3.1 Introduction

The development of the Central Plains Water Enhancement Scheme has been driven by the project vision outlined in Section 2. This has shaped the proposed design of the irrigation system component of the scheme that is the subject of these applications. This section will cover the following:

- Description of the irrigation scheme layout and components;
- Outline of the construction programme; and
- Outline of how the scheme will be operated.

This material will form the basis for the assessment of effects on the environment in Sections 7 and 8 below.

3.2 Scheme Area

The scheme area is defined as the area that will be serviced by water from the irrigation supply network. The total area covered is 101,800 ha as shown in Figure 3-1. The northern and southern boundaries are marked by the Waimakariri and Rakaia Rivers respectively. The western boundary will run along the inner margin of the Canterbury Plains from just below the Rakaia Gorge Bridge, around the base of the Malvern Hills, and north to the Kowai River. The eastern boundary will follow State Highway 1 north from the Rakaia River bridge, skirts around Dunsandel, and once over the Selwyn River, trends northeast and then north across the plains to the Waimakariri River.

Some of the farmland in this area will not be irrigated, as the owners of some 20 – 25% of land are not shareholders in the scheme. There will be approximately 60,000 ha of irrigated land within the scheme area of which some 30,000 ha is currently irrigated from groundwater.

Some components of the scheme will be located outside of this area, in particular, the Waianiwaniwa Reservoir in the northeastern Malvern Hills, and the upper Waimakariri River intake and reservoir supply canal north of the Kowai River junction with the Waimakariri River (see Figure 3-1).

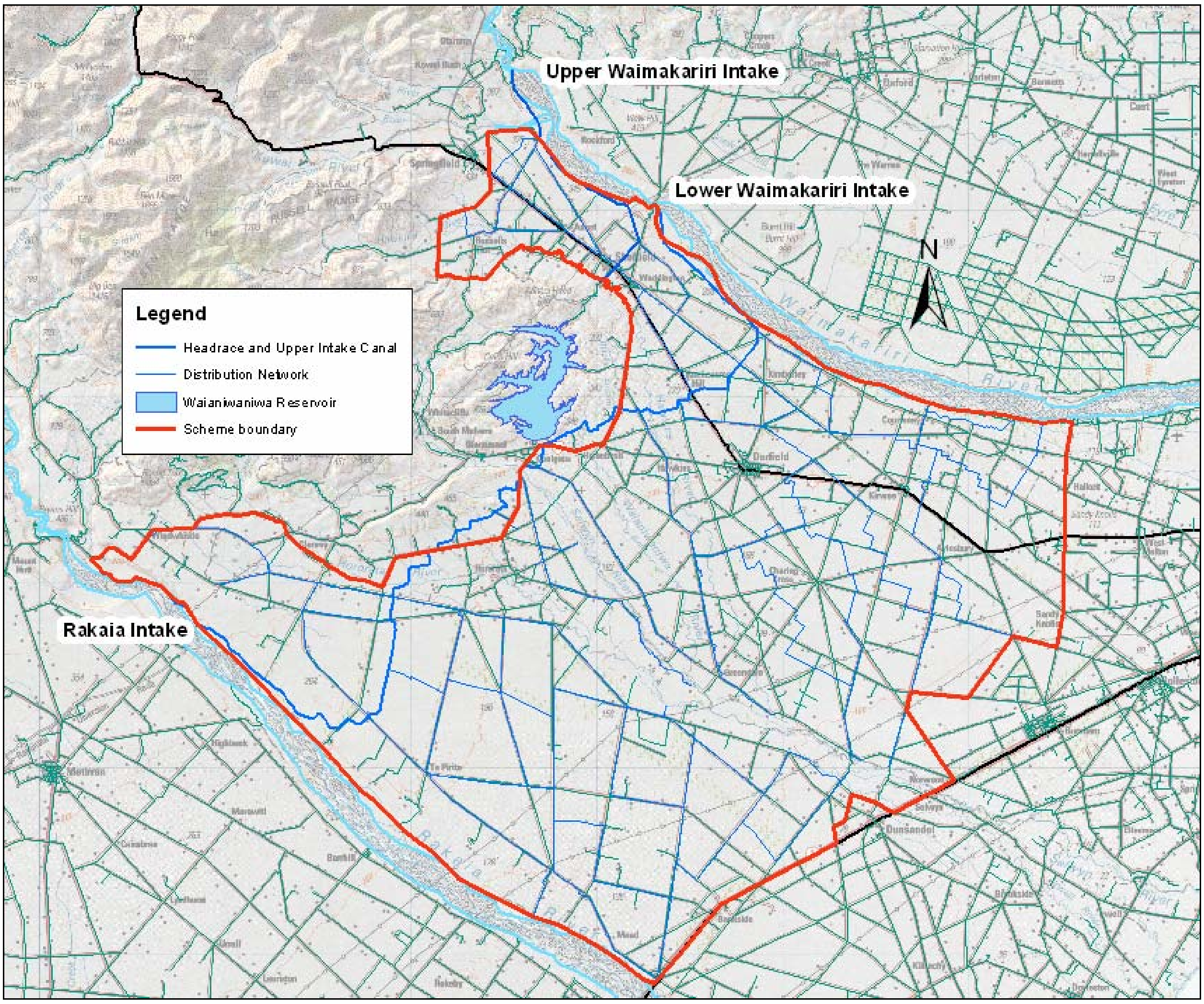

FIGURE 3-1: Scheme Area

3.3 Water Takes

As outlined in Section 1, the Central Plains Water Trust has already made application to take water from the Rakaia and Waimakariri Rivers. These applications are CRC021091 and CRC054601. Both applications have been deemed to be notifiable by Environment Canterbury and therefore establish Central Plain's priority for water in each of the rivers. The first application is for the take from the Rakaia River plus the take from the Gorge Bridge in the Waimakariri River, each take being for 40 m^3/s, with the Rakaia take shared between the Ashburton Community Water Trust and Central Plains Water. The second application is to enable the Waimakariri River take to be from above the Kowai River and is also for 40 m^3/s, but this take cannot be exercised conjointly with the Gorge Bridge take such that the combined take exceeds 40 m^3/s. To assist with the understanding of the current applications, the rationale for these takes is explained, in association with other existing takes (actual and permitted) from the rivers.

