain and valley areas will be affected by the headworks facilities, and headrace canal where it ‘climbs’ to the main plains surface. The Malvern Hills area will be affected by the inlet canal and tunnel, dam, and Waianiwaniwa reservoir. The inner Canterbury Plains will be affected by the headrace, and down the plains from this will be the network of distribution races and the land to which the water will be applied. Each of these environments will be described in terms of their topography, geology, geomorphology, soils, climate, and hydrology.

6.2.1 Waimakariri River

The Waimakariri River is one of the largest braided rivers in New Zealand, with a total catchment area of 3,654 km^2. It rises along the Main Divide of the Southern Alps, some 60 km to the north and northwest of the scheme area. It flows ~ 90 km through mountains, intermontane basins, and foothills ranges to issue out onto the inner Canterbury Plains at Otarama, just upstream of the proposed upper Waimakariri intake site. The catchment area above this point is ~ 2,200 km^2 and it is this area that supplies the river flow for the scheme’s intakes on the Waimakariri River.

Two intakes are proposed, and there will be associated headworks for each, and the intake canal and headrace will traverse the south bank to take these up onto the plains surface. The total length of the valley affected is ~ 21 km, from Otarama near the inner margin of the plains where the river emerges from the mountains, down to Bleak House Corner on the Old West Coast Road about 9 km southeast of Sheffield. In this stretch there are a number of significant features including the Kowai River entering from the true right at 3 km, the Gorge Bridge at 10 km, and Browns Rock at 13.7 km on the true left bank. The main channel of the river is constricted at each of these points as described below.

Valley Landforms

In the 21 km stretch that will contain elements of the scheme, the valley varies in width from 0.4 km to 3.1 km. It is entrenched 80 m below the main plains surface at Otarama, declining to about 50 m at the Gorge Bridge, and 35 m at Bleak House Corner.

The valley side landforms consist of steep terrace faces, in places rising to the main plains surface in a single step, while in others there are up to three flights of lower terraces before the main plains surface is reached. The inlet canal from the upper Waimakariri intake will traverse most of a single 80 m high terrace face for the first ~3.5 km, then cross a second ~20 m terrace face for the last ~2.5 km. The headrace from the lower Waimakariri intake will traverse a single 35 – 40 m high terrace face.

The valley floor varies in width from 100 m to 2.9 km, and consists of the main river fairway (described below), flanked in places by a floodplain and low terraces. The fairway occupies between 55 – 95 % of the valley floor, and for both the inlet canal and headrace traverses, it is at the base of the terrace. The rest of the valley floor is occupied by floodplain and low terraces varying from a few metres wide to 0.6 km across. The headworks (river works, gate structures, flushing basins, fish screens, return flow channels, and sediment settling basins) associated with the two intakes will be situated on the floodplain. The Kowai River enters from the true right 3.5 km northeast of Springfield. It has formed a large low angle alluvial fan 2 km across, extending out 1.4 km across the Waimakariri valley floor and constricting the main channel to a width of ~ 450 m. The inlet canal carrying water from the upper Waimakariri intake will cross this fan, and a settling basin is proposed for the northern side.

At the Gorge Bridge the valley narrows to 100 m where the river has had to cut through greywacke bedrock. The valley is constricted for about 1.2 km, before widening out again downstream. This will be the site of the lower Waimakariri intake.

There is a further partial restriction of the valley floor at Browns Rock on the true left bank about 4 km downstream of the gorge. This does not affect this proposal, but is the site of intakes for stockwater and irrigation schemes on the north bank of the Waimakariri River.

Channel Characteristics

The channel of the Waimakariri River is distinctively braided through most of the 21 km stretch affected by this proposal. However, there are several points where the channel is constricted for short sections, and the long profile of the river thus shows six separate reaches as follows.

- *Reach 1* is at Otarama where the upper Waimakariri intake will be located. This reach is the last kilometre or so of the long river reach where the Waimakariri has passed through the front ranges of the Canterbury High Country before issuing out onto the plains. In this reach the river transitions from a meandering to a braided channel. The siting of the intake in this reach takes advantage of the more stable form of the meandering channel.

- *Reach 2* is ~ 2.6 km long, and is fully braided, with channel width reaching 1.5 km. The main low flow channel has in recent years occupied the central parts of the fairway.
- *Reach 3* is a short ~ 2 km section where the braided channel is constricted by the Kowai River fan entering on the true right, and small bedrock outcrops of greywacke and basalt on the true left. These constrictions force the river into an 800 m long straight reach just downstream of the apex of the fan.
- *Reach 4* runs for about 6 km, and is fully braided and up to 1.75 km wide. Low flow is in multiple braids, and these hug the true right bank for some 3.3 km before swinging across the bed to the true left bank and becoming restricted to one or two main braids.
- *Reach 5* is a short gorge reach of about 1 km length, crossed by the Gorge Bridge. Flow is constricted to a 100 m wide channel by greywacke bedrock outcrops, and there are two channel meander bends. The lower Waimakariri intake will be sited in this reach, taking advantage of the stable channel bank on the true right side where flow is directed against the greywacke bedrock outcrop.
- *Reach 6* is downstream of the Gorge Bridge, and is a fully braided section, varying from 750 m to 1.9 km wide. At about 3.5 km downstream of the Gorge Bridge the river flows past Brown's Rock, which is composed of more compact gravels, and this has caused a small constriction in the valley floor.

The overall channel slope through the 21 km stretch is ~ 1 in 210, varying from 1 in 150 between Kowai River and the Gorge Bridge, to 1 in 275 just below the bridge.

Hydrology

Most of the flow of the Waimakariri River as it enters the scheme area is derived from precipitation in the upper catchment. In winter, much of this falls as snow, and this is not released to the river until the spring thaw. For this reason there is a strong seasonal pattern to the typical pattern of river flow, with higher flows from September – December as the snow melts. The summer/autumn months of February and March have the lowest flows. On top of this annual pattern are the flood flows that can occur at any time of the year in response to heavy rainfall in the catchment. The months with the largest floods are September – November, while February and March are least influenced by floods.

Table 6-1: Summary flow statistics for Waimakariri River at Old Highway Bridge

		Flows (m^3/s)	7 day low flow		Floods	
River (Site)	**Catchment Area (km^2)**	**Mean Flow**	**Mean annual**	**10 yr return period**	**Mean annual**	**10 yr return period**
Waimakariri (Old Highway Bridge)	3210	122	40.2	27.4	1495	2344

Source: http://www.ecan.govt.nz/Our+Environment/Water/Rivers/RiverFlows/North-low-flow-statistics.htm (accessed 21/10/05)

Table 6-1 summarises flow data for the Waimakariri River at the Old Highway Bridge site, which is ~65 km downstream of Otarama. Although this site is some distance away from the scheme area, it is considered to be a satisfactory approximation of the flow regime as no significant tributaries join the river as it flows across the plains, and there are assumed to be no major net losses or gains to groundwater over this reach. Mean flow of about 120 m^3/s varies between a 7-day low flow of 40 m^3/s and a mean annual flood of ~1,500 m^3/s.

The monthly pattern of flow is shown in Figure 6-1 The higher flows of September – December will be used to fill the Wainiwaniwa Reservoir, and this water will typically be used for irrigation during the months of lower river flow in February and March.

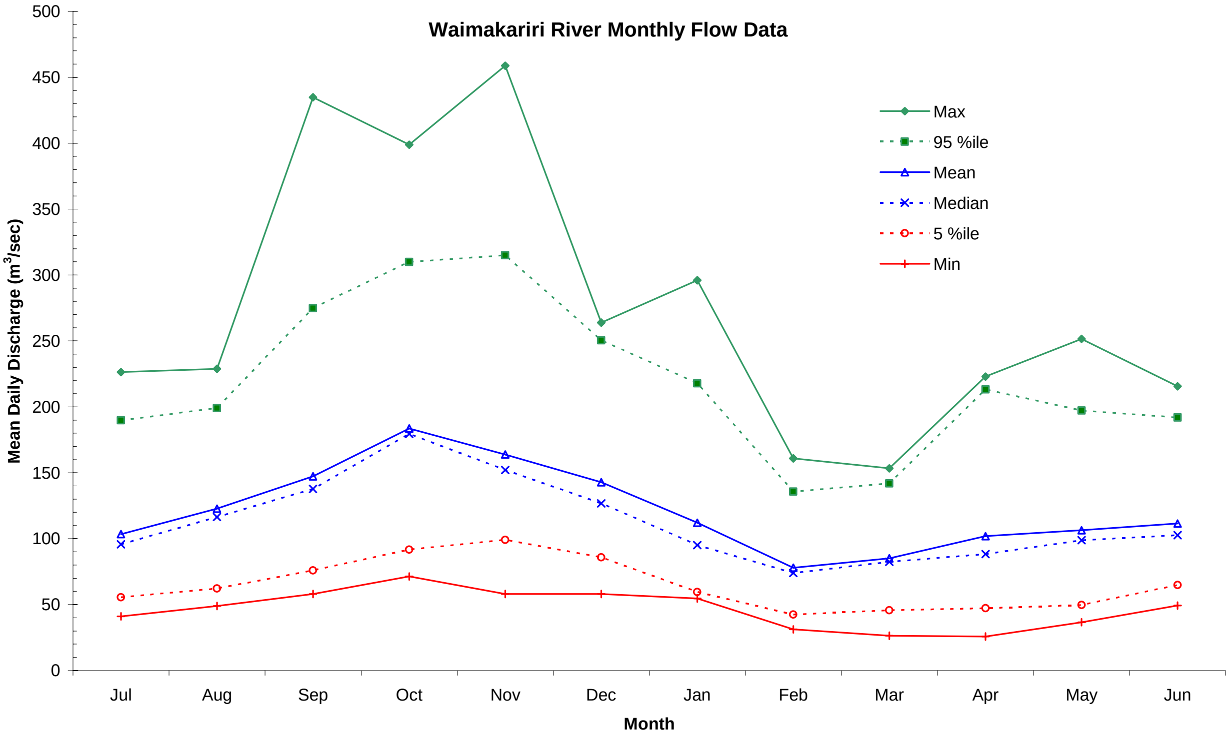

Figure 6-1: Mean monthly flows in Waimakariri River at Old Highway Bridge

6.2.2 Rakaia River

The Rakaia River is usually regarded as the largest unregulated braided river in New Zealand, and has a catchment area of 2,910 km^2. It rises along the Main Divide of the Southern Alps, some 75 km northwest of the scheme area. It flows ~ 85 km through mountains, broad intermontane basins, and foothills ranges and an associated gorge to issue out onto the inner Canterbury Plains just west of Windwhistle. The catchment area above the intake is ~ 2,600 km^2, and it is this area that supplies the river flow for the scheme's intake on the Rakaia River.

One intake is proposed with associated headworks, and the headrace will traverse the north bank to take the water up onto the plains surface. The total length of the valley affected is ~ 10 km, from 3 km north of the Highbank Power Station (which is across the river on the south bank), to map reference NZMS 260 L36: 141-328. In this stretch the river has a uniformly braided pattern.

Valley Landforms

The Rakaia River has cut a wide, straight valley through the plains surfaces along the stretch affected by the proposal. The valley widens gradually from 2 km to 2.6 km along this 12 km stretch. The main plains surface is about 100 m above the riverbed at the intake area, declining rapidly in 12 km to be only 35 – 40 m above the river where the headrace begins to flow north away from the river. The valley sides rise up to the plains surface through a series of terrace steps, and there will be four of these where the headrace moves out of the valley to flow north across the plains. Here the lower terrace is between 15 – 20 m high, while the upper ones are between 5 m and 10 m high.

The valley floor is up to 1.8 km wide, and is mainly occupied by the bare gravels of the braided river channel. In the first ~ 3 km of the affected reach the river flows against the base of the main terrace for about 1.7 km. Downstream of this are sections of farmed low floodplain and terraces up to 750 m across on both sides and the river.

Channel Characteristics

The non-flood channel of the Rakaia River flows in a mainly meandering reach for 8.5 km downstream of its gorge, entering its braided reach at about map reference NZMS 260 K36: 071-388. The proposed Rakaia River intake will be located within the last few hundred metres of the meandering section, which provides a more stable location for the structure. The river is uniformly braided throughout the 12 km stretch affected by the proposal, and unlike in the Waimakariri River there are no constrictions to the flow. The active floodplain varies in width from ~ 650 m to 1.5 km, with the main belt of low flow braided channels varying in width from ~350 m to 1.5 km across.

Hydrology

Although the Rakaia and Waimakariri Rivers drain adjacent Southern Alps catchments of similar size[*] there are differences in their hydrological characteristics. The catchment areas above the scheme intake points are ~2,200 km^2 of the Waimakariri River, and 2,600 km^2 for the Rakaia River, yet the mean flow in the Rakaia is 221 m^3/s, almost 100 m^3/s more than in the Waimakariri River. This probably is an orographic effect as the Rakaia catchment drains higher mountains containing a significantly greater area

[*] The catchment areas shown in Tables 6-1 and 6-2 suggest the Rakaia has a smaller catchment. This reflects the location of the flow gauging stations, with the Waimakariri recorder located only 5 km from the mouth, while the Rakaia recorder is 65 km from the mouth. However, no significant tributaries join either river in their lower reaches, and the two sites are considered to appropriately represent the flow as it passes the intakes for the Central Plains Water Enhancement Scheme.

of glacier ice. Thus, the snowmelt season in the river is one month longer, and peaks two months later. October – December are the months most affected by floods, while February and July – August are least affected by floods. The season of low flows can last from February to September.

Table 6-2: Summary flow statistics for Rakaia River at Fighting Hill

River (Site)	Catchment Area (km^2)	Flows (m^3/s) Mean annual	7 day low flow Mean annual	7 day low flow 10 yr return period	Floods Mean annual	Floods 10 yr return period
Rakaia (Fighting Hill)	2626	221	92	76	2514	3701

Source: http://www.ecan.govt.nz/Our+Environment/Water/Rivers/RiverFlows/North-low-flow-statistics.htm (accessed 21/10/05)

Table 6-2 summarises flow data for the Rakaia River at Fighting Hill, which is near the upstream end of the Rakaia Gorge, about 18 km upstream of the intake sites. Although this site is some distance away from the scheme area, it is considered to be a satisfactory approximation of the flow regime as no significant tributaries join the river downstream of here, and there are assumed to be no major net losses or gains to groundwater over this reach. Mean flow of 221 m^3/s varies between a 7-day low flow of 92 m^3/s and a mean annual flood of 2,514 m^3/s.

The monthly pattern of flow is shown in Figure 6-2. The higher flows extend from October to January, with lower flows persisting from February through to September.

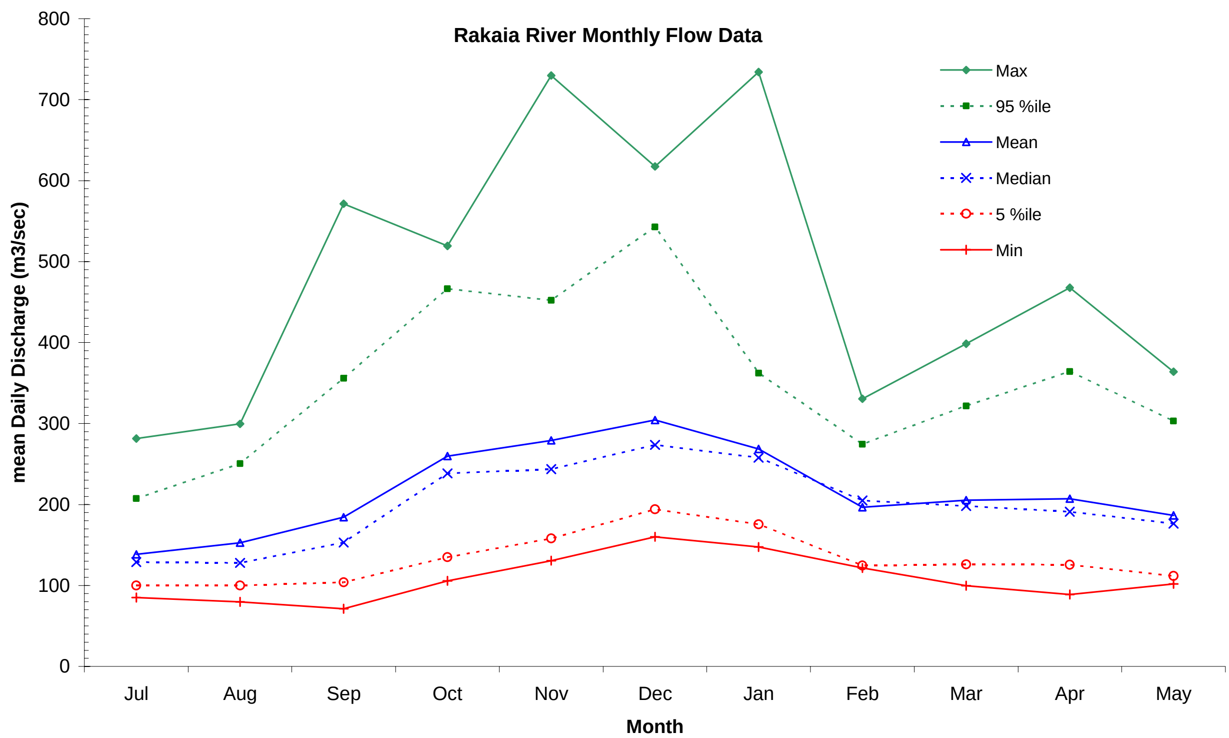

Figure 6-2 Mean monthly flows in Rakaia River at Fighting Hill

6.2.3 Waianiwaniwa Catchment

The Waianiwaniwa catchment is in the eastern Malvern Hills, and the lower part of the valley will be the site of the proposed Waianiwaniwa Dam and Reservoir. The catchment is roughly circular and covers about 55 km^2, with a high point of 807 m in the northwest corner in the Wyndale Hills, and a low point of ~ 235 m where the river leaves the hills to flow out onto the inner Canterbury Plains. This is a part of the landscape that will be significantly affected by the Central Plains Water Enhancement Scheme. The dam and reservoir together will cover about 12 km^2, which is 22 % of the catchment area.