3.3.1 Rakaia River takes

The existing abstractors from the Rakaia River, all of whom have a higher priority of access to the water are summarised as follows:

There is currently 28 m^3/s of Rakaia River water (including connected groundwater) allocated for irrigation: 17 m^3/s to Barrhill-Chertsey, 2 m^3/s allocated to irrigation to the south of the river (South Rakaia), and 9 m^3/s to existing irrigators the north of the river in the Central Plains area (North Bank). In addition there is 1.9 m^3/s allocated for stockwater. Of this 29.9 m^3/s, the Barrhill-Chertsey water has the lowest priority. Barrhill-Chertsey's consent is for irrigation and power generation although this consent has yet to be exercised. All other consents are for irrigation only, but under the existing allocation regime are assumed to occur year round.

The National Water Conservation Order (Rakaia River) (NWCO) states that abstraction from the river cannot exceed 70 m^3/s. The existing stockwater and irrigation consents can take up to a maximum flow allocation of approximately 30 m^3/s from the Rakaia River, which leaves approximately 40 m^3/s for additional takes. The maximum proposed water take for CPWE is 20 m^3/s and the ACWT proposes to take 20 m^3/s on an equal priority basis. Water taken for the proposed CPWE scheme would therefore be taken in compliance with all aspects of the NWCO.

The conditions under which the proposed Rakaia take would operate are detailed in Table 3-1. For each month Table 3-1 details the NWCO minimum Rakaia River flows[1], the minimum river flow above which the CPWE scheme can begin to take water and the river flow at which the full flow of 40 m^3/s or the balance of the water available to be abstracted could be taken. Note that the taking of water under the NWCO is subject to a 1 to 1 sharing rule, which is for every 1 m^3/s of water abstracted from the river, 1 m^3/s of water is left in the river for in-stream values/uses. Table 3-1 is based on a total of 60 m^3/s (including 1 to 1 sharing) being required by the higher priority abstraction bands on the river.

Discussions between the Ashburton Community Water Trust and Central Plains Water Ltd have resulted in the agreement to share equally the 40 cumecs applied for. When the existing consents were operated "as is" with existing priorities, the water allocation and sharing rules can be visualised using Figure 3-2. The presently unallocated water was divided to give a 50:50 split between Ashburton and Central Plains, up to a maximum combined take of 40 m^3/s. The maximum allowable take of 70 m^3/s is depicted across the top of Figure 3-2. With the 1:1 sharing rule in the NWCO, this take occurs only if the river flow is 140 m^3/s above the minimum flow. This is shown on the left side of the Figure. The in-between flows require the take to be reduced proportionately.

The agreement with the ACWT also allows any unused water in each party's share to be used by the other party, should they require it. Therefore while the CPWL share is nominally 20 m^3/s it is conceivable that at times it could take the full 40 m^3/s applied for in the total Rakaia application.

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[1] Flows as measured at the Fighting Hill gauging station in the Rakaia Gorge.

Table 3-1: Rakaia River flow levels for each month

Month	NWCO minimum river flow (m^3/s)	Minimum river flow for taking of water after allowing for existing takes (m^3/s)	River flow when remaining 40 m^3/s can be taken (m^3/s)
January	124	184	264
February	108	168	248
March	105	165	245
April	97	157	237
May	95	155	235
June	96	156	236
July	91	151	231
August	92	152	232
September	90	150	230
October	106	166	246
November	129	189	269
December	139	199	279

As noted above, the Barhill-Chertsy water take consent has not yet been exercised. In the event that this consent lapses, it is the view of CPWT that the water would then once again become available for allocation, and that the CPWT and ACWT should have priority access to this water, as their existing water take application has been limited by the amounts already allocated. In the event that these future scenarios occur, the scheme of allocations shown in Figure 3-2 two would change accordingly.

Glenroy irrigators are currently preparing proposals to abstract water from the Rakaia River to irrigate land within the Central Plains command area. Agreement has been reached with the Glenroy irrigators that when the infrastructure for the Central Plains Scheme is in place, they will take water from the scheme rather than from their own intake sites. The Glenroy takes are therefore to be seen as included within the allocation sought from the Rakaia River.

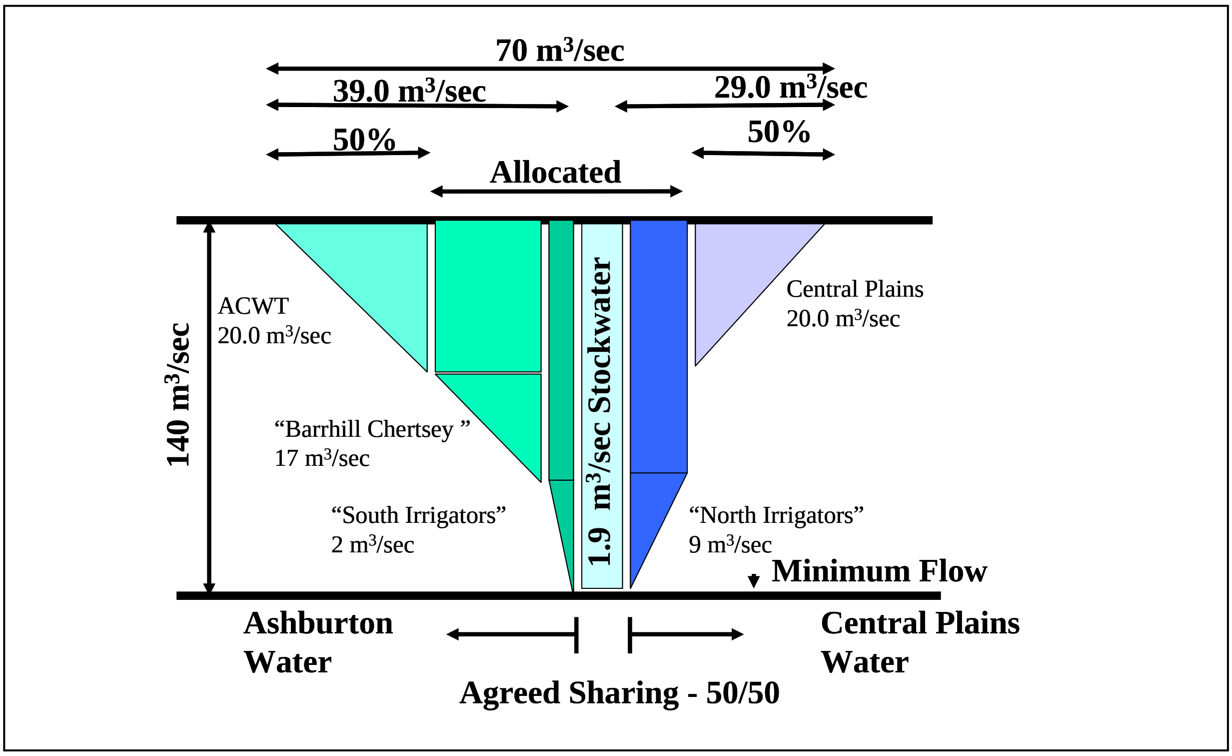


Figure 3-2: Rakaia River Takes

3.3.2 Waimakariri River takes

When the full allocation to Waimakariri Irrigation Ltd (WIL) is taken into account, the existing consented takes from the Waimakariri River are:

- WIL 10.5 m3/s
- Other Irrigators 5.9 m3/s
- Stockwater 3.6 m3/s

The Waimakariri River Regional Plan (WRRP) has established a minimum flow in the river of 41 m^3/s for allocation of "A" permits. The total allocation limit for "A" permit water is 22 m^3/s of which 20 m^3/s is permitted to other abstractors. This therefore provides 2 m^3/s of "A" permit water for CPWE. When any more water is required for irrigation of the Central Plains, it is assumed to be "B" permit water with a lower priority and will be subject to higher minimum flows. The minimum flow for "B" permit water is set at 63 m^3/s.

The WRRP provides a mechanism to allocate the available water between the minimum flows for "A" and "B" permits on a pro-rata basis, except that stockwater has been exempted from the restriction provisions. Thus the approximately 18 m^3/s of water available for irrigation use can be apportioned equally between users over the flow range of 41 m^3/s to 63 m^3/s. For the purposes of this calculation, the unmodified flow in the Waimakariri River as determined at the Old Highway Bridge at Kainga must be used. This is the measured flow, plus an allowance for the removals for irrigation and stockwater upstream.

It should also be noted that WIL operates a run of river irrigation scheme and therefore their take is reduced in the winter to that required for stockwater and flow enhancement. The CPW applications make use of this winter water to assist in filling the reservoir. This does not affect the priority rights of WIL to water for run of river irrigation nor their current use of water during the off season.

The takes from the Waimakariri River can be visualised by reference to Figure 3-3 following. This shows the existing takes to the left totalling 20 cumecs, and how apart from the stockwater takes, as the unmodified flow reduces from 63 cumecs to 41 cumecs the take is proportionately reduced. The CPWL take to the right also reduces in the same manner as all water users of Class A water are treated with equal priority. The Class B take above 63 cumecs does not have a flow sharing requirement such as for the Rakaia River take, and therefore flow above 63 cumecs up to the 38 cumecs required by CPWL can be taken if it is available.