Waianiwaniwa Valley Landscapes and Rock Types

There are three main landscape types in the catchment: steep higher elevation ridges, rolling hills and tablelands, and valley floor, with characteristics related to the underlying geology.

Steep ridges occur along Cairn Ridge in the centre of the catchment, the Wyndale Hills, and the adjacent east-west trending ridge along the northern catchment boundary. They cover about 17 km^2, and are the highest parts of the catchment, underlain by greywacke and argillite of the Torlesse Complex Terrain. These hard rocks typically rise to elevations of 400 – 500 m asl, and reach 807 m in the Wyndale Hills in the far northwest of the catchment. Here the hills are up to 500 m above the valley floor, although elsewhere they are lower at 150 m – 250 m above the valley.

Rolling hills and tablelands occupy most of the catchment area, covering some 31 km^2, mainly in the central, south, and eastern parts. Elevation is at between 250 – 400 m asl, which is up to 150 m above the valley floor. The rolling hills are underlain by Tertiary coal measures on either side of Bush Gully in the central part of the catchment. The more widespread hills with tablelands at ~ 320 – 350 m asl are underlain by weathered gravels of the Hororata Formation. The rolling hills result from erosion of the underlying coal measures, while the tablelands represent depositional surfaces relating to periods of cold climates during glacial advances in the nearby Rakaia valley. The lower slopes of the rolling hills and tablelands will be inundated by the waters of the Waianiwaniwa Reservoir. At the maximum depth near the dam, about 50 m elevation could be affected, but away from here only the lower 25 m or less will be flooded.

Valley floors occupy about 7 km^2 along the Waianiwaniwa River and some of its tributaries. At the widest point the valley floor is 1.5 km across, but for most of its ~12 km length it is 400 m – 500 m wide. Elevations are between 235 m and 320 m asl. It is underlain by gravel deposits, most of which were laid down during the Last Glacial Maximum about 20,000 years ago, and reworked since then by floods mainly in areas close to the present channel. It is the valley floor area that will be flooded by the reservoir, which will extend for about 9 km up valley from the dam, inundating approximately 6 km^2 of this landscape type.

Waianiwaniwa River

The Waianiwaniwa River is a 33 km long tributary of the Selwyn River. It flows through the Malvern Hills before issuing onto the inner Canterbury Plains 1.6 km northeast of Coalgate. The channel carries water through the hills, but on the plains flow is subsurface, although during floods the surface channel will carry water.

Through the Malvern Hills the river flows east-northeast before turning to flow south towards Coalgate. It is less than 10 km from the top of the catchment to its outlet past the Homebush Ridge, but the valley length is 14 km. The channel is distinctively sinuous, following a tightly meandering course of ~ 2 km for each 1 km of valley length. The channel is 2 – 5 m wide, and entrenched ~ 3m below the floodplain. There are 10 left bank tributaries draining well defined valleys 2 – 5 km long. There are only 5 right bank tributaries, although these drain the same total area as the more numerous left bank streams. The main right bank tributaries are Bush Gully (6.5 km long), an unnamed valley on the north side of Cairn Ridge (5.5 km long), and Oyster Gully (3.75 km long).

Waianiwaniwa Valley Land Uses

The main land use in the valley is for pastoral farming, with the river flats comprising the most fertile soils and productive land. There are also ~ 12 km^2 of plantations. Over half of this is in the Coalgate Forest (3.6 km^2), Wyndale Hills (2.0 km^2), and along Pig Saddle Road (1.1 km^2). The remainder is in about 40 patches varying in size from 0.7 km^2 to 2 ha.

The Tertiary coal measures in the central part of the catchment have been mined for coal. Five mines are mapped along Bush Gully, but only one is still actively worked.

6.2.4 Other Minor Rivers of the Foothills

A number of other rivers will be affected by the Central Plains Water Enhancement Scheme, although to a very minor extent. These are the Hororata and Hawkins Rivers, which along with the Waianiwaniwa River are tributaries of the larger Selwyn River. These drain the Malvern Hills and Big Ben Ranges that form the foothills and front ranges of the Southern Alps to the northwest of the scheme area. These carry water in their upper reaches, but for most of their courses they only have intermittent surface flow as water travels via subsurface pathways. The Kowai River is a tributary of the Waimakariri River, and this will also be affected by the scheme.

Selwyn River

The Selwyn River rises in the 1,600 m high Big Ben Range some 24 km northwest of Coalgate. It is fed by tributaries from the north slopes of the Harper Hills, and the central Malvern Hills, and has a catchment area above Coalgate of 235 km^2. Flow is monitored at Whitecliffs, 6.5 km west-northwest of Coalgate, and at Coes Ford near Leestonand summary flow statistics are shown in Table 6-3.

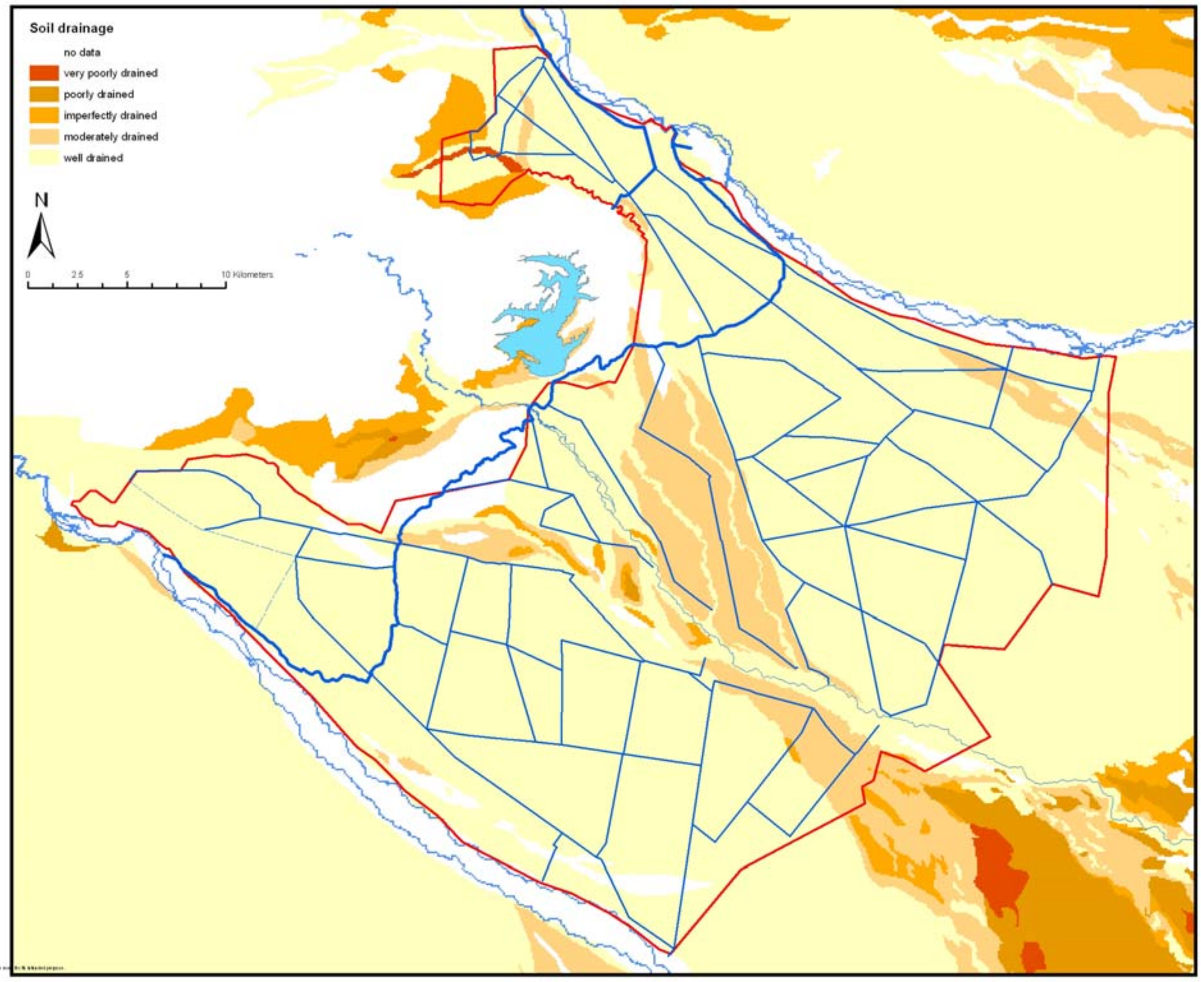

FIGURE 6-11: Soil drainage in CPWS area

Downstream of Coalgate it flows out onto the Canterbury Plains and follows a 53 km long course southeast to Lake Ellesmere. It follows the junction of the huge coalescing alluvial fans built up by the Waimakariri and Rakaia Rivers, and for much of this distance it flows below ground except during floods. Permanent flow returns to the channel about 15 km from the lake, and the flow statistics for the Coes Ford monitoring station (7.3 km from the lake) are shown in Table 6-3.

Table 6-3: Summary flow statistics for Selwyn River

		Flows (m^3/s)	7 day low flow		Floods	
River (Site)	**Catchment Area (km^2)**	**Mean Flow**	**Mean Annual**	**10 yr return period**	**Mean Annual**	**10 yr return period**
Selwyn (Whitecliffs)	164	3.3	0.80	0.58	79	152
Selwyn (Coes Ford	678	3.3	0.63	0.31	156	338

Source: http://www.ecan.govt.nz/Our+Environment/Water/Rivers/RiverFlows/North-low-flow-statistics.htm (accessed 21/10/05)

The scheme will affect the Selwyn River in a number of ways. The headrace will cross the channel near Coalgate via an embankment and siphon. Further downstream on the plains there will be a number of bywash wetlands within the scheme area. Outside of the scheme area there may be effects on the lower channel where increased groundwater flow may add to the discharge in the channel and increase the permanently wetted channel length.

Hororata River

The Hororata River rises in the 950 m high Rockwood Range 21 km west-northwest of Hororata, and receives tributaries from the south facing slopes of Harper Hills, and western Malvern Hills. The catchment area above Hororata is 95 km^2, and the river flows a further 17 km southeast across the plains before joining the Selwyn River. Most of its ~40 km course is across the plains, and there is only permanent flow in the upper 10 km.

The scheme only affects the Hororata River where the headrace crosses it near the western end of the Harper Hills. There will be a siphon beneath the river, and possibly a short section of embankment.

Hawkins River

The Hawkins River rises in the 1,200 m high Russell Range, 10 km west of Springfield, and receives tributaries from the north slopes of the east and north Malvern Hills. The catchment area above Sheffield is ~ 120 km^2, and it flows a further 27 km south from here to join the Selwyn River. As with the other foothills rivers, it is dry through much of its course for most of the year.

The scheme only affects the Hawkins River where the inlet canal from the upper Waimakariri River intake crosses it at Sheffield. There will be a short section of embankment and a siphon beneath the channel.

Kowai River

The Kowai River rises in the ~ 2,000 m high Torlesse Range, and receives tributaries from the north Malvern Hills. Its catchment area is 155 km^2. It will be affected by the scheme at a point less than 2 km from its confluence with the Waimakariri River, where the inlet canal from the upper Waimakariri River intake will cross beneath the channel in a siphon.

6.2.5 Central Plains

The Central Plains Water Enhancement Scheme area occupies the Canterbury Plains between the Waimakariri and Rakaia Rivers between the foothills, and State Highway 1. This area has distinctive physical characteristics that will influence the detailed design of the water distribution network of races. The plains here can be divided into two groups, separated by the Selwyn River. The northern half comprises the Waimakariri Plains and the southern half the Rakaia Plains.

Waimakariri Plains

The Waimakariri Plains cover about 530 km^2 between the Waimakariri and Selwyn Rivers. At their highest point next to the Kowai River they are 380 m asl, sloping down to 65 m asl at the Selwyn River 42 km south-southeast. The northern 105 km^2 centred on the township of Sheffield will be irrigated from a pumped supply taken from either the upper of lower Waimakariri River intakes. The bulk of the area, covering 425 km^2 and centred on Darfield, will be irrigated by gravity supply from the headrace.

This part of the Central Plains was formed by the Waimakariri River depositing gravel and sand material during multiple cold climate periods associated with glacial advances in its upper catchment. At its maximum extent the glacier reached onto the inner plains margin, probably more than 500,000 years ago. During the glacial advances the Waimakariri River was vigorously aggrading and depositing gravel to build up huge low-angle alluvial fans. The smaller foothills rivers were also more active and aggrading their beds. In addition, large quantities of glacially-derived silt were blown from the braided river beds and deposited as loess on the surrounding landscape, in particular on the southern bank of the river carried by northwest winds.

Remnants of the earlier alluvial fans occur in terraces in the Sheffield Plains area (Woodlands Formation), and in the eastern Malvern Hills (Hororata Formation). Subsequent glacial advances were less extensive, but the Waimakariri River was vigorously aggrading and the bulk of the alluvial fan deposition that formed the Darfield Plains occurred in the most recent the Last Glacial Maximum between about 50,000 and 20,000 years ago. These gravels are known as the Windwhistle and Burnham Formations. They have subsequently been reworked in areas alongside the Waimakariri River, and the Hawkins, Waianiwaniwa, and Selwyn Rivers, and this younger material is known as the Springston Formation. There is about 1 m of loess on the older Windwhistle surface, about 0.7 m on the Burnham surface, but very little on the Springston surfaces.

The central swathe of the scheme area passing southeast through Darfield is underlain by the Windwhistle Formation, and it is flanked to the northeast and southwest by the Burnham Formation. Together, these surfaces comprise about 80 % of the area of the Waimakariri Plains. The Springston Formation occupies narrow strips along the Hawkins and Waianiwaniwa Rivers, and a larger area in the northeast corner of the scheme area.

Rakaia Plains

The Rakaia Plains cover about 500 km^2 between the Rakaia and Selwyn Rivers. At their highest point near Windwhistle they are ~ 450 m asl, sloping down to 65 m asl at the Selwyn River 44 km southeast. The northern 115 km^2 around Windwhistle will be irrigated from a pumped supply taken from the Rakaia River intake. The bulk of the area, covering 385 km^2 and centred on Te Pirita, will be irrigated by gravity supply from the headrace.

The formation of the Rakaia Plains was very similar to that described above for the Waimakariri Plains, although the character of the plains is slightly different here. The Rakaia Glacier was larger and extended onto the inner plains margin more extensively during the earlier glaciations. Deposits of the Woodlands formation are widespread west of Hororata, and include large areas of moraine. Younger Windwhistle

Formation moraines and outwash surfaces also occur extensively closer to the Rakaia Gorge. Together, these formations underlie all of the Windwhistle Plains.

To the southeast, the Windwhistle Formation is not extensively preserved, and the main Te Pirita Plains area is underlain by the younger Burnham Formation. The Springston Formation underlies about 20 % of the plains in a strip along the north bank of the Rakaia River. The Rakaia Plains lie on the north or up-wind side of the river, thus loess deposits are not as thick as on the Waimakariri Plains.

Lower Plains

The southeastern boundary of the scheme area runs approximately along State Highway 1, and the plains surfaces continue downgradient for 15 – 24 km to the coast and Lake Ellesmere. The overall topography of these lower plains continues from the Rakaia and Waimakariri Plains described above. However, almost all of the area is underlain by the younger Springston Formation gravels.

6.2.6 Lowland Spring-fed Streams

The Selwyn River flows across the lower plains as described above. A number of other small streams and rivers rise in springs in the lower plains and flow to Lake Ellesmere or the Pacific Ocean between the lake and the Rakaia River. These may be indirectly affected by the Central Plains Water Enhancement Scheme.

The use of water for irrigation within the scheme area will result in some leakage to the groundwater table, enhancing the discharge through this system, which flows downgradient towards the coast and Lake Ellesmere. Some of this water emerges at the surface in springs before it reaches the coast, and these form a distinctive element of this part of the lower Canterbury Plains. Several hundred springs occur in an irregular arc around the western and northern shores of Lake Ellesmere, and these feed numerous small streams. The springs form a band about 5 km wide extending north from near the Rakaia mouth to Dunsandel, and then east to Lincoln, and north to Halswell. This band of springs is mostly within 6 to 16 km of the lake edge, and there are only scattered springs between it and the lake.