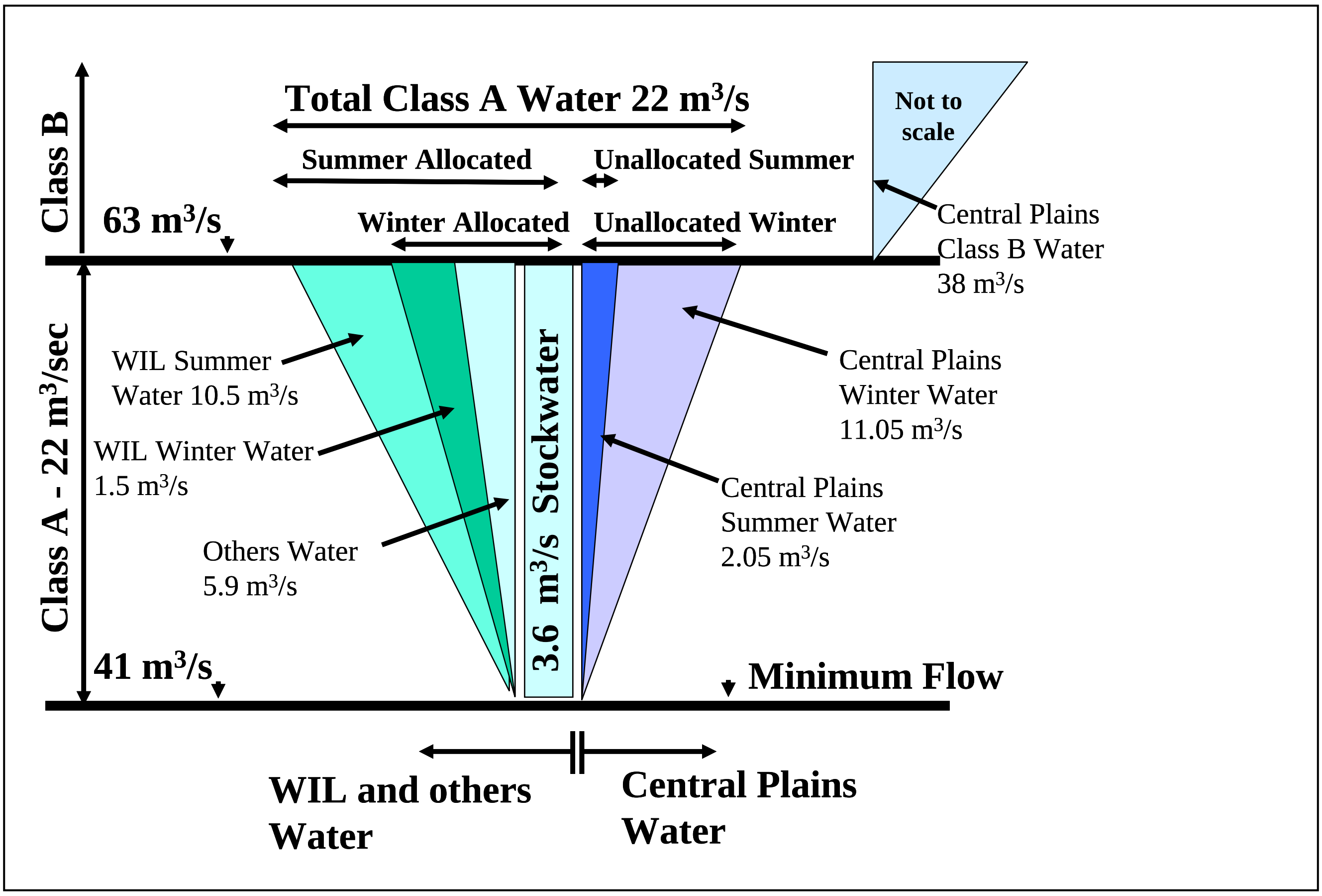


Figure 3-3: Waimakariri River Take

3.4 Intakes and Headworks

The intakes and headworks from the rivers are designed to perform the following functions:

- Safely and reliably divert the required flow from the rivers;
- Remove and dispose of as much of the diverted sediment as practical;
- Minimise the risk of entrapment of fish within the scheme;
- Provide operational control of the flow into the scheme; and
- Enable maintenance and repairs during scheme operation as required.

It is proposed to take water for the scheme from two intakes in the Waimakariri River, and one in the Rakaia River. The location and general features of these intakes have been described in the previous applications for water takes as follows:

- *Assessment of Environmental Effects for Waimakariri and Rakaia Rivers Water Takes* Report prepared for the Christchurch City Council, Selwyn District Council, and Ashburton Community Water Trust Inc., by URS New Zealand Ltd. December 2001.
- *Assessment of Environmental Effects for Waimakariri River Water Take near Kowai River Confluence* Report prepared for the Central Plains Water Trust, by URS New Zealand Ltd. June 2005.

In the section below material from the earlier reports is presented, along with such extra information as may be required to fully describe the proposed activities.

3.4.1 Rakaia River intake

The site selected for the intake from the Rakaia River is about 8 km downstream from the Gorge Bridge at a level of about 245 masl (metres above sea level), which is suitable for feeding into a headrace canal across the top of the plains. It is on the true left bank of the river at the upstream end of a relatively stable berm, shortly after the river enters the broad braided fairway that leads to the coast. The location has been selected to provide a relatively stable intake site that can be protected from flooding and erosion, that will avoid excessive costs of canal works to climb the adjacent river terraces, and will supply water by gravity to the largest feasible area of the plains. The proposed intake system is illustrated in Figure 3-4 and would consist of the following works:

1. A low diversion bank, if required, across part of the riverbed to direct water towards the intake area
2. A low level breachable gravel weir, if required, to turn water into the intake channel

3. An excavated channel, as required, off a major braid to ensure water enters the intake channel

4. Works to protect the intake system from erosion and flooding, such as stopbanks, rock groynes, rock lined banks and vegetative protection

5. A gated intake structure at the downstream end of the diversion channel

6. A short sediment trap including a overflow spillway, downstream from the intake gates, to settle fine gravels and coarse suspended sediments (i.e. sands and a small proportion of silts) and then discharge them back to the river via a sluice gate and side channel or they may be removed mechanically from time to time.

7. A gated flow control structure at the downstream end of the sediment trap to control the flow approaching the fish screen and the subsequent intake canal to the headrace.

8. Fish screens shortly downstream from the sluicing race to exclude (particularly) downstream migrating fish from the scheme works and return them to the river (see more detail below)

9. A pump station about 6 km downstream from the control structure to lift water up the terraces for the Windwhistle areas that are higher than can be serviced from the gravity intake

10. A sidling canal to carry water to the top of the river terraces and into the main scheme canal.

The majority of the intake works prior to the sidling canal would be on a relatively undeveloped river berm.

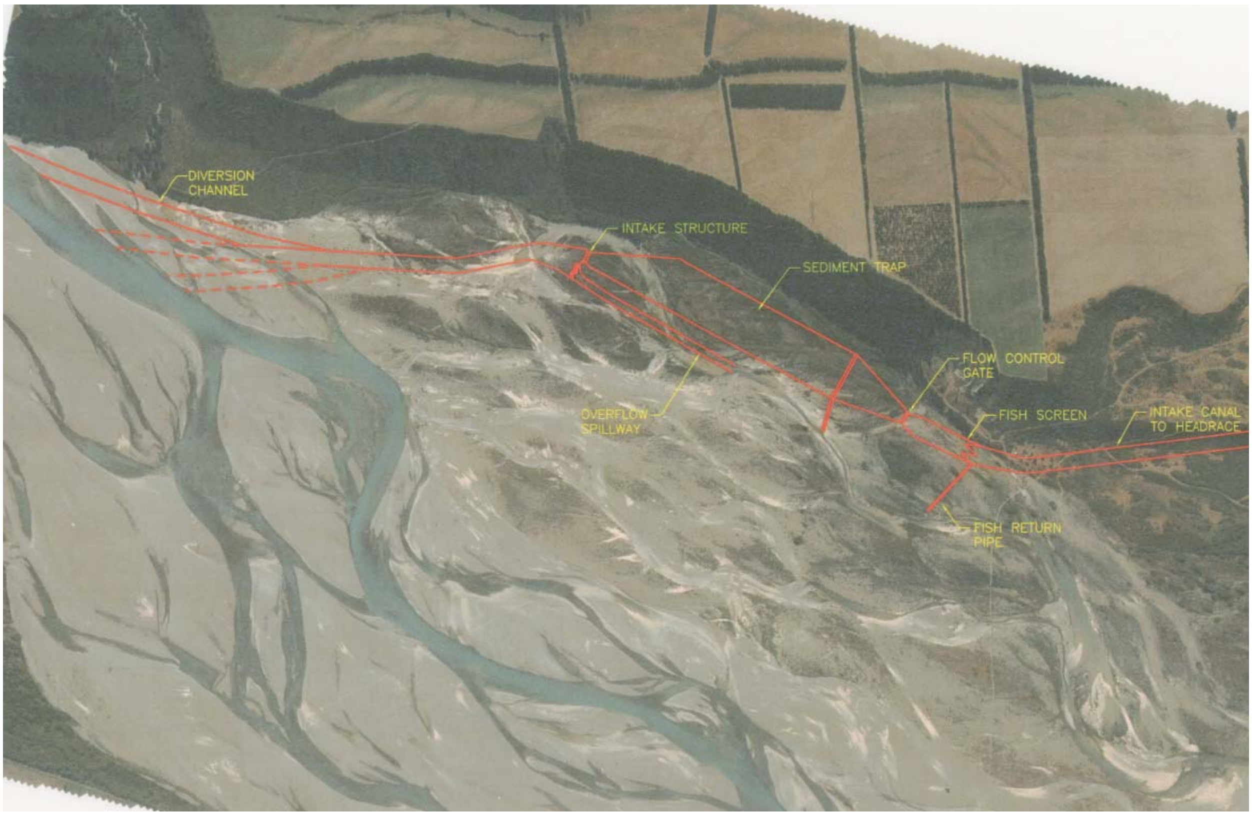


FIGURE 3-4: Rakaia River Intake (Scheme features shown at approximate locations)

3.4.2 Sediment management

Bed load material (i.e. gravels) will be largely excluded at the intakes and only a small amount will enter the scheme. This will be achieved by:

- Design of the intake structures: the intakes will be raised above bed level and will be constructed on the outside of bends where the river flow will scour a stable deep channel, and
- Operation during floods: the intakes will be closed during higher flows when sediment concentrations are higher. This will be able to be practised more extensively on the Central Plains scheme than on other Canterbury schemes, because the large storage facility in the Waianiwaniwa reservoir will allow uninterrupted supply to the scheme to continue while intake gates are closed.

Any gravels that do enter the intakes will settle within a short distance below the intake gates and will be either flushed out in periodic sluicing operations or will be removed mechanically from time to time as required.

Suspended load has needed more careful examination. Suspended load is the portion of sediment that is supported throughout the water column by turbulence, and is swept along at about the local flow velocity. Murray Hicks (NIWA) has made available all known data on suspended sediment concentrations and river discharge in the Rakaia and Waimakariri Rivers. There are 74 samples from the Rakaia River and

17 from the Waimakariri River. These data were used to produce suspended sediment rating curves, enabling a calculation of the amount of sediment that will enter the scheme at different river flows.

The most important properties that govern the settling of suspended sediment are particle size, shape and specific gravity. Hicks's information includes a sample from the SH1 Bridge on the Rakaia River during a 2844 m^3/sec flood on 10 January 1994. This was a depth averaged sample, the flow was recorded upstream at Fighting Hill, and the recorded discharge was slightly above the level of the mean annual flood (2415 m^3/sec). The size fractions were 36 % clay, 37 % silt, and 27 % sand; with 69 % of the sand in the very fine sand size range. This compares with Hicks's opinion (*pers comm*) that the expected proportion of sand in the suspended load of a river draining a greywacke catchment is ~ 30 %, reducing with lower discharges.

The upper and lower Waimakariri and the Rakaia intakes are proposed to contain suspended sediment traps of almost identical size. The traps, which will be built within 1 km downstream of the intake structure, will be designed to settle coarse suspended sediments (i.e. sands and a small proportion of silts). A capacity of approximately 80,000 m^3 per sediment trap is necessary to reduce intake flow velocities and to achieve the residence time required for settling. The sediment trap will be a widened canal section which will be approximately 100-150 m wide and 400 m long. We expect the traps to collect about 20,000 m^3 of sediment per year, total from all sources, depending on the level at which the gates will be closed. Further design refinements will be able to be made before construction following further river sediment sampling.

It is intended that settled sediments will be flushed periodically, as described in the AEE, or they may be removed mechanically from time to time. These operations will be optimised after practical experience.

3.4.3 Fish screens

Fish screens will be installed a short distance downstream from the sediment trap and flow control gates. The purpose of the screens will be to prevent entry of fish into the scheme race and to provide a bypass for them to return to the Rakaia River. Final details of design will be developed with experts in this field and to the approval of ECan as consenting authority. Current best practice for design is being developed by the ECan Working Group, whose work to date indicates the following features:

1. Screens will be either rotary or flat screens that will be designed to be cleaned automatically of both debris and algae
2. They will be installed at a maximum of 45^0 angle to the flow so as to encourage fish to sweep past the screens towards bypass channels and to facilitate passage of debris
3. They will be installed in a series of V-formations to reduce the geographical extent of the screen site
4. Screen mesh size will be about 3 mm, depending on the form of mesh finally selected, to exclude the large majority of downward migrant salmonid fry

5. Approach velocity to the screens will be a maximum of 0.12 m/s to enable salmonid fry to move away from the screens towards the bypasses

6. Bypasses with a total flow rate of 2 m^3/s will be designed to ensure fish are taken from the race and screen area with minimum damage

7. A return channel will lead fish to a significant flowing braid of the River.

The discharge of 2 m^3/s of fish bypass water results from diversion of this water from the River, and is not part of the 40 m^3/s water take for irrigation and ancillary purposes being applied for.

3.4.4 Waimakariri River intake – lower site

Two sites have been selected for intakes from the Waimakariri River, with the lower site at the Gorge Bridge. Locations of the works are shown in Figure 3-5. This site is on the true right bank at a level of about 250 masl providing a suitable location for feeding the headrace canal across the top of plains. The site has a deep and stable channel running along the bank of the river at the lower end of the Waimakariri Gorge, immediately before turning right to enter the braided fairway that leads to the coast. By using this site it is expected that there will be no need for river training works, or at the worst only occasional or minimal works.