The largest of the lowland spring-fed streams is the Irwell River, which rises to the northwest of Dunsandel. It starts about 1 km south of the Selwyn River, and flows in a sinuous course some 23 km to enter Lake Ellesmere 6.5 km south of the Selwyn mouth. Along its course it is joined by a number of short spring-fed tributaries.

There are numerous other shorter streams flowing from this band of springs in the 10 – 15 km arc around the western and northern shores of Lake Ellesmere. These include Birdlings Brook, Boggy Creek and Wood Creek that flow into Lake Ellesmere west of the Selwyn River; and the L11 River that rises near Lincoln, and enters the lake just east of the Selwyn mouth. All of these streams are downgradient of the Central Plains irrigation area, and may experience enhanced flows due to elevation of the groundwater table in this area.

6.2.7 Lake Ellesmere / Te Waihora

The final downgradient surface water feature that may be affected by the scheme is Lake Ellesmere/Te Waihora. This 18,900 ha (at 0.8 m asl) brackish lake is about 1.4 m deep, and it overlaps the eastern ends of the southern part of the Waimakariri fan, and the northern part of the Rakaia fan.

The surface catchment of the lake covers some 2650 km^2, and extends from the foothills and front ranges of the Southern Alps in the northwest, to parts of Banks Peninsula in the southeast. The main river draining into the lake is the Selwyn, and this catchment occupies nearly 60 % of the lake's catchment area.

Inflow to the lake is derived from the sources listed in Table 6-4.

Table 6-4: Mean Inflows to Lake Ellesmere*

Source of Inflow	m^3/s	% of Total
Permanent rivers, streams and drains	*12.3*	61.0
Rainfall on the lake	*3.6*	18.0
Seawater from artificial openings	*2.4*	14.6
Seawater overtopping Kaitorete Spit	*1.3*	6.0
Groundwater	*0.1*	0.4

*Data from Crawford *et al* 1996

Mean total inflow is estimated to be 19.7 m^3/s, varying through the years from 10.9 m^3/s in February, to 31.76 m^3/s in August. Except for brief occasions during floods when there is flow along the whole length of the Selwyn River, the permanent rivers, streams and drains flowing into the lake are fed from groundwater, either as springs in the zone of springs that occurs around the lake margin, or from the re-emergence of the Selwyn in its lower channel reaches. A study of the age and origin of groundwater in the Central Plains (Stewart *et al*, 2002) showed that this groundwater has several sources. Small amounts at the northeastern and southwestern ends of the lake come from the Waimakariri and Rakaia Rivers, while the bulk of the water derives from rainfall infiltration on the plains, or seepage from the Selwyn River. The age of the groundwater shows a general increase down the plains, and with depth below the surface. Close to Lake Ellesmere, ages can be greater than 60 years. Further up the plains groundwater from the Waimakariri and Rakaia Rivers is about 25 years old, while the average age of Selwyn and rainfall-derived groundwater is around 40 years. These ages may have ramifications for the length of time that groundwater quality effects may take to be seen in the lower plains area and Lake Ellesmere.

The inflows of water to the lake carry a variety of dissolved constituents and suspended particulate matter that affect water quality in the lake. These include nitrogen, phosphorus, micro-organisms, and suspended sediment. The nutrient status of the lake has been assessed in detail by Ward *et al* (1996), who point out the difficulties encountered in standard assessments based on nutrient concentrations and algal biovolume. From these the lake can be classified as highly eutrophic, but the expected undesirable features associated with such a condition do not occur. Total nitrogen (TN) and total phosphorus (TP) are regularly monitored in the lake. Site CRC300954 is in the centre of the lake and has been sampled on a monthly basis since 1996. This shows a mean TN concentration of 2.33 g/m^3, and a mean TP concentration of 0.27 g/m^3. Interestingly, the concentration of TN rose through the late 1990s, peaking at 7.5 g/m^3 in August 1999. Since then TN has followed a declining trend, and from mid 2001 it has fluctuated in a fairly narrow range of 0.75 – 3.1 g/m^3. Variations in TP have been less dramatic, although it too has since 2001 fluctuated in a narrow range of between 0.02 – 0.37 g/m^3.

Significant aspects of the physical environment of the lake and its catchment are the inter-related issues of river flooding, lake level variations and its outlet to the sea. There is no natural permanent outlet for the lake, and without any human intervention, the lake level would have to rise to about 4 m above sea level before it breached the narrow part of the spit in the southern corner of the lake. A typical lake level is about 0.8 m above sea level, and at this stage the lake area is around 19,000 ha. However, by the time the lake level has risen to 2.7 m asl, it covers over 30,000 ha and floods low-lying land. Historically, high lake levels threatened the Maori settlement at Tuamutu Pa, and since European settlement high water levels have threatened farming operations on low-lying land right around the lake. Therefore the lake has a long history of being artificially opened. Maori used to let the lake out every 2 – 3 years, and this was recorded in the 1850s and 1860s. In 1868, the first opening by Europeans occurred, and since then openings have been made every year. Once heavy earthmoving machinery was available, mouth openings were more frequent, and since 1947 there has been an agreed regime of lake levels and opening times. Between 1945 and 1993 there were on average 3.3 opening per year (maximum 7, minimum 1), and lasting on average from 3 – 4 weeks.

Changes in the groundwater flow regime resulting from the Central Plains Water Enhancement Scheme may increase groundwater inflows to Lake Ellesmere, and this in turn may affect the regime of lake level fluctuations, and the need for outlet openings.

6.3 Groundwater Systems

The groundwater environment of the Central Plains region will be affected by the proposed water enhancement scheme, both in terms of water quantity, and water quality, within the scheme area, and in the lower plains area downgradient of the scheme. It is therefore necessary to describe this groundwater system, both in terms of water quantity, and water quality. The information discussed below on the groundwater systems of the Central Canterbury Plains was supplied by Aqualinc (2005b).

A great deal of information on Canterbury groundwater resources has been collected over many decades, and most of this is held by the Canterbury Regional Council in a number of databases. To make sense of the large amount of information, it is appropriate to develop computer models of the groundwater systems, in particular making use of Geographic Information System (GIS) techniques. Aqualinc (2005a) have developed such a model, and they have updated and extended this to develop an understanding of the groundwater system for this proposal. Details of the modelling processes are found in their report (Aqualinc, 2005b). The following information is taken from that report, and includes a description of the modelled present groundwater table level, trends in water levels over time, and water quality status and trends.

6.3.1 General Hydrogeological Setting

The Canterbury aquifer system is complex, and has been deposited primarily by fluvial action and subsidiary aeolian processes. This has resulted in distinct layers of water bearing aquifers and aquitards varying in thickness and extent. The aquifers generally extend from the foothills of the Southern Alps through to the ocean. The precise mechanism of discharge of the deeper aquifers at the coast is uncertain, but a combination of the following two mechanisms is likely to occur (Brown *et al.,* 1995):

- The deeper confined aquifers extend past the coastline and discharge into the ocean via lateral flow off the continental shelf located about 40 km from the shore; or
- Groundwater discharge from the shallower confined aquifers is limited to upward leakage through the ocean floor sediments within 3 km from the coastline.

Groundwater levels are typically deeper inland and shallower near the coast. Inland, the deeper aquifers have a lower piezometric head than the shallow layers and therefore there is an overall downward hydraulic gradient and recharge to lower layers. Nearer to the coast, deeper aquifers typically have a higher piezometric head than the shallower layers and therefore there is an overall upward movement of water. Many of the wells installed in deep aquifers near the coast flow under artesian pressure.

Groundwater is primarily recharged from river/stream leakage, land surface drainage due to rainfall and irrigation.

Surface waters interact actively with groundwater. Inland, the major rivers are typically perched higher than groundwater and therefore provide a continuous recharge to the groundwater system. Closer to the coast, the rivers become more variable, sometimes gaining and sometimes losing water to groundwater, depending on the relative height between the groundwater table and the river water surface.

River water and groundwater travel in a general south-east direction from the foothills to the coast. Banks Peninsula acts as an (mostly) impermeable barrier to groundwater, and therefore flow paths divert either side of this feature. Lake Ellesmere and the Avon-Heathcote Estuary act as constant head boundaries for the shallow aquifer, as does the coast.

6.3.2 Hydrogeological Characteristics

The hydrological system consists of the aquifer (water bearing) and aquitard (water movement delaying) layers. These layers are interpreted from bore log information including screen elevations, and geological data. There is considerable natural variation in both thickness and depth below ground level, and the description of the hydrogeological system that is used herein simplifies these and consists of five aquifer and four aquitards, equating to nine hydrogeological layers in total.

The base of the aquifer system probably extends to about the depth of gravel material, which is believed to be about 600 m below ground level based on oil exploration wells (John Weeber, ECan Hydrogeologist, *pers. comm.*). This is well beyond the economic reach of wells drilled for groundwater abstraction, thus the primary focus of this report is wells in the top 100 – 200 m depth range. In the model, five aquifers have been assumed, the first four being well accepted, with the fifth being added to represent all deeper water bearing layers. The resulting nine-layer system is documented below in Table 6-5

6.3.3 Hydrogeological Layers

The general slope of subsurface layers is from the alpine foothills to the coast. The gradients of subsurface layers are flatter than the land surface over most of the plains. Consequently, layers are deeper inland than they are towards the coast. The differentiation between the shallower coastal layers (between State Highway 1 and the coast), and the deeper inland layers (between State Highway 1 and the foothills) is shown in Table 6-5

Table 6-5: Hydrogeological layers beneath the Central Canterbury Plains

Hydro-geological layer		Depth ranges assigned (m bgl)	
#	Name	Coastal (SH1 – coast)	Inland (SH1 – foothills)
1	Aquifer 1	0-35	0-45
2	*Aquitard 1*		
3	Aquifer 2	35-80	45-110
4	*Aquitard 2*		
5	Aquifer 3	80-130	110-140
6	*Aquitard 3*		
7	Aquifer 4	130-190	140-200
8	*Aquitard 4*		
9	Aquifer 5	190+	200+

The resulting hydrogeological block model of the layers is shown in Figure 6-3. This shows the Canterbury Plains from the Waimakariri River south to the Rangitata River. A cross section compiled from wells within 4 km of a line down the Selwyn River from near Coalgate to Lake Ellesmere and ending beneath Kaitorete Spit is shown in Figure 6-4.

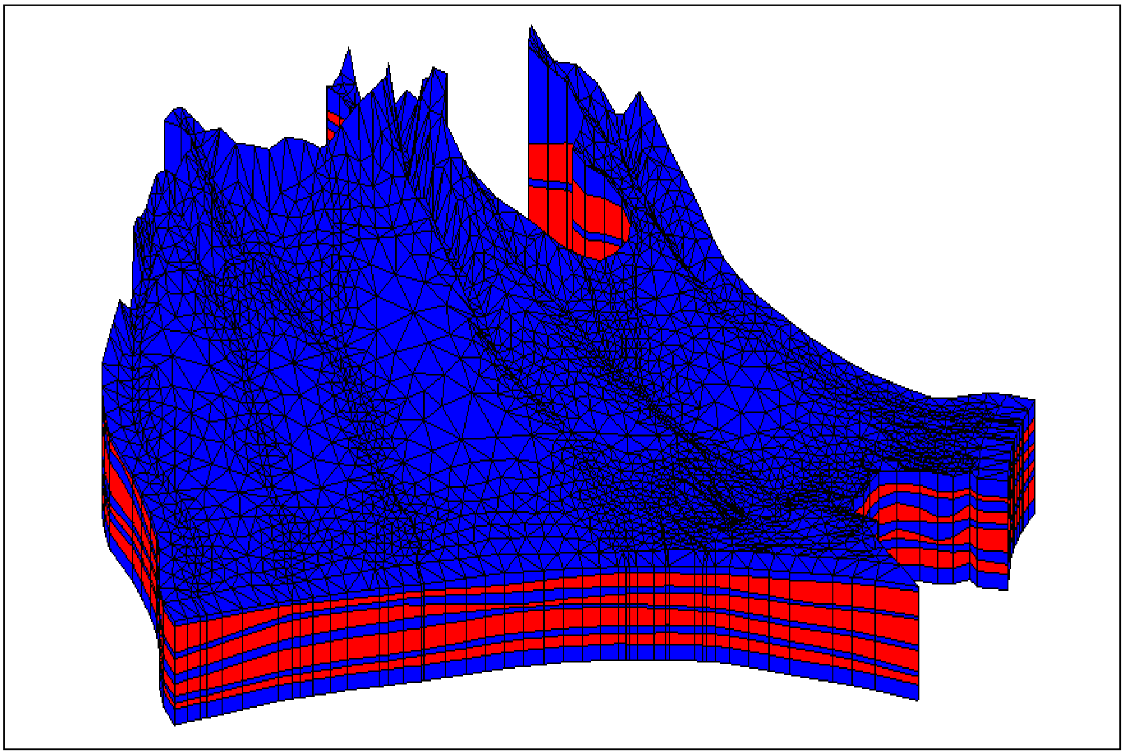

Figure 6-3: Hydrogeological layers beneath the Canterbury Plains from Waimakariri River (right), to Rangitata River (left) (Viewed to the NW. Blue layers represent aquifers, and red layers represent aquitards.)

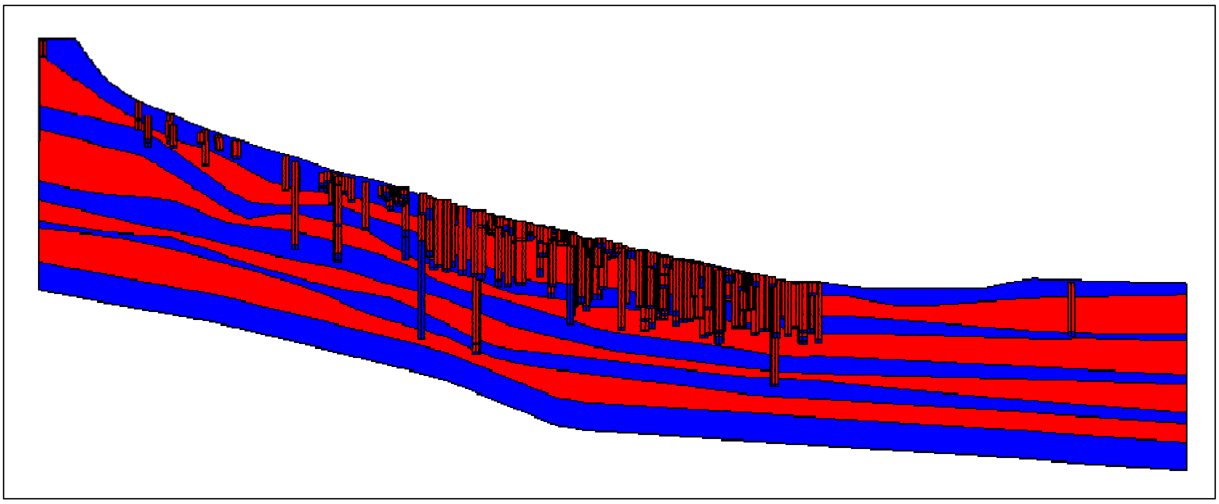

Figure 6-4: Schematic cross section of Hydrogeological layers beneath the Canterbury Plains along a line down the Selwyn River from near Coalgate (left), to Kaitorete Spit (right). (Blue layers represent aquifers, and red layers represent aquitards. Vertical bars are wells.)

6.3.4 Groundwater Level Data

Groundwater level data has been supplied by Canterbury Regional Council and was used for model calibration and verification, and also to evaluate the current state of the groundwater system. Figure 6-5 shows the steady-state water table elevation, simulated using the groundwater model for the status quo conditions, which is land use and other development as of 30 June 2002. Steady state is a time averaged estimate, given average conditions for the period from 1967 – 2005, under the status quo land use conditions.

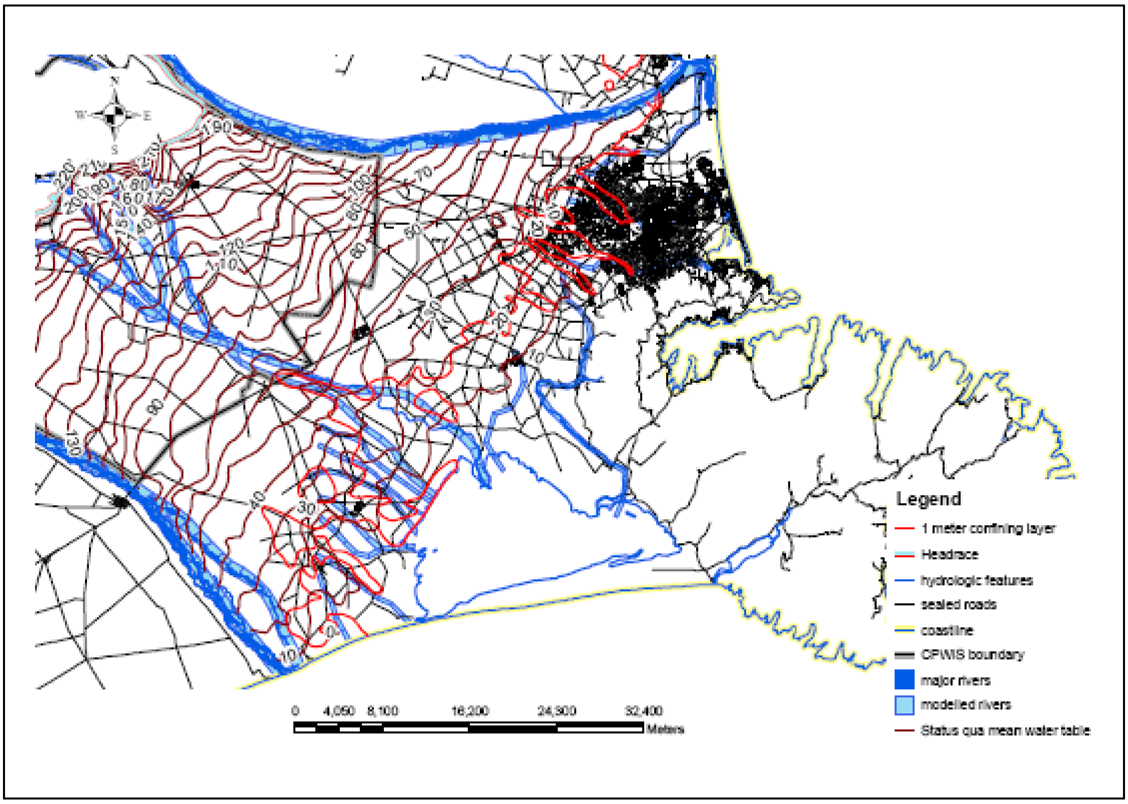

Figure 6-5: Mean piezometric surface (m above sea level) under status quo conditions

This shows a relatively uniform pattern beneath the Scheme area, with generally east-southeast flow of Rakaia Plains groundwater, and south-southeast flow of Waimakariri Plains groundwater. The piezometric contours rise towards the middle and lower reaches of the Rakaia River, and in upper and middle reaches of the Waimakariri River, indicating these reaches are contributing to groundwater flow. The contours northwest and west of Lake Ellesmere show the reverse pattern along the lower Selwyn River and other smaller streams, where the notches in the contour lines show the water table falling towards the river and stream channels. This indicates groundwater contributes to flow in these surface water bodies.

6.3.5 Groundwater Table Trends

Groundwater levels in Canterbury Regional Council's wells database were used to determine whether there were long-term trends in water levels in the groundwater system. It was apparent that water levels are on average declining, and that the decline is most pronounced in the spring.

6.3.6 Groundwater Quality

Groundwater quality in the area of the proposed Central Plains Water Enhancement Scheme and down stream there of has been studied with respect to its current state as well as any trends that are observed up to August 2005. The focus of this analysis is on the substances that will be affected by a change in agricultural behaviour.

Groundwater quality data was obtained from Canterbury Regional Council, and this database was analysed to derive the following descriptions.

Nitrates

There are 10,390 observations of nitrate-nitrogen (NO_3-N) taken from 1,545 wells north of the Rakaia River mouth. The average concentration is 5.7 g/m^3 NO_3-N (standard deviation 5.1 g/m^3). Figure 6-6 shows the cumulative distribution of mean nitrate concentration in the 359 wells with more than 5 observations. Only 2.5% of values are above the drinking water limit, and the average value (~5.0 g/m^3 NO_3-N) is less than half of the drinking water limit (MAV, 11.3 g/m^3 NO_3-N). Including all wells, the number of samples that exceed the MAV[†] is 5%.

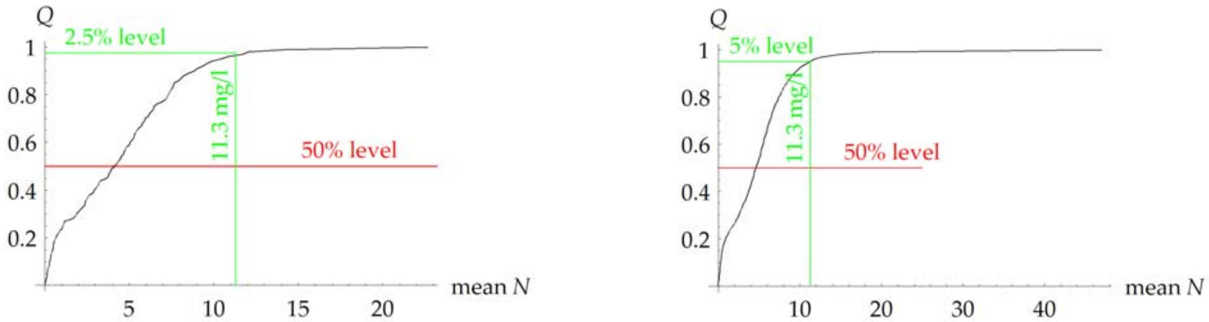

Figure 6-6: Cumulative distribution of the mean nitrate-N concentration in groundwater samples for wells with more than five samples (left) and all samples (right)

[†] MAV= Maximum Acceptable Value, which is 11.3 g/m^3 or mg/l NO_3-N.

Taking the smaller area covered by the Central Plains Water Enhancement Scheme, there are 636 wells in aquifer 1 north of the Rakaia River that have nitrate-nitrogen analyses. The average minimum value for these observations is 2.7 g/m^3 NO_3-N (standard deviation 2.9 g/m^3), the average maximum value is 4.5 g/m^3 NO_3-N (standard deviation 4.9 g/m^3), and the overall average is 5.5 g/m^3 NO_3-N .

Hanson (2002) drew attention to a general increase in nitrate-nitrogen concentrations in Canterbury groundwater, although he found that there were variations in the trend. A simple analysis of the trend in nitrate-nitrogen concentrations in wells in the Central Plains area is shown in Figure 6-7. This includes data from the upper two aquifers where available. This shows that while there is a scattering of wells with increasing NO_3-N concentrations, most are stable, and some have declining trends. Although a less rigorous analysis than Hanson's, the same general pattern has been found in this study.

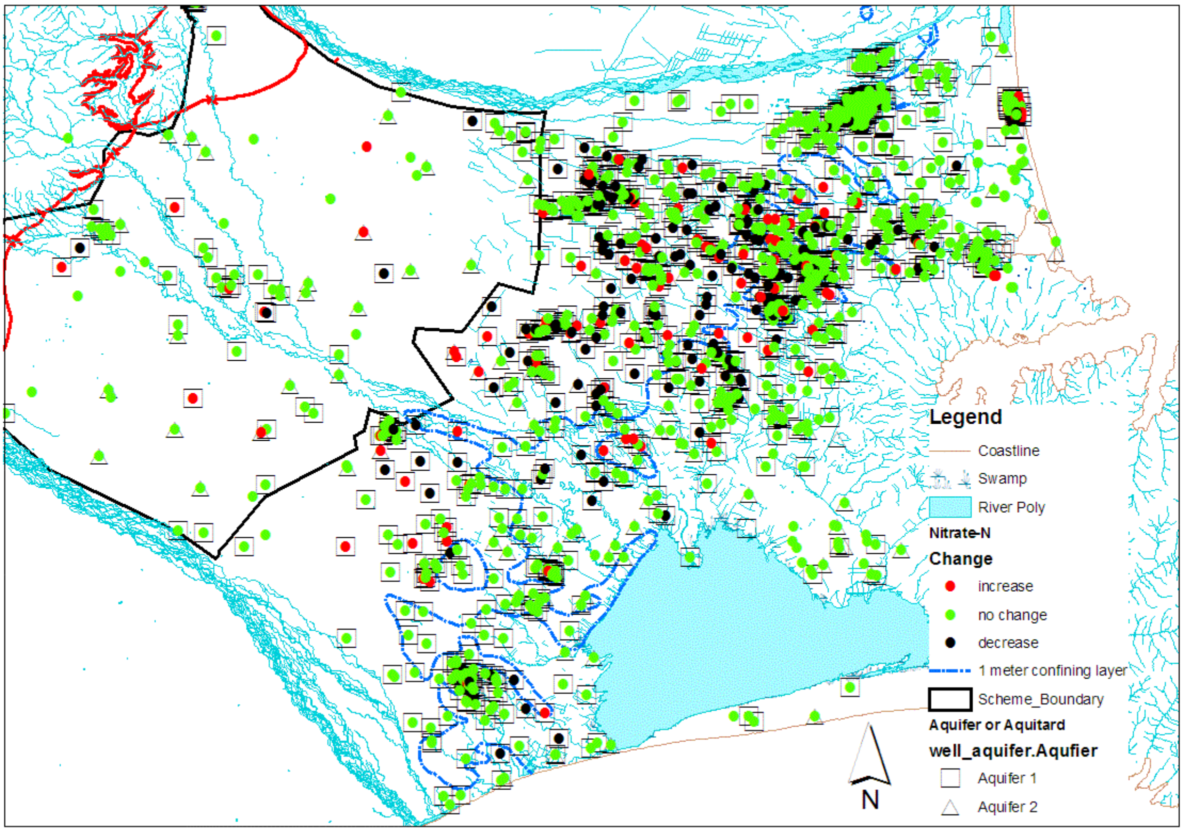

Figure 6-7: Change in nitrate-N over the period of record for wells with more than five observations. (No change is ±1 g/m^3 over the period of the record.)

Figure 6-8 shows the maximum recorded concentrations of nitrate-N in aquifer 1 relative to the MAV. A few values exceed the MAV, and there are numerous values between ½ of MAV and the MAV. In the area immediately down stream from the proposed Central Plains Water Enhancement Scheme area north of the Rakaia and extending to just north of the Selwyn there is a predominance of maximum values between ½ of MAV and MAV.

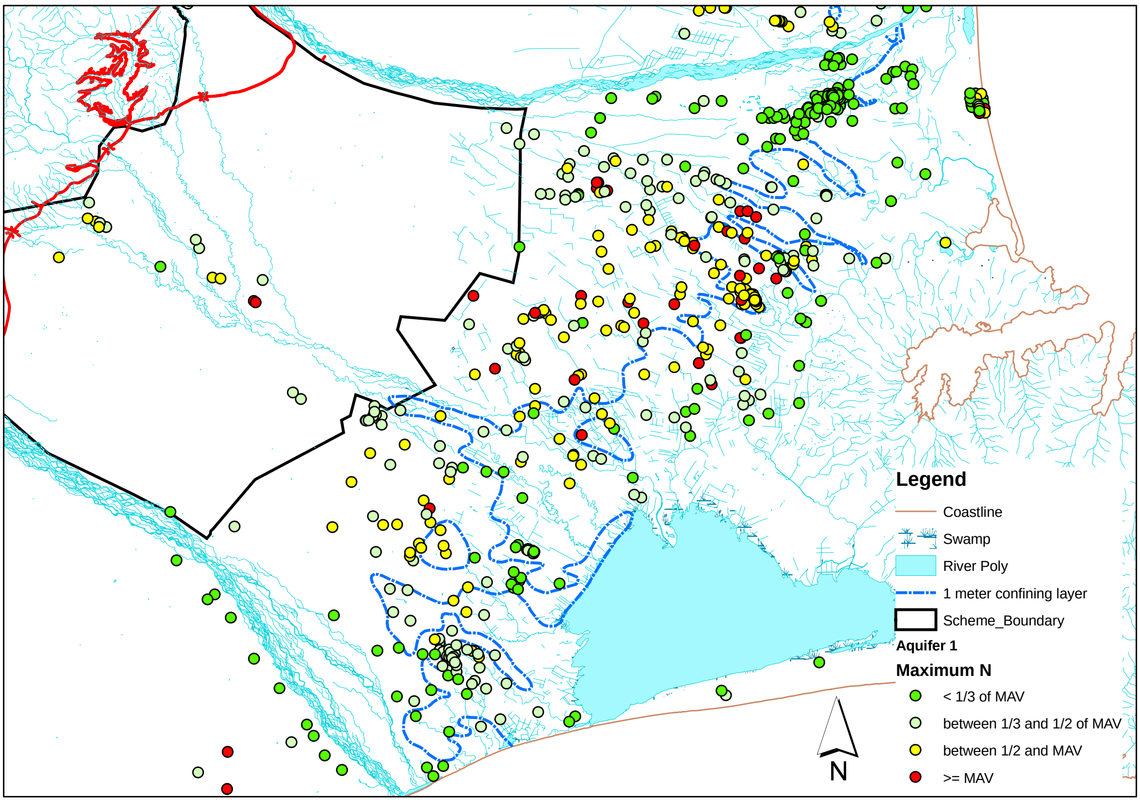

Figure 6-8: Maximum observed concentrations of nitrate-N observed in Aquifer 1 relative to MAV

6.3.7 Phosphorous

There are very few analyses of dissolved reactive phosphorous in the Central Plains Water area and downstream from this. All these analyses (excepting 1) show very low levels of phosphorous (<1 mg/l).

6.3.8 Other Constituents

Outside of the Christchurch City area, the analyses of groundwater within the Canterbury Regional Council's water quality database show generally good quality water within the study area.

Groundwater analyses for faecal coliforms show only 9 % of all samples above the detection level which was usually 1 cfu/100 ml. Of those samples, 78 % were from two wells (L37/0914 and M35/5998), and the remainder showed values less than or equal to 5 cfu/100 ml.

Pesticides are generally not considered a problem in groundwater of the Central Plains area. In Canterbury, as a whole detection rates for pesticides in non-targeted surveys approach the national level (12-14 %), with most detections being from South Canterbury (Close *et al*., 2001; Smith, 1993).

6.4 Soil Environments of the Central Canterbury Plains

The soils of the scheme area have developed on the alluvial fan surfaces as formed by the Rakaia and Waimakariri Rivers, or as reworked by the Selwyn River and its tributaries, and in places overlain by varying depths of loess cover. Thus the parent material for the soils is greywacke, either in the form of gravel and sand deposits of the fan surfaces or the silty loess cover on top. These parent materials strongly influence soil characteristics, with soil texture, age and drainage conditions controlling the variability within these broad categories. Soils developed on gravel deposits are typically yellow brown earths found on the Windwhistle and Burnham Formations, while those developed on loess are yellow grey earths. Soils of the young fan surfaces, low terraces and river floodplains lack strong profile development due to their young age and are classed as recent soils. These are usually associated with the Springston Formation.

In relation to the proposed use of water for irrigation, several characteristics of the soils are significant: soil depth and texture, soil moisture holding capacity, and soil drainage.

6.4.1 Soil Depth and Texture

Soil depth is mapped in four classes that follow the Proposed Natural Resources Regional Plan (PNRRP) soil typology used for calculating irrigation demand, which are:

- deep with no stones (> 0.9 m);
- soils with stony subsoils, moderately deep (0.45 – 0.9 m);
- soils with stony subsoils, shallow (0.20 – 0.45 m); and
- soils with stony or very stony topsoil.

Stony soils are commonly referred to as light or bony soils, and are more difficult to work. They are likely to support more pasture-based land uses. The shallow soils are also likely to support pasture-based land uses, but with careful management could support some arable uses. The moderately deep and deep soils will be able to support a range of arable land uses. The distribution of these soil types is shown in Figure 6-9, which has been derived from the Canterbury Regional Council soils GIS database. The spatial distribution shows distinctive patterns related to the Rakaia and Waimakariri alluvial fans and the Selwyn River systems within the scheme area.

Rakaia fan surfaces have predominantly stony soils developed in the Burnham Formation, as the area has limited loess cover on this up-wind bank of the river. In contrast, the Waimakariri fan surfaces have a mixture of stony, shallow, and moderately deep soils, reflecting the more extensive loess cover on this downwind side of the river. The deeper soils are found closest to the source of the loess deposits in the Waimakariri River bed.

Moderately deep soils occur along the lower Selwyn River, and the Hawkins and Waianiwaniwa Rivers. These are developed in Springston Formation and recent gravels derived from reworking of the older

Burnham Formation deposits. The soil parent material is finer, which has allowed more rapid soil development and thus deeper soil profiles have developed here.