For the Central Plains intake it is proposed to construct a tunnel through the rock outcrop that also serves as an abutment to the Gorge Bridge. A stockwater race intake was tunnelled through the rock outcrop in earlier years. Further investigation is needed before selecting the exact location, but it would be about 100 – 200 m upstream. The tunnel would have an intake structure with gates at the upstream end and would then pass through some 300 - 550 m of rock before exiting into the intake channel.

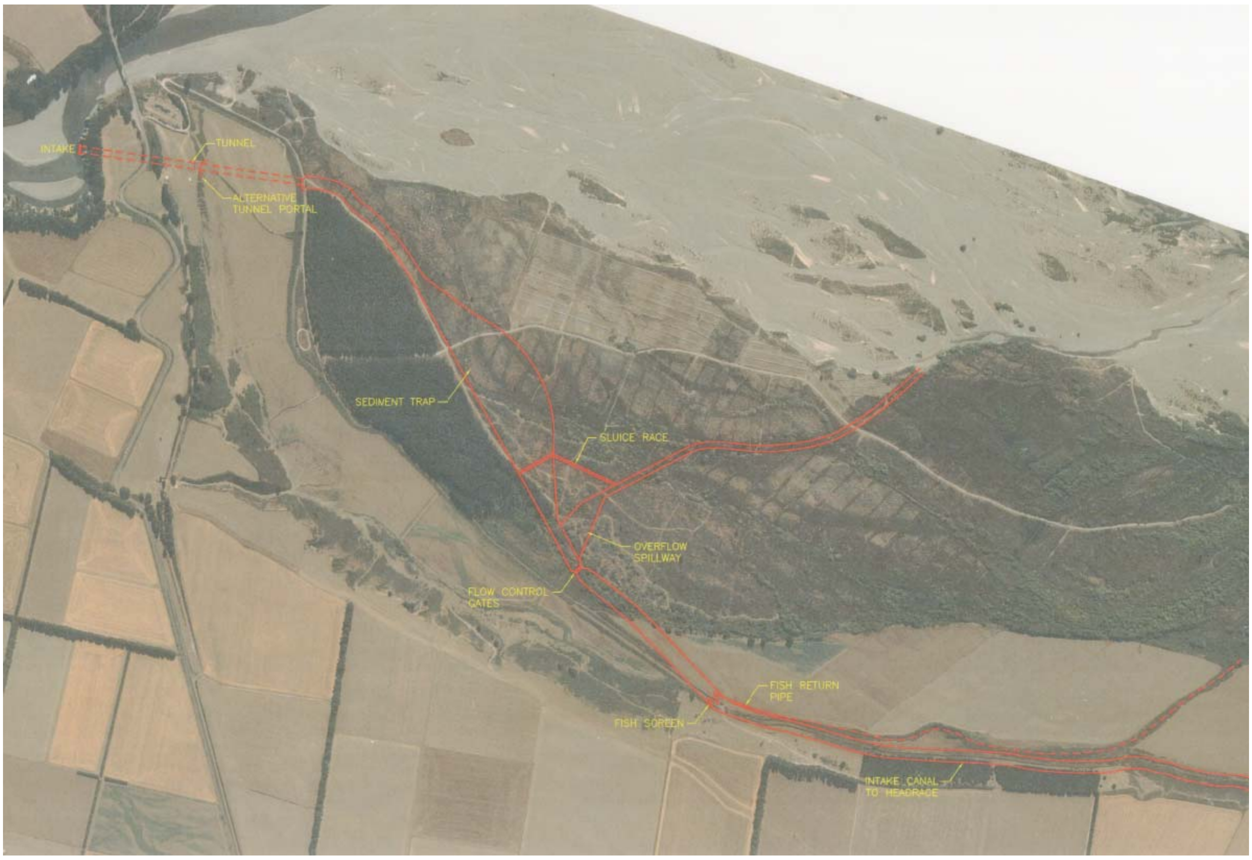


FIGURE 3-5: Waimakariri River intake – lower site (Scheme features shown at approximate locations)

Downstream from the tunnel, works would be similar to the proposed Rakaia intake, i.e. sediment trap and sluice race about 1 – 1.5 km downstream from the intake, overflow spillway, flow control gates, fish screens and return channels, and sidling canal to take water up the terrace to the plains. It is likely that existing stockwater race flood control works might have to be strengthened. As with the Rakaia intake the majority of the works prior to the sidling canal would be on a relatively undeveloped river berm. The alignment of the sidling canal past the fish screen is coinciding with the stockwater race alignment.

3.4.5 Waimakariri River intake – upper site

It is proposed to construct a second intake on the Waimakariri River at a higher site so as to provide water at a level that enables gravity flow to feed the proposed Waianiwaniwa reservoir. Locations of the works are shown in Figure 3-6. Gravity supply is preferred over the alternative of pumping from the lower Waimakariri headworks so as to buffer the scheme against future electricity price rises and it minimises energy use so reflects efficient use of resources. The selected site is on the true right bank at a level of 300 masl, some 3 km upstream from the Kowai River confluence with the Waimakariri, and at the lower end of the upper Waimakariri River Gorge. It is at the downstream end of a stable and generally single thread section of the river through the gorge, where the channel is starting to move away from the right bank. River diversion works are likely to be needed from time to time to maintain an adequate flow on the right bank into the intake channel. These diversion works would not include a weir or a dam to direct the flow into the intake.

Downstream from the diversion channel, works would be similar to the proposed Rakaia intake, i.e. a gated intake structure, sediment trap and sluice race, overflow spillway, flow control structure and fish screens and return channels. Then the canal would be piped underneath the Kowai River before entering a sidling canal to take water up the terrace to the plains. This canal would be a major structure, running for 6 km along the face of a terrace that is some 80 m high at the upstream end. A pump station is planned, 1 km downstream from the Kowai siphon, to pump water to the top of the terrace to enable irrigation of the plains in the Springfield/ Russells Flat/ Sheffield area.

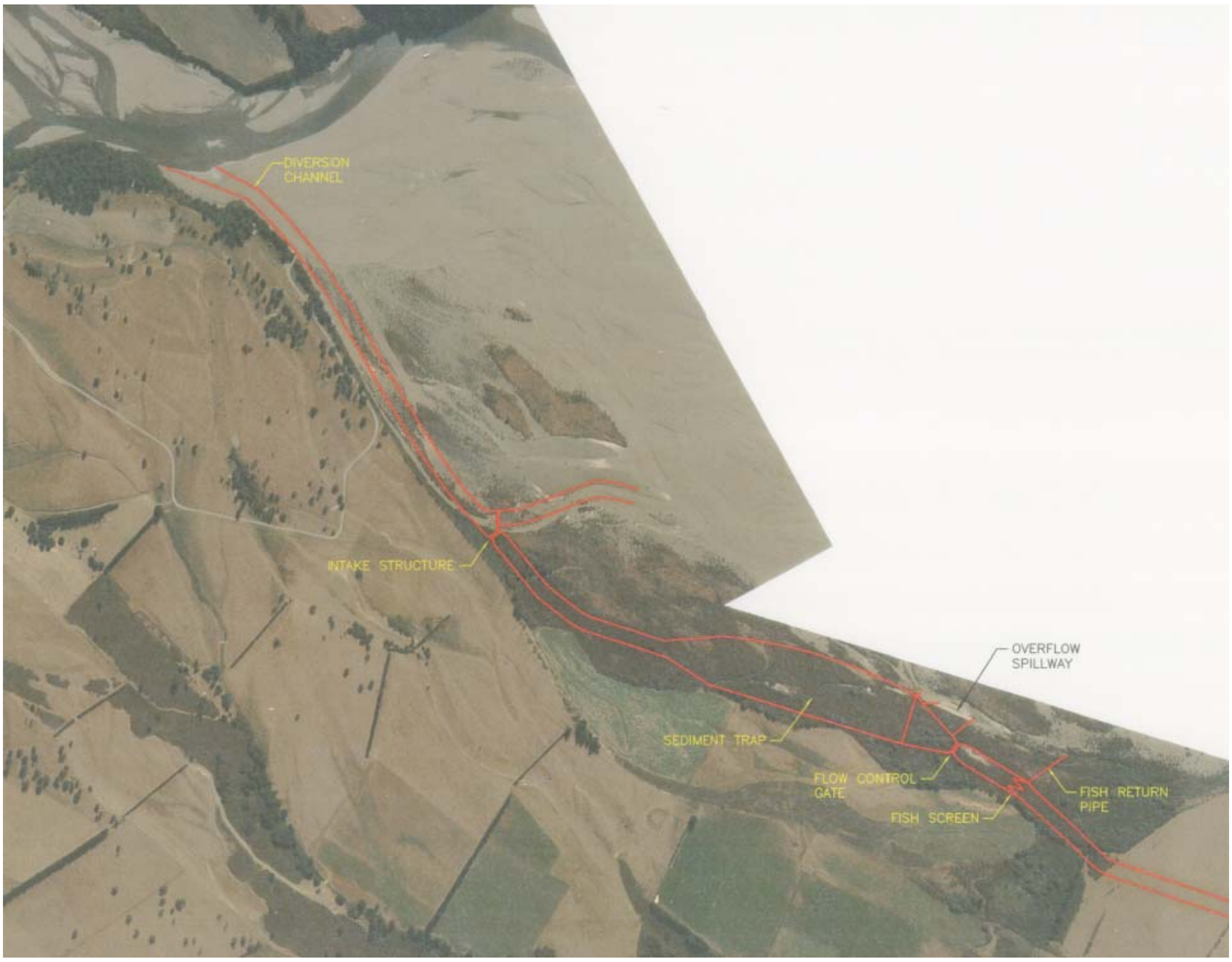


FIGURE 3-6: Waimakariri River intake – upper site (Scheme features shown at approximate locations)

3.5 Inlet Canal and Tunnel to Waianiwaniwa Reservoir

It is proposed to fill the Waianiwaniwa Reservoir via an ~ 15.5 km long inlet canal from the Waimakariri River, to a ~ 3 km long tunnel through the eastern Malvern Hills, discharging into the northeastern arm of the Reservoir. This gravity option is preferred as it would obviate the need for a pumped supply to the Reservoir from the headrace canal via a pump station near Coalgate. However, both options are being applied for in case the pumped option emerges as a viable option during the detailed design stage.

The intake structure and headworks facilities have been described above in Section 3.4, and in the application for the water take (URS, June 2005). These will be placed at various locations in the bed of the Waimakariri River about 3 km above the Kowai River confluence. The intake will be at an elevation of about RL 300 m, and the low gradient (approximately 1 in 1000 grade) intake canal will start near the Kowai River.

3.5.1 Canal route

The proposed canal route runs generally southeast along the true right side of the Waimakariri River to Gorge Hill, then swings to the south and southwest past Sheffield to the northeasten edge of the Malvern Hills. This is shown in Figure 3-7. The headworks will occupy parts of the ~ 3 km section upstream of the Kowai River confluence.

Immediately down valley of the Kowai River siphon, the canal will begin to climb the 80 m high terrace above the Waimakariri River. This climb will take most of the ~ 7 km distance between the Kowai River confluence and Gorge Hill. Just upstream of the hill, the route turns to the south southeast, and enters an ~ 20 m deep cutting that will take the canal 1.8 km around Gorge Hill to Waimakariri Gorge Road where it will again be at the plains surface, which is here between 295 - 300 masl.

The canal then runs southwest approximately 3.2 km along the 300 m contour line passing just south of Sheffield to the Hawkins River. The canal will then enter a small valley in the Malvern Hills taking it the last 300 m to the tunnel entrance.