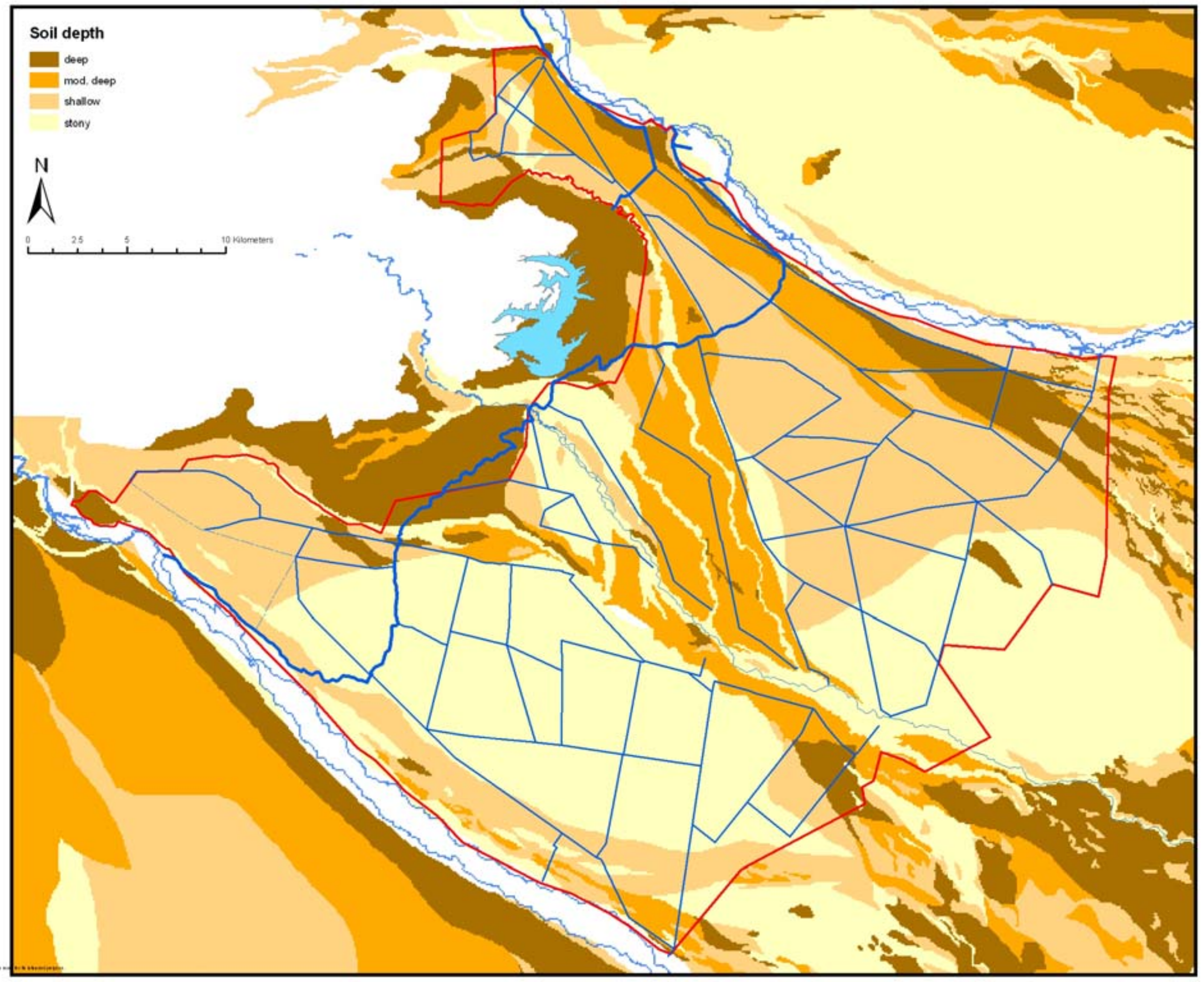

FIGURE 6-9: Soil depth in CPWS area

Deep soils are found on the old alluvial surfaces of the Woodlands and Hororata Formations along the inner plains margin; in loess deposits on low terraces along the south bank of the Waimakariri River; and in alluvial sands along the Hororata and Selwyn Rivers.

6.4.2 Soil Moisture

Soil moisture status is very important for determining irrigation water demand In the PNRRP irrigation water demand is based on the following three broad classes of soil profile average water holding capacity (PAW).

- PAW = < 75 mm;
- PAW = 75 – 110 mm; and

- PAW = > 110 mm.

Soils with low water holding capacity will require more frequent irrigation than those with higher PAWs. In general, soils with higher content of fine materials (silt and clay), and organic matter will have better PAW characteristics. Soil PAWs are mapped in Figure 6-10.

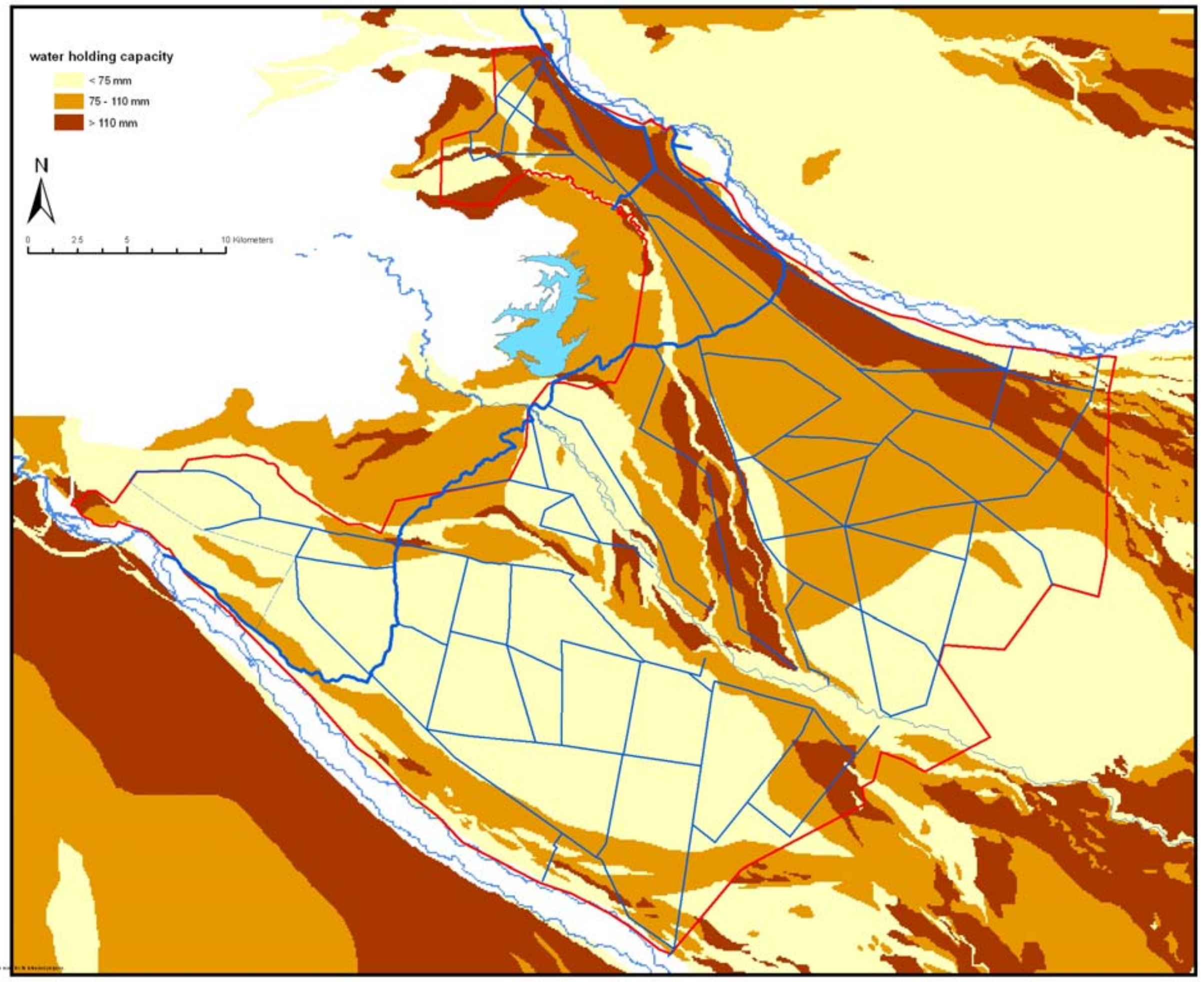

FIGURE 6-10: Soil profile average water holding capacity in the CPWS area

The stony and shallow soils of the Rakaia fan surfaces have low water holding capacity, while on the Waimakariri fan surfaces these soils only occur in the far eastern sector of the scheme area. The highest PAW soils occur in a narrow strip along the south bank of the Waimakariri River and down the lower reaches of the Hawkins River. This again reflects the greater loess content of soils along the south bank of the Waimakariri River, and the finer alluvial materials deposited in the lower Hawkins River floodplain.

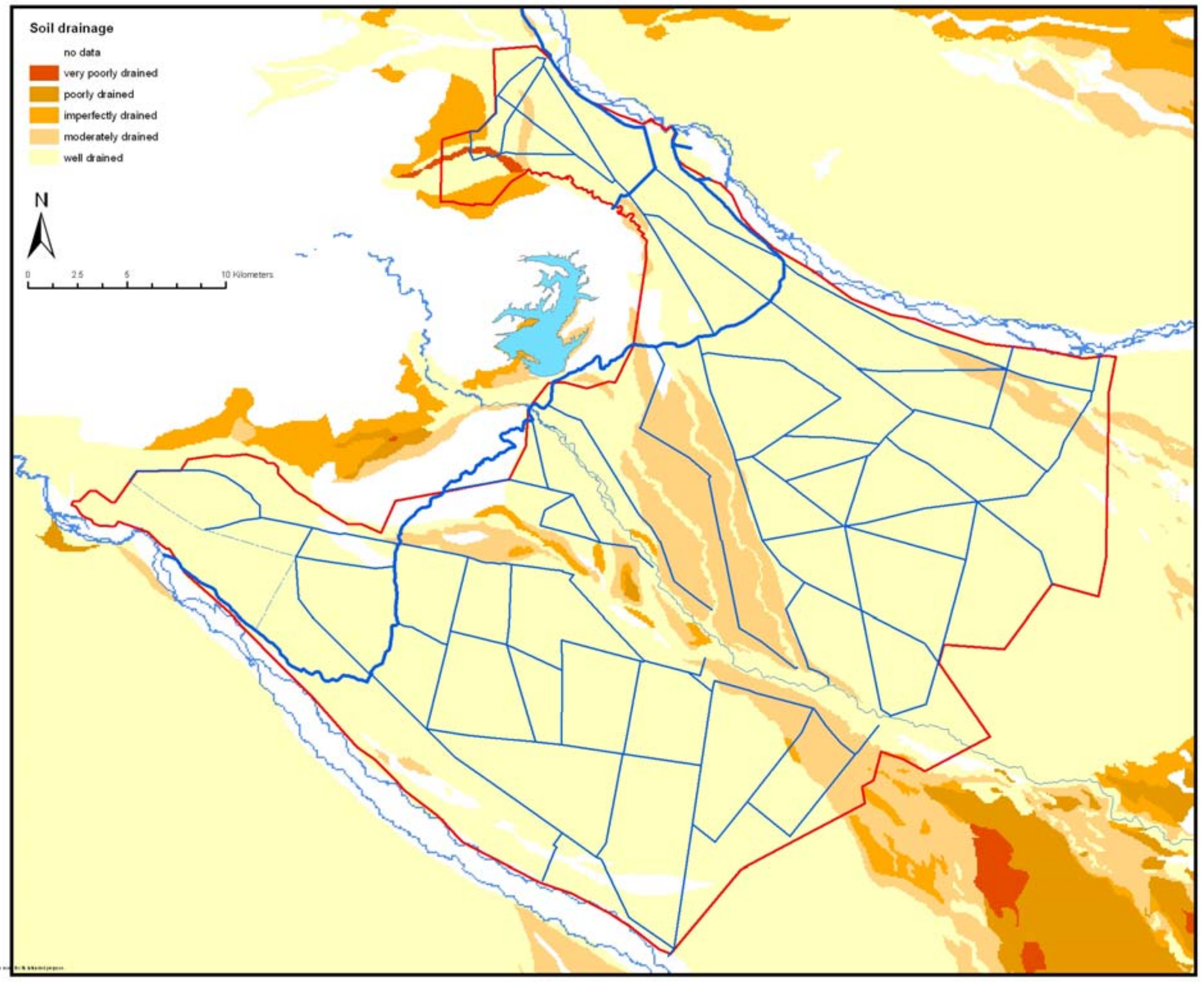

FIGURE 6-11: Soil drainage in CPWS area

6.4.3 Soil Drainage

Soil drainage affects the ability of the soil to be worked, and its ability to hold moisture. The Canterbury Regional Council soils GIS database includes a soil drainage layer based on the following qualitative categories.

- Well drained
- Moderately well drained
- Imperfectly drained
- Poorly drained
- Very poorly drained

Most of the soil materials are free draining gravel or silt, and this is reflected in the wide occurrence of free draining soils mapped across the scheme area (see Figure 6-11). The only areas of moderately to poorly drained soils occur along the lower areas of the landscape in the floodplains of the lower Selwyn River, and its other foothill tributary rivers. The less free-draining characteristics of these soils reflect the close proximity to the surface of the groundwater table.

6.5 The Climatic Environment

The distinctive characteristics of the Central Plains climatic environment are a major factor driving the need for the scheme. Although there is a potentially long growing season outside of the winter months, growth is limited by the lack of available water, and this can occur for eight months from October through to the following May. Several aspects of climate are important: rainfall, evapotranspiration, and wind.

6.5.1 Rainfall

Aqualinc (2005b) depicts the spatial pattern of rainfall across the central and mid Canterbury Plains as shown below in Figure 6-12. This is based on summary data from rainfall stations shown in Table 6-6

Table 6-6: Rainfall measurement sites

Rainfall site	NIWA site No	Measurement period used	Average annual rainfall (mm)	Average irrigation season (Sep-Apr) rainfall (mm)
Burnham Sewage Plant	H32631	Complete period from 1970-2003	640	400
Christchurch Gardens	H32561	Complete period from 1970-2003	640	380
Coldstream No 3	H41153	Complete period from 1970-2003	610	410
Darfield	H32412	1970-1971 taken from Hororata 1972-2003 taken from Darfield	790	500
Hororata	H31591	Complete period from 1970-2003	850	560
Lyndhurst	H31771	Complete period from 1970-2003	780	520
Somerton	H31792	Complete period from 1970-2003	750	480
Springburn	H31643	Complete period from 1970-2003	910	630

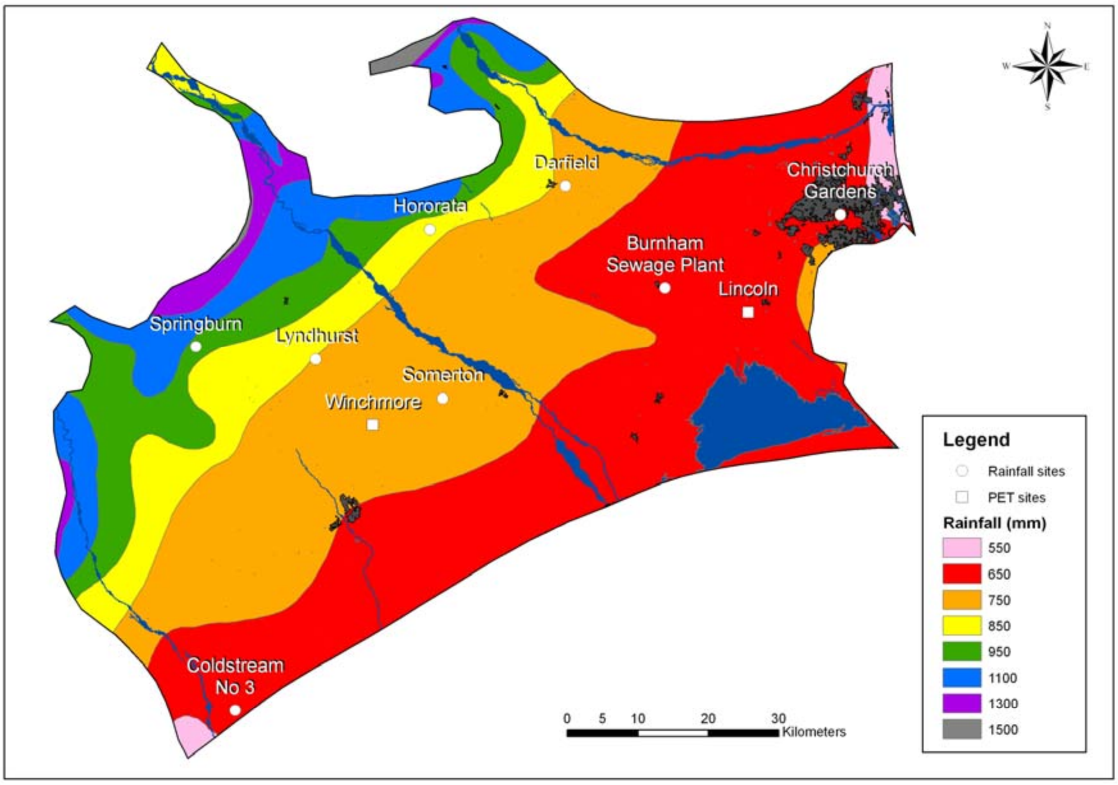

Figure 6-12: Rainfall isohyet zones, rainfall stations and PET stations across the Canterbury Plains from Waimakariri River to Rangitata River.

There is a general increase in rainfall from the coast at ~ 600 mm/yr, to ~1000 mm/yr at the inner plains margin. The Rakaia Plains sector of the scheme area shows an increase from ~720 mm/yr along the line of State Highway 1 to 1000 mm/yr at the Harper Hills. The eastern part of the Waimakariri Plains sector is drier, with ~650 mm/yr mean annual rainfall along State Highway 1, increasing to ~800 mm/yr at Darfield, and 1000 mm/yr at Homebush Ridge. Table 6-7 shows monthly rainfall for several stations within and adjacent to the scheme area (compiled from NZ Meteorological Service data up to 1980). There is little variation throughout the year, with no pronounced wet or dry seasons.

Table6-7: Monthly rainfall for selected stations in Central Plains region (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	*Year*
Hororata	78	57	67	78	72	64	70	68	53	64	59	67	*797*
Darfield	71	61	62	67	78	62	65	68	62	69	64	72	*801*
Winchmore	65	56	67	75	65	55	64	65	47	62	64	68	*753*
Rakaia	66	58	56	57	65	69	64	60	63	58	54	75	*745*
Lincoln	56	47	57	54	64	63	68	56	47	45	52	57	*666*

Ryan (1987) shows there are 80 – 100 raindays per year across the plains, increasing to over 100 days per year in the foothills. Conversely, there are 20 – 40 days per year that would be part of dry spells, where a dry spell is defined as a period of 15 days with each day having 1mm or less rainfall.

6.5.2 Evaporation

Open water evaporation across the Central Plains falls between 900 – 1000 mm per year (Ryan, 1987). This was based on a limited number of weather stations, and there is no reliable long-term recording of evaporation from the scheme area. However, data from the Winchmore Research Station is considered to be appropriately representative as it lies in a very similar setting in the Ashburton sector of the plains. Table 6-8 shows monthly data for raised pan evaporation, Penman open water evaporation, and Penman potential evapotranspiration (PEt), based on the mean of observations from 1970 – 2000 (data supplied by NIWA). This shows high rates of evaporation from October to March, with the annual total exceeding mean annual rainfall for most parts of the scheme area.

Table6-8: Monthly evaporation at Winchmore* (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	*Year*
Raised pan evaporation	189	143	112	68	42	31	32	50	80	122	148	172	*1188*
Penman open water evaporation	132	105	86	55	47	39	41	49	60	88	99	119	*920*
Penman potential evapotranspiration	138	105	81	43	25	15	18	34	57	91	111	132	*851*

* Data 1970 - 2000

6.5.3 Water balance

An indicative water balance can be calculated from monthly rainfall minus PEt, and this shows a deficit of rainfall over PEt from October to March, with November – February being highest (45 – 70 mm per month). This demonstrates the need for irrigation to allow more intensive land use in the Central Plains area. A more thorough calculation of the water balance utilises soil moisture data, and Table 6-9 shows indicative water balances, expressed as the number of days per month when soil moisture is exhausted for the stony, shallow and deep soils that occur in the scheme area.

Table6-9: Days per month that soil moisture is exhausted for typical soils in the Central Plains area*

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	*Year*
Stony soils (PAW = 20 mm)	23	19	16	10	2	0	0	0	10	18	20	22	*140*
Shallow soils (PAW = 60 mm)	22	17	13	7	1	0	0	0	1	9	17	20	*107*
Deep soils (PAW = 120 mm)	21	17	13	7	1	0	0	0	0	2	9	18	*88*

* After Bowden *et al*, 1983.

This shows the effect of soil moisture holding capacity on the water balance, with the lighter soils requiring a longer irrigation season potentially from September to April, or even early May in some years.

6.5.4 Wind

Wind is a significant element of the climatic environment. The hot dry nor' westers increase rates of evaporation, while the main rain-bearing conditions are brought by south and southwest winds. Mason *et al* (1996, Figure 3.2) show wind roses for Darfield and Hororata, which have very similar patterns. Three wind directions dominate: northwest (~21 %), northeast (~20 %), and southwest (~18 %).

Wind speed and direction could also be important at the Waianiwaniwa Reservoir for wave formation and generation of nuisance dust during periods of low water levels. Winds from the north (~10 %), and northeast (~20 %) would be significant, but only at times when the reservoir level is low and large areas of dry bed are exposed.

6.5.5 Climate change

Temperature and Rainfall

Mason *et al* (1996) report that there appear to have been some climate changes in the general Plains area, including a slight overall temperature increase, and decreasing rainfall. Examination of long term temperature record from Lincoln shows mean annual maximum temperature fluctuated around 17^{o} C from 1900 – 2000, while the mean annual minimum temperature has shown an increase of about 1.5 ^{o} C since 1945. The rainfall record from Ashburton shows a long-term decline in annual rainfall from 1940 – 1990 from about 850 mm down to 650 mm per year. However, since 1990 the trend has reversed and the mean annual rainfall has risen ~150 mm.

River Flow Regimes

Of considerable significance to the Central Plains scheme is the availability of water from the Waimakariri and Rakaia Rivers. Long-term changes in flow in these rivers relates to climate changes in their upper catchments, in regions well away from the main scheme area. McKercher and Henderson (2004) have recently examined shifts in flood and low flow regimes in New Zealand rivers. They found that many rivers' flood and low-flow flow regimes were different in the periods 1947 – 1977, and 1978 – 1999, and that since 1999 there may have been a shift back to the 1947 – 1977 pattern. This is correlated with shifts in the Interdecadal Pacific Oscillation (IPO).

Although the Waimakariri and Rakaia Rivers flow from adjacent catchments, their long-term flow regimes appear to have responded differently to shifts in the IPO. While floods were more variable in the Waimakariri River from 1947 – 1977, in the Rakaia River they were more variable in the 1978 – 1999 period. More importantly, the low flows in the Waimakariri River were higher over the 1978 – 1999 period, while there was no significant difference in low flows in the Rakaia before and after 1977/78. If the IPO has shifted back to a pattern more like the 1947 – 1977 period, then low flows in the Waimakariri River may be more of a constraint on water supply to the headrace and Waianiwaniwa Reservoir in coming decades. The reason for the differences in regime between the Waimakariri and Rakaia Rivers is not discussed by McKercher and Henderson (2004). It is possible these differences relate to the larger proportion of glacial ice in the Rakaia catchment, and the attenuating effect this would have on the release of water to the river.

6.6 The Biological Environment

The following descriptions of the biological environment have been provided by Kingett Mitchell Ltd.

6.6.1 Terrestrial Ecology

Waimakariri and Rakaia Rivers

The Waimakariri and Rakaia Rivers are two of the largest and most significant braided rivers in New Zealand. They consist of large shingle flats and fast flowing rapids and runs for most of their length. The Central Plains Water Enhancement Scheme (CPWS) will take water from these two rivers for irrigation of the upper Canterbury Plains.

Canterbury Regional Council and the Department of Conservation (DoC) classify these braided river systems as sites of natural significance and provide unique river terrace and gravel habitats for many plant and bird species including five threatened plant species (*Coprosma pedicellata*, *Helichrysum dimorphum*, *Pseudopanax ferox*, *Luzula celata* and *Muehlenbeckia ephedroides*) and five threatened bird species (black stilt, banded dotterel, black-fronted tern, crested grebe and wrybill). Significant avifauna habitat sites on the gravel riverbeds are currently under threat from gravel extraction, in-channel works, weed invasion, and human and animal interference. Natural riparian habitat is confined to relict sites scattered along former terraces, is heavily modified by farming activities and is dominated by exotic tree, shrub and herbaceous species, especially willows, gorse and broom.

Waianiwaniwa River Valley

The Waianiwaniwa Valley is a broad, flat-bottomed river valley in the Malvern Hills. The proposed Waianiwaniwa reservoir will extend behind the dam face just upstream of Homebush Road and will have a maximum water level of approximately 280 m above sea level.

The environment is heavily modified for pastoral based agriculture and indigenous habitats are all but absent. Riparian vegetation is dominated by willows and other exotic plant species. Few native plant and animal species exist within the valley and all are represented in other parts of the wider Canterbury region. Threatened plant and terrestrial animal species have not been identified within the valley.

Potential sensitive sites in the valley that are listed in district plans or national databases include one cultural site, one heritage site and up to eight heritage trees within and adjacent to the proposed reservoir inundation area. All sensitive trees are exotic species; there are no sensitive sites containing significant indigenous vegetation.

Scheme Area

The Central Plains Water Enhancement Scheme area covers the alluvial plains between the braided, alpine-fed Waimakariri and Rakaia Rivers from approximately the western foothills east to State Highway 1, and includes the Selwyn, Waianiwaniwa, Hawkins and Hororata Rivers. The river channels generally comprise dry stony riverbeds and occasional pools. Water races are the only surface water features within the Scheme area that have contiguous surface flow from the foothills to the coast.

Landuse is primarily farming and the landscape is covered with exotic grassland, shelterbelts and small forestry plantations. Significant natural habitats are almost absent. Existing riverine and wetland riparian vegetation is highly modified and dominated by exotic plant species (e.g., willows, gorse and broom). These environments are sensitive to stock impacts but would respond positively to increased water availability. Native flora and fauna abundance and diversity is low, although two threatened species (i.e., *Juncus holoschoenus* var. *holoschoenus* & *Melicytus flexuosus*) have been identified in the Selwyn and Hororata Rivers. Increased water availability due to the Central Plains Water Enhancement Scheme may enhance these sites and improve conservation opportunities for the threatened species.

Lowland Waterbodies

The lowland area of the Canterbury Plains covers the alluvial plains between the Waimakariri and Rakaia Rivers from State Highway 1 to the east coast primarily including rural areas, with Christchurch City's urban environment in the eastern part of the area.

A greater volume of available groundwater in this lower catchment area currently creates many wetland and riverine habitats compared with the Scheme area. Most wetland and riparian habitats within the lowland area are heavily modified by farming activities and are dominated by exotic plant species, especially willows which are common along the margins of most waterbodies. These sites respond well to habitat improvement and provide opportunities for conservation initiatives. Native flora and fauna abundance and diversity are relatively low although several threatened species are present.

Restoration efforts to improve wetland and riparian riverine environments are underway in many significant sites, particularly in urban areas. These sites are less sensitive to environmental change due to active management.

Lake Ellesmere/Te Waihora

Lake Ellesmere is a large brackish waterbody that is a dominant feature of the Canterbury Plains. Many spring-fed streams and drains flow through agricultural farmland before discharging into the lake. Although most of the lake's margins are heavily modified by farming activities, Lake Ellesmere still exhibits a range of outstanding conservation features including significant populations of waders, waterfowl and swamp-birds, and numerous threatened and culturally significant bird species; varied wetland vegetation types; and a diverse flora including approximately 30 plant species.

6.6.2 In-stream Habitat

The main channels of the large braided Waimakariri and Rakaia Rivers provide a limited amount of suitable habitat for aquatic flora and fauna, because they have swift flows, high suspended sediment concentrations, high bed loads and are hydrologically disturbed. In contrast, the minor side braids, seeps, springs and riparian wetlands of both rivers provide more stable channels, less streambed disturbance, and therefore greater instream habitat.

The Waianiwaniwa River valley has predominantly agricultural landuse, which is reflected in the characteristics of the instream habitat of the meandering waterways that drain the predominantly pasture, gorse shrubland and pine forest covered hills. Although the waterways contain reasonably diverse instream habitat, the channels themselves are generally moderate-highly modified through agricultural practices, lack of riparian shade, stock access and stream bank erosion.

The Scheme area supports a variety of water body types including foothills-fed rivers (e.g., Selwyn River and tributaries) and water races, but few seeps, springs or wetlands. The upper Selwyn River and its tributaries (i.e., the Hawkins and Hororata Rivers and the Glendore and Wairiri Streams) drain a highly modified agricultural catchment and are predominantly dry in their middle reaches for most of the year. Where the degree of flow permanence is sufficiently high (e.g. parts of the Selwyn and Hororata Rivers), the coarse substrate and natural channels of these streams provide diverse instream habitat for fish and invertebrates. Existing water races within the irrigation area include the Paparua, Malvern and Selwyn water races. In general, the water race network provides poor running water habitat and some limited but valuable wetland aquatic habitat.

Lowland waterbodies downgradient of the irrigation area include tributaries of Lake Ellesmere/Te Waihora and spring-fed tributaries of the Waimakariri and Rakaia Rivers. Lake Ellesmere is fed by as many as 34 permanent lowland waterways (mostly spring-fed) of variable size, with the degree of surrounding landuse and channel modification significantly affecting instream values. Fieldwork undertaken in spring 2005 found that the lower Selwyn River, Harts Creek and Hanmer Road Drain have diverse and stable instream habitat, whilst the Irwell River and Wood Creek were especially poor (due to a combination of low flow and degraded physical habitat).

Of the lowland spring-fed streams draining to the coast, the most well-known are the Avon and Heathcote Rivers, which have been highly modified through urbanisation, but continue to provide valuable instream habitat for a range of species. In contrast, Tent Burn and Jollies Brook are also highly modified but contain poor instream habitat due to increased siltation. Lowland tributaries of the Waimakariri River (Otukaikino and the Styx River) provide stable relatively high quality instream habitat, in the context of other Canterbury lowland water bodies.

The majority of the surface/groundwater draining through the Central Plains Scheme drains towards the Rakaia River mouth lagoon, Cooper Lagoon, and Lake Ellesmere, with little if any reaching the Waimakariri/Brooklands lagoon, and Avon/Heathcote Estuary. The Brooklands Lagoon, Rakaia River mouth and the Avon-Heathcote Estuary all provide significant and highly valued habitat for a range of aquatic plant, invertebrate, fish and bird species. Lake Ellesmere, which is artificially opened in summer and winter, is highly turbid due to re-suspension of the predominantly fine sediments. Most of the marginal swampland of the lake has been drained and converted to farmland, with rushes (Juncaceae), sedges (Cyperaceae) and salt marsh plants now common throughout the riparian margins. In its current state, Lake Ellesmere provides poor aquatic habitat. In contrast, Coopers Lagoon is a small waterbody, with clear water and submerged macrophytes providing good habitat.

6.6.3 Water Quality

Waimakariri and Rakaia Rivers

The water quality of the alpine-fed Waimakariri and Rakaia Rivers is very high in the headwaters, with high dissolved oxygen, low nutrient concentrations and low indicator bacteria numbers when compared to other river types in the region and compared to national water quality guidelines. Turbidity and suspended solid concentrations reflect the active erosion in the catchment, with occasional high suspended solids and turbidity values measured. Water quality degrades with distance from the headwaters, typically increasing in concentration of NOx-N (nitrite plus nitrate-nitrogen) and bacteria, with little change in turbidity.

Waianiwaniwa River Valley

The water quality of the Waianiwaniwa River and its tributaries appears typical of a foothills-fed river, with generally high clarity and dissolved oxygen concentrations, slightly elevated nutrient concentrations and occasionally high concentrations of faecal indicator bacteria. The concentrations of parameters (e.g. dissolved oxygen, dissolved inorganic nitrogen, and water clarity) measured for this study were variable, reflecting the mixed landuse and extent of riparian vegetation. The tributary from Oyster Gully has poorer water quality, perhaps reflecting more intense agricultural landuse within its catchment. Coal mining within the Waianiwaniwa catchment has the potential to decrease pH and increase trace metals and sulfate at times, although these data were not available at the time of writing

Central Plains Streams and Water Races

Overall, the water quality of the Selwyn River is similar to that of other foothills-fed rivers in the Canterbury region, with high dissolved oxygen concentrations and high clarity. Nitrogen concentrations generally slightly exceed water quality guidelines, whereas phosphorus concentrations are generally close to guidelines. Water quality in the upper reaches of the Selwyn River does not appear to be declining. Washpen Creek has similar water quality to the Selwyn River. In contrast, the Hawkins River has much higher nitrogen concentrations; well in excess of water quality guidelines to prevent nuisance growths of periphyton. *E. coli* numbers for the Hororata River indicate possible contamination by faecal material. For other parameters, water quality in the Hawkins River is similar to the Selwyn River. The water quality of the Hororata River is intermediate between that of the Selwyn and Hawkins, also demonstrating elevated NOx-N concentrations and *E. coli* counts.

Water quality of the upper reaches of water races in the area initially reflect the water source (Rakaia, Waimakariri, and Selwyn Rivers and tributaries), but water quality typically declines with distance from source. The downstream decline in water quality within water races is reflected in increasing concentrations of phosphorus and faecal indicator bacteria and decreasing clarity.

Lowland Waterbodies

The lowland streams draining into the coastal area north of the Rakaia River appear to have generally better water quality than the tributaries of Lake Ellesmere, based on sampling carried out during August 2005. Dissolved nitrogen and phosphorus concentrations are generally lower, as the groundwater source is lower in nutrients due to its proximity to and increased recharge from the Rakaia River.

Water quality of the tributaries of Lake Ellesmere is typical of lowland streams in the Canterbury region, with high concentrations of nutrients and bacteria and at times, high suspended solid concentrations.

Of these streams, the Irwell River exhibits very low dissolved oxygen at times, which is likely to be related to the very low flows resulting in ponded water in the river. NOx-N[‡] concentrations in the Irwell River are lower than most other Lake Ellesmere tributaries. Dissolved Reactive Phosphorus (DRP) concentrations in the Irwell River appear to be increasing.

The upper reaches of the Halswell River, in the vicinity of its spring sources, demonstrate good water quality, with low NOx-N and low DRP, typically within or close to water quality guidelines for preventing nuisance algal growths. Downstream in the canal section, at Hodgens Bridge, the water quality declines markedly, with nutrient concentrations at, or above those of other Lake Ellesmere tributaries.

Harts Creek has low phosphorus concentrations that are typically below guideline levels, but nitrogen concentrations are elevated. As phosphorus will be limiting; inputs of phosphorus into this waterway may need to be strictly controlled to prevent excessive periphyton and macrophyte growth. DRP concentrations in Harts Creek already show evidence of increasing over time.

Doyleston Drain and Boggy Creek have historically had very high NOx-N concentrations, which have exceeded guidelines to protect aquatic ecosystems from toxicity effects at times. NOx-N concentrations may need to be controlled in these catchments to ensure that the frequency that this guideline is exceeded does not increase.

The LII River and Hanmer Road Drain are typical of lowland streams, with generally elevated nitrogen and phosphorus concentrations. The LII River has a higher median DRP than most other lowland tributaries, however levels are declining. NOx-N concentrations are also declining in the LII River.

The water quality of the Selwyn River at Coes Ford is substantially different from that upstream at Whitecliffs and Coalgate. At Coes Ford, the water quality of the Selwyn River is typical of a lowland

‡ NO_x-N = nitrate nitrogen (NO_3-N), and nitrite nitrogen (NO_2-N).

stream. This is not surprising, given that continuous flow down the reach of the river occurs very rarely and the major source of baseflow in the lower reaches is groundwater, as is the case for the other lowland streams. NOx-N concentrations in the lower Selwyn River have increased over time.

Wetlands, Coastal Lagoons and Estuaries

Lake Ellesmere is the largest and most ecologically significant wetland in coastal Canterbury, and is a brackish coastal lagoon, with areas of lower salinity near the Selwyn River mouth. Water quality in the lake is affected by the high nutrient load from the lowland tributaries and is hypertrophic, with very high chlorophyll a biomass. Clarity is low due to wind and wave action. Dissolved oxygen concentrations are high, partly due to photosynthetic production, and remain high in bottom waters, due to extensive mixing. Other freshwater wetlands in coastal Canterbury have variable water quality, ranging from mesotrophic to eutrophic.

6.6.4 Algae, Macrophytes, and Invertebrates

Waimakariri and Rakaia Rivers

The braided Waimakariri and Rakaia Rivers are characterised by a high flood frequency, mobile bed sediments, and naturally high concentrations of inorganic suspended sediment and low nutrient concentrations. Because of the high flood frequency in major and minor braids, biomass and cover of periphyton and macrophytes is very low. Invertebrate communities are dominated by the common mayfly *Deleatidium* and other pollution-sensitive taxa (especially cased caddisflies). Groundwater-fed seeps at the edge of the active channel are infrequently disturbed and are biodiversity hotspots. Overall, biological communities present reflect the relatively pristine nature of these two mountain-fed rivers.

Biological communities of the Waimakariri and Rakaia Rivers are regarded as being highly distinctive within the region, due to their low periphyton and macrophyte biomass, and high abundance of pollution-sensitive invertebrate taxa. Periphyton, macrophyte, and invertebrate communities of these two braided rivers are considered particularly sensitive to any reductions in flood frequency or increase in nutrients.

Waianiwaniwa River Valley

Waterways within the Waianiwaniwa River valley are strongly influenced by the predominantly farming landuse. Habitat (e.g. fine sediments, sluggish flows), rather than nutrients per se seem to be the main factors limiting biological communities; influenced in particular, by the extent of riparian shading and stock access to waterways. Flow intermittence is also expected to limit the biota. Based on sampling in spring 2005, macrophyte cover is high in unshaded tributaries, with common submerged taxa including watercress, starwort, *Azolla*, and *Myriophyllum*. The mainstem, which presumably has lower flow permanence and has coarser bed sediments than the tributaries, had low macrophyte cover. Sampling in spring 2005 found that periphyton cover was generally low where macrophyte cover and shading was high, but thicker mats and filamentous algae were present in the mainstem where shading was low. Invertebrate communities within the valley are dominated by pollution-tolerant taxa, particularly the common snail *Potamopyrgus antipodarum* and oligochaete worms. Bush Gully stream had 80% high cover with filamentous green algae and the invertebrate community was dominated by *Oxyethira* (an algae-piercing caddisfly) and ostracods.

Overall, there is nothing particularly distinctive or unique about the periphyton, macrophyte or invertebrate communities within the Waianiwaniwa River valley. With the exception of one site in the upper reaches of the valley (above 280 m), invertebrate taxa richness was typical for similar stream types in Canterbury. At all sites in the valley, Quantitative Macroinvertebrate Community Index (QMCI) scores were low compared to other foothills-fed streams in Canterbury. Periphyton, macrophyte, and invertebrate communities within the valley are regarded as being indicative of moderately degraded habitat, and not particularly sensitive to environmental changes such as landuse intensification.

Central Plains Streams and Water Races

Biological communities of foothills-fed streams of the Canterbury Plains are affected to varying degrees by flow intermittency, agricultural landuse, nutrient enrichment and lack of riparian shading. Macrophyte cover is generally relatively low, most likely due to a mixture of flood disturbance and predominantly stony substrata, as nutrient concentrations are generally high enough to not limit growth. Periphyton biomass can get relatively high in streams such as the Hawkins River, following sustained periods of low flows. Invertebrate communities are mostly dominated by caddisflies and molluscs. Based on QMCI scores, invertebrate community health is greatest in the upper Selwyn River (at Whitecliffs), and in the mid-lower reaches of the Hororata River; both sites typically have QMCI scores >6, which is higher than average values for foothills-fed streams in Canterbury (mean = 5.8). Water races have comparatively low values compared to perennial reaches of foothills-fed streams, but are an important source of aquatic biodiversity in the Central Plains area, where natural streams are often dry.

The upper Selwyn River (from Coalgate upstream) and the Hororata River have a high degree of flow permanence and flow variability, and their biological communities are considered to be moderately sensitive to increases in nutrients or sedimentation caused by landuse intensification, or reduced flow. Benthic communities of the Hawkins River, Blacks Stream and more intermittent reaches of the Selwyn River are probably more tolerant of environmental change.

Lowland Streams

The majority of lowland streams in the Canterbury Plains are characterised by very stable, spring-fed flows, high nutrient concentrations, and correspondingly high macrophyte cover. Periphyton biomass is typically limited by high macrophyte cover and lack of suitable stony substrata. Lowland invertebrate communities are dominated by molluscs (especially the common snail Potamopyrgus antipodarum) and crustaceans (amphipods and ostracods). The perennially-flowing reaches of the Selwyn River (from about Coes Ford downstream) have the greatest dominance of pollution-sensitive taxa (especially cased caddisflies and *Deleatidium* mayflies), presumably due to its predominantly gravely bed sediments, and greater flow variability than other spring-fed lowland streams. Birdlings Brook, Hanmer Road Drain, and Silverstream (a tributary of the Selwyn River) also have mainly stony streambeds and relatively high QMCI scores for lowland streams.

Low flows, intensive catchment development (pastoral and urban), fine sediments, lack of riparian shade, and macrophyte clearance all influence lowland stream communities. The mainly stony-bottomed Selwyn River, Silverstream, Birdlings Brook and Hanmer Road Drain are considered the most sensitive to further habitat degradation, particularly sedimentation. The biota of most other lowland streams is considered tolerant (and generally indicative) of increased nutrients or sedimentation.

Most of the streams experience low flows and reduced habitat during summer. Of particular note is the Irwell River, which has reasonably good instream habitat, but has become increasingly affected by low summer flows and flow intermittency over the past decade.

Wetlands

Wetland extent and condition in Canterbury have been significantly affected by wetland drainage and vegetation clearance. Within the Canterbury Plains it is only in the lowlands that wetlands with significant areas of standing water persist. Periphyton and macrophyte biomass are typically high within freshwater wetlands. Compared with other freshwater habitats, wetlands typically have the greatest diversity of macrophytes. In freshwater wetlands, invertebrate taxa are dominated by "slow-water" taxa such as hemipterans, dipterans, crustaceans and molluscs. Estuaries such as the Avon-Heathcote estuary are typically dominated by molluscs, polychaete worms and crabs.

Wetland periphyton, macrophyte, and invertebrate communities within the PEA generally reflect the modified, predominantly agricultural landuse, and are considered to be tolerant of further landuse intensification. The major threats to wetland ecosystems are considered to be any further reduction in wetland area or quality caused by vegetation clearance, stock access, or reduced groundwater levels and drainage.

Lake Ellesmere/Te Waihora

Lake Ellesmere is very shallow, turbid and hypertrophic (extremely eutrophic). High turbidity is caused by wind and wave action keeping the predominantly fine lake sediments in suspension. High turbidity and wave action greatly limit benthic algal productivity; however phytoplankton biomass is extremely high compared to other lakes in New Zealand. Green algae dominate phytoplankton communities and toxic blue-green algal blooms are uncommon, probably due to the wind-exposed, turbid nature of the lake. High turbidity and wave action are also responsible for low macrophyte biomass, although dense stands of macrophytes (especially *Ruppia* spp., *Potamogeton pectinatus*, and *Lepilaena bilocularis*) have been recorded in the past. Benthic invertebrate diversity is low, and dominated by chironomids (especially *Chironomus zelandicus*), crustaceans, molluscs (especially *Potamopyrgus antipodarum*), and oligochaete worms. The zooplankton community also has low diversity and is dominated by copepods and mysid shrimps.

Periphyton, macrophyte, and invertebrate communities within Lake Ellesmere are already strongly influenced by high nutrient concentrations, soft sediments and high turbidity. Therefore, the existing community of the lake is considered relatively tolerant of potential increases in nutrients and suspended solids caused by landuse intensification.

Artificial lake openings also create water quality gradients within the lake (especially salinity), at a frequency that is considerably greater than would occur naturally. Therefore, the existing lake biota reflect the current water level management regime, and it would require a significant reduction or increase in water levels or frequency of lake openings to have a significant effect on the biota.

Groundwater Ecosystems

Groundwaters most likely support an abundant and diverse fauna throughout the Canterbury Plains, but their biota are less studied and poorly understood compared to surface waters. Limited sampling to date indicates that groundwater fauna in the PEA are dominated by crustaceans, and that they are probably limited by available organic matter (food). Shallow groundwater communities near streams (in the hyporheic zone) will be particularly sensitive to reduced river flows or groundwater levels. Increases in groundwater nutrients or organic matter may increase microbial activity and invertebrate abundance, although it is unclear what effect it may have on species composition.

6.7 Fish and Recreation

The following information on fish and recreation was provided by Kingett Mitchell Ltd.

6.7.1 Fish Communities

Fish values vary considerably across the Canterbury Plains and reflect the distance of water bodies from the sea and differences in instream habitat quality and quantity, riparian habitat quality and water quality in water bodies within and downgradient of the Scheme area.

Fish conservation values are highest in the intermittent water bodies within the Scheme area (Selwyn, Hororata, Hawkins and Waianiwaniwa River), where Canterbury mudfish (nationally endangered) are widespread. The presence of mudfish in these areas reflects the lack of predators (particularly eels and trout), due to a lack of permanent water and intermittent connection between water bodies. The Waimakariri and Rakaia Rivers, and lowland water bodies have comparatively lower fish conservation values, due to the presence of predators (especially trout and salmon). In addition, numerous lowland streams have modified, and in some cases degraded, instream and riparian habitat and poor water quality.

Five fish species (longfin and shortfin eel, Canterbury galaxias, upland bully and Canterbury mudfish) have been recorded from the Waianiwaniwa River. The most significant of these, in terms of its conservation status is Canterbury mudfish, which is classified as nationally endangered and regionally rare.

The greatest diversity and abundance of fish occurs in coastal spring-fed streams, Lake Ellesmere and the lower reaches and seeps, springs and wetlands of the Rakaia and Waimakariri Rivers. Water races within the Scheme area support a fish community with limited diversity, but one which includes occasional Canterbury mudfish that exist within partially connected wetlands close to the water race network. The diversity of fish communities that exist within Lake Ellesmere tributaries varies considerably; the lower

Selwyn and Halswell Rivers have the greatest number of species recorded (11) and Wood Creek has the lowest (2).

A recent survey of salmonid distribution found that adult brown trout habitat exists in a large proportion of water bodies in the Canterbury Plains. Brown trout habitat in waterbodies within the Scheme area is somewhat limited due to the ephemeral nature of most of these waterbodies. Of the Lake Ellesmere tributaries, the lower Selwyn River, Silverstream, Boggy Creek, Doyleston Drain and Hanmer Road Drain were the most heavily used for spawning by brown trout in the most recent spawning season.

6.7.2 Fishery Values

The water bodies within the Canterbury Plains support some or all of the following fisheries:

- Salmon;
- Sea run brown trout;
- River resident brown trout;
- Coarse fish;
- Whitebait;
- Eels; and
- Other commercial fish species.

The Waimakariri and Rakaia Rivers were nationally two of the most heavily fished rivers by trout and salmon anglers in the 2001/02 fishing season. The frequency of use of the trout fishery within the Lake Ellesmere catchment and a majority of the other coastal spring fed streams within the Canterbury Plains declined markedly between the 1994/95 and 2001/02 fishing seasons, presumably due to declining catch rates.

Lake Ellesmere supports highly valued commercial, customary and recreational eel fishery, commercial mullet and flounder fishery and also some lesser trout and recreational whitebait fishery values. Lake Ellesmere tributaries also provide important local and in some cases regionally valued commercial, customary and recreational eel fisheries and, in the case of the lower Halswell River, a valued coarse fish fishery.

The Waianiwaniwa River and water bodies within the Scheme area support some limited trout fishery values and possibly some commercial, customary and recreational eel fishery values.

6.7.3 Recreational Values

The water bodies within the Canterbury Plains support some or all of the following recreational values:

- Sightseeing.

- Walking.
- Picnicking.
- Camping.
- Bird watching.
- Swimming.
- Jet and other motorised boating.
- Canoeing/kayaking.
- Sailing.
- Fishing.
- Hunting.
- Off roading.

The lower Waimakariri River (upstream of SH1 bridge) has a low value for passive recreational activities (picnicking, camping, horse trekking, bird-watching and swimming) but is highly valued for off-road vehicles (four-wheel driving, trail biking and mountain biking). This section of the river has a moderate use for water fowl and small game hunting. The braided nature of the river provides good opportunities for jet-skiing, rafting and jet boating, and is used moderately often for canoeing/kayaking.

The Waimakariri River downstream of SH1 bridge is highly valued for sightseeing and picnicking and has moderate use by walkers and swimmers. This stretch of river is highly used for jet-skiing, power boating and sail boating.

The lower Rakaia River has moderate scenic and natural appeal, and is frequented by a wide range of recreational visitors. The lower Rakaia River is valued highly for jet-boating and is used moderately often for passive activities (sightseeing, walking, picnicking and camping), four wheel driving and waterfowl and small game hunting.

Recreational values of the upper Waianiwaniwa River (area affected by the reservoir) and the water bodies within the Scheme area are expected to be limited to occasional game bird and small game hunting and other non aquatic activities such as horse trekking, trail bike riding and four wheel driving.

Lake Ellesmere tributaries and coastal springfed streams provide local, and in some cases, regionally important recreational values including walking, sightseeing, canoeing and bird watching.

Lake Ellesmere has some significant attributes that make the recreation experience highly valued in a national and international context (bird watching), a regional context (game bird shooting and land yachting) and a local context (wind surfing). Lake Ellesmere also receives medium frequency use by sightseers, picnickers, campers, jet boating, water skiing, jet skiing, power boating and land sailing, low use for walking, canoeing/kayaking, rowing and sailing and high use for bird watching and board sailing.

The Waimakariri and Rakaia River mouth lagoons are frequently used for water skiing, jet skiing and power boating. They receive medium use by walkers, campers, board sailors and game bird shooters, and low use by kayakers.

6.8 The Social Environment

Information on the social environment is taken from a report prepared by Taylor Baines and Associates Ltd.

6.8.1 Profiles of the communities

Four geographical areas, based on area units established by Statistics New Zealand, are likely to experience the effects of the proposed irrigation scheme. They are:

1. Rural Darfield comprising the eastern $^2/_3$ rds of the Waimakariri Plains from Racecourse Hill southeast to Burnham and including Kirwee;
2. Darfield Township;
3. Te Pirita area comprising the eastern half of the Rakaia Plains; and
4. Malvern comprising the western half of the Rakaia Plains, Malvern Hills, and Sheffield/Springfield area.

Statistical data from these areas are shown in Table 6-10

Table 6-10: Population changes in the scheme's area - 1986 to 2001

	1986	2001	% change 1986-2001
Malvern	2,445	2,592	+6.0
Rural Darfield	1,452	2,646	+82.2
Darfield Township	1,122	1,404	+25.1
Te Pirita	318	555	+74.5
Selwyn District	20,685	27,312	+32.0
New Zealand	3,263,283	3,736,095	+14.5

Source: Statistics New Zealand.

The Malvern area has several small communities including Hororata, Whitecliffs, Glentunnel, Coalgate, Sheffield, and Springfield, which are likely to experience the effects of the scheme. Malvern had a small increase in residents from 2,445 to 2,592 between 1986 and 2001. It had relatively more 'couple only' families and one person households than did Selwyn District as a whole in 2001. Household incomes in Malvern were generally lower than the district pattern, with 54 per cent of the area's households reporting that their annual incomes were $50,000 or under (cf. 45 per cent for Selwyn District). A considerable number of Malvern's residents are employed at workplaces outside the area, while some of them have settled there for lifestyle reasons. Malvern's workforce comprised relatively higher proportions of self-employed persons, employers, and unpaid workers in family businesses than did Selwyn District's workforce in 2001. The agriculture, forestry and fishing sector provided more than half the jobs (54 per cent) for people whose workplace was in the Malvern area. Each of the townships in the Malvern area has only a few business enterprises, although bentonite, a clay with many specialised industrial uses is processed at Coalgate, and there is a sawmill and a salmon processing plant at Hororata. Skiing, ice skating, salmon fishing, and jet boating, are popular recreational activities which attract visitors to the area.

Population growth in Rural Darfield was very strong between 1986 and 2001 when the number of residents rose from 1,452 to 2,646 due to rural subdivision. Households in Rural Darfield had relatively higher annual incomes than the district's households. Forty-two per cent of them reported that their incomes were $50,001 or over in 2001 (cf. 39 per cent for Selwyn District), and only 9 per cent indicated their income was $20,000 or under (cf. 13 per cent for Selwyn District). There were relatively higher proportions of self-employed persons, employers, and unpaid workers in family businesses, in Rural Darfield's workforce compared with the district's workforce. The agriculture, forestry and fishing sector provided 59 per cent of the jobs for people whose workplace was in Rural Darfield in 2001, while 28 per cent of workers resident there were employed in that sector. The township of Kirwee, which acts as a dormitory settlement for people working in Christchurch, is likely to experience the effects of the scheme. It has several sports clubs and community organisations, and a small number of business firms.

Darfield Township had a moderate increase in population from 1,122 to 1,404 between 1986 and 2001. The age structure of the township's population in 2001 was relatively older than the district's population as there was a higher proportion of elderly people aged 65 years and over (20 per cent cf. 8 per cent for Selwyn District) among its residents. It also had higher proportions of 'couple only' families and one person households, and relatively fewer one family households than Selwyn District. Twenty-four per cent of households in Darfield Township reported that their incomes were under $20,000 or under in 2001 (cf. 13 per cent for Selwyn District), and the income distribution among the township's households indicates they were economically disadvantaged compared with the district's households. The workforce of Darfield Township had lower proportions of self-employed persons, employers, and unpaid workers in family businesses than did the district's workforce. The community/social/personal sector provided 28 per cent of the jobs for workers resident in Darfield Township in 2001. A further 18 per cent of its workers were employed in the wholesale/retail/hospitality sector, and 16 per cent in manufacturing. A wide range of community organisations are based at Darfield. While the township has a broad range of business activities, its economy is closely linked to the agricultural sector. There are some signs that the township's economy is becoming more diversified, however, with the opening of several eating establishments and a block of motels. Darfield is the gateway to some outdoor recreational activities in the district including fishing, boating and skiing, and visitors passing through the township make purchases from local business firms.

Te Pirita is a lightly populated area bounded by the Selwyn and Rakaia Rivers where farming is the major economic activity. A number of dairy units have recently been established in the area on land formerly used for sheep and dry land farming. The population of Te Pirita increased by 75 per cent from 318 to

555 between 1986 and 2001, while the district's population grew by 32 per cent over the same period. The age structure of Te Pirita's population in 2001 was relatively younger than the district's population as there was a higher proportion of children aged 14 years and under (27 per cent cf. 25 per cent for Selwyn District) among its residents. Te Pirita had lower proportions of one family and one person households, and a higher proportion of 'one parent' families than the district as a whole. Forty-one per cent of households in the area reported that their incomes were more than $50,000 or under in 2001 (cf. 39 per cent for Selwyn District). The workforce of Te Pirita had higher proportions of self-employed persons, employers, and unpaid workers in family businesses than did the district's workforce. The agriculture, forestry and fishing sector provided 87 per cent of the jobs for people whose workplace was located in Te Pirita, while 59 per cent of workers resident there were employed in that sector.

6.8.2 Profiles of farmers

Farmers within the boundaries of the scheme have the greatest opportunity to directly benefit from the additional quantity of water delivered to their farms. To derive this benefit, however, they may have to change their methods of production. Just as some farmers in Rural Darfield have had their lifestyles changed by the need to alter their work schedule to accommodate the demands of groundwater irrigation, so will existing dryland farmers in the scheme's area encounter similar challenges as they farm their land more intensively.

An analysis of the questionnaires returned in 2001 by farmers who expressed interest in having their land irrigated by the scheme found that 43 per cent of them were solely engaged in livestock production, while 28 per cent combined cropping activities with livestock. Only eight per cent entirely devoted their properties to arable production, and about ten per cent were either wholly engaged in dairying or also had other forms of livestock production. A breakdown of the total hectares devoted to these various types of land use reveals a similar pattern. The responses of the farmers who completed the questionnaire were also classified according to the size of their holdings. Fifty-six per cent of the 214 farmers who completed the entire questionnaire had land holdings of between 100 and 499 hectares, and another 21 per cent of them held less than 50 hectares of land. Three-quarters of farmers engaged in arable/livestock, arable and dairy production reported holdings of 100 to 499 hectares, while just under half of livestock farmers indicated they had medium size holdings. Moreover, the proportions of livestock farmers with small (under 100 hectares) and large size (500 hectares & over) holdings were higher than for the other three main types of land use.

In terms of hectares, livestock production is the dominant land use of the farmers who responded to the questionnaire. Thus any changes in land use and production methods demanded by the economics of accessing water from the scheme will be most evident for this category of farmers. The proportion of land which is currently devoted to dairying or horticulture is relatively small compared to livestock and arable production, indicating that there is scope for expansion of these two activities.

A number of farmers were also interviewed as part of the second phase of the social assessment in 2001. The interviews revealed that farmers within the scheme area were currently irrigating part of their properties from deep bore wells, and most had contingency plans to extend irrigation from that source.

Farmers with properties in the Wairiri Valley, who at the time expected the scheme's reservoir would be established at that location, wanted compensation measures not only to address issues concerning the farm business, but also other factors such as changes of lifestyle and future plans. Furthermore, farmers outside the area of the scheme had concerns about its impact on water quality and quantity in their localities.

6.9 The Cultural Environment

6.9.1 Maori Cultural Environment

An assessment of the impacts of the Central Plains Water Enhancement Scheme on Ngāi Tahu values has been prepared for CPW on behalf of Te Taumutu Rūnanga, Te Ngāi Tūāhuriri Rūnanga, and Te Rūnanga o Ngāi Tahu by Dyanna Jolly Consulting. The following material is taken from that report.

The Central Plains are rich in Māori history, and are part of the cultural heritage of Ngāi Tahu. Today the plains are a highly altered landscape; characterised largely by farming activities. However, Ngāi Tahu history and identity remains strongly connected to this landscape.

Ngāi Tahu has occupied the area between the Waimakariri and Rakaia rivers, Te Waihora and Kākāpōtahi (Malvern foothills region) for many generations. Hapū and whānau travelled between coastal villages and foothill regions as the seasons changed, following the waterways that ran from mountain to sea. The area has many culturally significant features, including:

- Awa — significant waterways
- Maunga — significant mountains and hills
- Urupā — burial sites
- Tūāhu — sacred alters
- Umu — ovens used in the preservation of foods
- Tuhituhi neherā — natural caves and land formations
- Wāhi pakanga — places where historical battles took place
- Mahinga kai — areas were food resources were gathered
- Wāhi raranga — places where weaving resource were gathered
- Huarahi — trails and access routes
- Wāhi kōhatu — significant rock formations with spiritual associations
- Wāhi mahi kōhatu — places where stones and minerals were mined
- Wāhi tāpuke — places where taonga where hidden for safe keeping
- Wāhi tapu — sacred places on the landscape
- Pā — fortified villages

Several Ngāi Tahu Claims Settlement Act (NTCSA) 1998 cultural redress sites are also associated with the project area, including *place names* that have been re-established on the landscape: Ruataniwha (Cam River) and Waikirikiri (Selwyn River); and *Statutory Acknowledgements*: Whakamatau (Lake Coleridge);

and *Nohoanga* (Rakaia River). The bed of Te Waihora was vested in Te Rūnanga o Ngāi Tahu as fee-simple estate as part of the Ngāi Tahu Settlement (s.168), and several mahinga kai areas associated with Te Waihora are recognised in the NTCSA: Te Waiomākua, Whakamātakiuru (Ellesmere Landing), Greenpark Huts, Pakoau, Waikirikiri and the Te Koraha Ancillary Claim.

The presence of Ngāi Tahu on the central plains is evidenced in the *wāhi ingoa* that remain on the landscape. These place names record Ngāi Tahu history, and point to the landscape features that were significant to people for a range of reasons. Some of the names are still used today; others remain only in customary knowledge base of tangata whenua.

In addition to the above information, the Proposed Selwyn District Plan contains a list of list of cultural sites, wahi taonga sites and management areas, silent file areas and mahinga kai sites. The following sites (Table 6-11) from that list will be near the major scheme facilities, including the intakes and associated headworks, the inlet canal, and the headrace, and the Waianiwaniwa Reservoir.

Table 6-11: Selwyn District Council Schedule of Cultural Sites in the CPWS Area

Site No.	Description	Location	Legal Description	Area	Map No.
C10	Findspot	Near Steeles Rd	Lot 4 DP 2619	Outer Plains	39
C13	Ovens etc	Near Homebush Rd	Pt Lot 1 DP 2898	Malvern Hills	40
C14	Ovens etc	Near Homebush Rd	Pt Lot 1 DP 2898	Malvern Hills	40
C15	Ovens etc	Near Homebush Rd	Pt Lot 1 DP 7925	Malvern Hills	40
C16	Ovens etc	Near Homebush Rd	Pt Lot 1 DP 7925	Malvern Hills	40
C17	Ovens etc	Near Auchenflower Rd	Lot 1 DP 23595	Malvern Hills	39
C18	Ovens etc	Near Auchenflower Rd	Lot 1 DP 23595	Malvern Hills	39
C23	Water ditches	Near Minchins Road	Lot 4 DP 77694	Outer Plains	36
C26	Pits, Ovens	Near West Coast Rd, Springfield	Lot 2 DP 27958	Malvern Hills	35/36
C27	Swamp, Ditches	Near Kowai Bush Rd	Lot 2 DP 27958	Outer Plains	35
C28	Ovens, Pits	Near Kowai Bush Rd	Lot 2 DP 27958	Outer Plains	35
C33	Oven	Near Rakaia Terrace Rd	Pt Lot 3 DP 2422	Outer Plains	43
C34	Oven	Near Sleemans Rd	Lot 2 DP 308750	Outer Plains	43

6.9.2 Historic Heritage

The Proposed Selwyn District Plan lists a number of heritage sites in the scheme area, and some will be close to the proposed infrastructure, although it is not proposed to directly affect these sites. They are listed in Table 6-12 below.

Table 6-12: Selwyn District Council Schedule of Heritage Sites in the CPWS Area

Site No.	Description	Location	Legal Description	Area	Map No.
H111	Waimakariri Gorge Bridge	Waimakariri Gorge	Road Reserve	Upper Plains	36
H131	Pigsties, Homebush Station	Homebush Rd	Pt Lot 1 DP 7925	Malvern Hills	40

H133	Bridge, Homebush Station	Homebush Rd	Pt Lot 1 DP 2898	Malvern Hills	40
H135	Homestead, Homebush Station	Homebush Rd	Pt Lot 1 DP 2898	Malvern Hills	40
H137	Water Tower, Homebush Station	Homebush Rd	Pt Lot 1 DP 2898	Malvern Hills	40
H138	Woolshed, Homebush Station	Homebush Rd	Lot 1 DP 2898	Malvern Hills	40
H147	Racecourse Hill Homestead	West Coast Rd	Lot 1 DP 75924	Outer Plains	40
H148	The Oaks Homestead	Homebush Road	Lot 4 DP 3739	Outer Plains	40

A number of heritage trees have been listed on Homebush Station, and those that are close to or potentially within the Reservoir footprint are listed in the table below.

Table 6-13: Selwyn District Council Schedule of Heritage Trees in the CPWS Area

Site No.	Description	Location	Legal Description	Area	Map No.
T41	Necklace poplar 'Virginianna *Populus x deltoides*	Homebush Station (imported 1852)	Pt Lot 1 DP 2898	Malvern Hills	40
T42	Californian Big Trees (0.5 acre) *Sequoiadendron giganteum*	Homebush Station (imported 1852)	Pt Lot 1 DP 2898	Malvern Hills	40
T45	Caucasian Fir *Abies normaniana*	Homebush Station (imported 1852)	Pt Lot 1 DP 2898	Malvern Hills	40
T48	*Pinus radiata* Largest in Canterbury 50.5 m planted c.1852	Homebush Station	Lot 2 DP 16113	Malvern Hills	40
T49	Hemlock *Psuedohetrophylla*	Homebush Station	Lot 2 DP 16113	Malvern Hills	40
T50	Indian pine, *Pinus walliciana*	Homebush Station	Pt Lot 3 DP 16113	Malvern Hills	40
T51	*Cupressus macrocarpa* planted c. 1860, 39 m tall, senescent	Homebush Station	Lot 2 DP 16113	Malvern Hills	40
T52	Himalayan cedar *Cedrus deodara*	Homebush Station	Pt Lot 2 DP 16113	Malvern Hills	40
T53	Lime trees *Tilia x europaea* c. 1975	Homebush Station	Lot 2 DP 16113	Malvern Hills	40
T60	Atlas cedar *Cedrus atlantica*	Homebush Station	Lot 2 DP 16113	Malvern Hills	40
T61	*Cupressus macrocarpus* 52.4 m high	Homebush Station	Pt Lot 3 DP 16113	Malvern Hills	40

In addition, there were over 70 coal mines operated in the Bush Gully area of the Waianiwaniwa Valley in the late 1800s, and five are mapped on the topographic maps.

6.10 Landscape Values

The following assessment of landscape values has been provided by Chris Glasson Landscape Architects.

The plains between the Rakaia and Waimakariri Rivers are part of a large and flat land mass sweeping down from the Southern Alps to the sea. They are a very dominant element of the Canterbury landscape. This landscape has unique forms, colours, vegetation, structures, climate, and the constant horizontality sets off the dramatic backdrop of the alps. For the inhabitants of the plains it is a landscape that is both found and made, and is constantly under change whether it be its distinctive weather patterns, colours, activities and uses. Above all the plains are a unique component in the mindset of New Zealanders.

6.10.1 Landscape Character

The scheme is located in the high and low plains of Canterbury, and between the Rakaia and Waimakariri Rivers. This is a part of a large region of ancient coalescing fans bounded by the sea and the foothills. The plains consist mainly of quaternary outwash gravels and recent alluvial deposits, and the soils are mainly yellow-grey earths to yellow-brown earths, recent gley and organic soils.

The alluvial soils range from stony sands to deep silt loams on the river flats and low terraces. The higher terraces and rolling downs are of deep clay soils with slow internal drainage.

The region is largely developed into pasture or cropping land with only a few patches of native revegetation remaining.

The high plains, located between 150 to 600m above sea level, experience higher rainfall than the low plains, more northwest winds giving rise to higher temperatures, and frequent frosts and occasional snow falls.

The vegetation cover is a remnant of its original glory. Essentially, the whole area was forested with short tussock and there were stands of kanuka and small leafed coprosma. Today, little of the indigenous vegetation remains due to the conversion to pasture and crops. Some stands of beech still exist in the hill gullies, and mixed scrub and hardwoods can be found along the riverbanks and terrace edges of Rakaia, Selwyn and Waimakariri Rivers. Plants here include kowhai, kohuhu, cabbage trees, coprosma and ribbonwood.

While the hill country has modifications, it is the high and low plains which have undergone a dramatic change to become a more modified landscape. The contrast between the unmodified natural downs and hills, and the patchwork landscape of the plains and the braided rivers is a distinctive phenomenon recognised throughout NZ. The symmetry and simplicity of the plains create a lasting impression. It is a linear landscape, not only with the horizontality of the plains but the long straight roads, conifer shelter belts, water races and fence lines. There is a repetition of the components throughout the plains landscape.

In the vicinity of Colgate and the Waianiwaniwa River area the landscape is more convoluted and this culminates with the indented narrow river valleys and steep hillsides.

The lower plains reflect a drier climate as seen in the vegetation types of short tussock land, matagouri and small leafed *Coprosmas* and *Olearias*. The settlement patterns are more intensive and frequent on the lower plains.