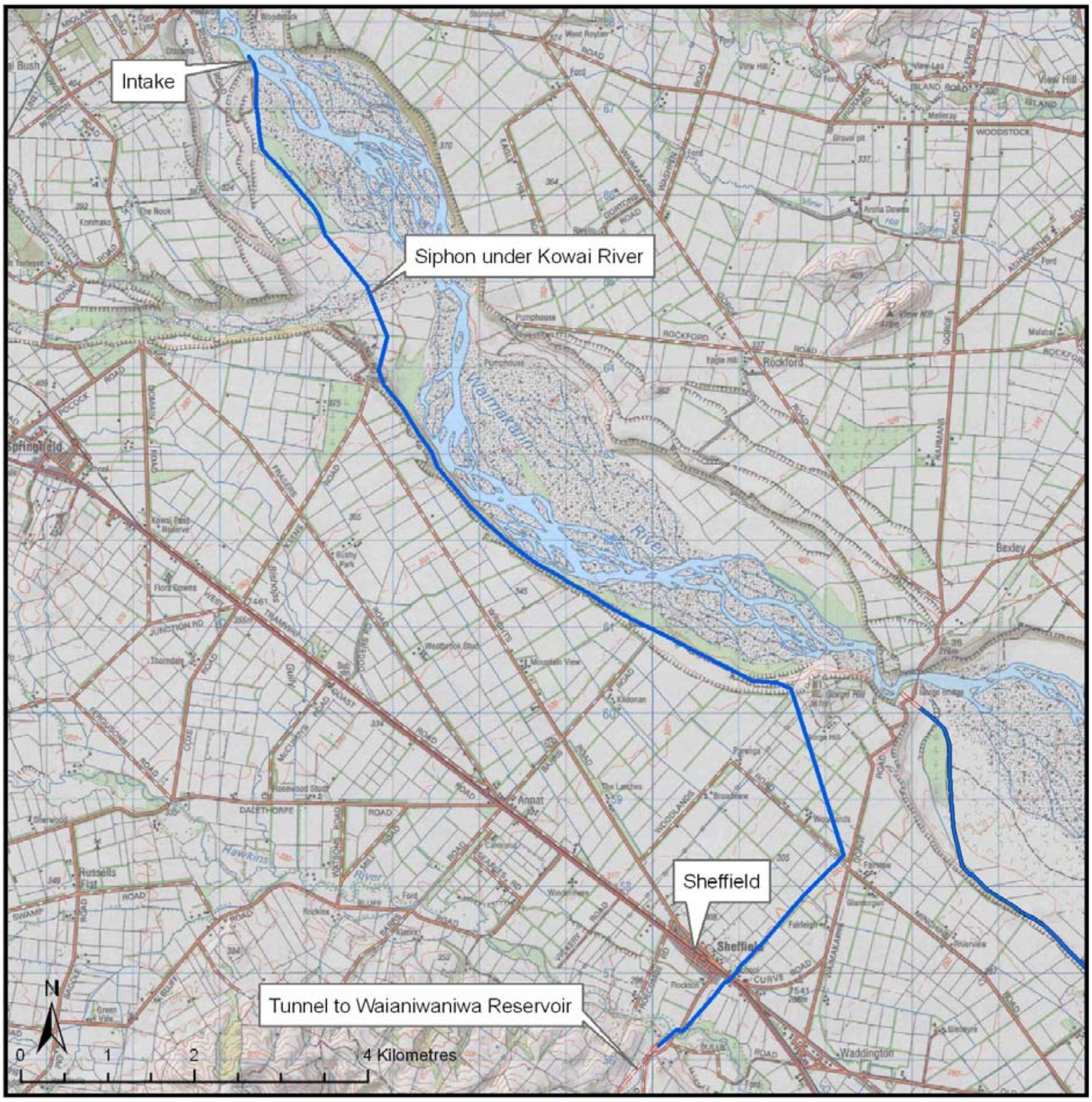


FIGURE 3-7: Alignment of the Inlet Canal to Waianiwaniwa Valley

3.5.2 Canal size

At this stage it is undecided how large the canal will need to be, as there are a number of options for the most efficient use of the various intakes. The maximum size of this canal would be needed if the scheme was only to use one Waimakariri River intake for both filling the reservoir and supplying the headrace. In this case a 40 m^3/s capacity canal would be needed. A minimum option would be a ~ 10 m^3/s capacity canal if it was only required to fill the reservoir.

For the purposes of this assessment, it is appropriate to assume that a 40 m^3/s capacity canal is required, the typical cross section of the canal will be similar to the headrace, described below. Along the flat sections of the route, it will consist of an excavated channel, 3 m wide at the base, and 20 – 25 m wide at the top, and 3.5 – 4.5 m deep. The excavated channel material will be used to form embankments to either side giving a 1 m freeboard. The total footprint of the canal and embankments where it is built at grade on flat land will be 40 – 50 m. If the required canal capacity is less than 40 m^3/s, the structure would likely be smaller than described above.

3.5.3 Canal crossings, cuttings, and traverses

The canal route will take it across a variety of topographic features, including streams, rivers, and terraces. In these places the design will vary from that described above.

Kowai River crossing

The canal alignment crosses the Kowai River at about map reference NZMS 260 L35: 267-649. The active bed is here about 250 m wide, and a siphon will be constructed to carry the water beneath the river enabling the Kowai River flow and sediment transport to continue unimpeded.

Hawkins River crossing

The canal crosses the Hawkins River about 650 m south of Sheffield at about map reference NZMS 260 L35: 302-563. To maintain grade and a straight alignment, it will be necessary to place the canal on 5 m high embankments across the shallow valley. The active channel of the river is 170 m across, and a siphon will carry the water beneath this.

Streams and Water races

The canal route crosses a number of small water bodies and water races, and these will be piped beneath the canal. The approximate locations of these crossings are as follows.

- Map reference NZMS 260 L35: 256-663 unnamed stream on north side of Kowai River
- Map reference NZMS 260 L35: 257-662 unnamed stream on north side of Kowai River
- Map reference NZMS 260 L35: 261-656 unnamed stream on north side of Kowai River
- Map reference NZMS 260 L35: 322-583 Kowai River Water Race near Waimakariri Gorge Road
- Map reference NZMS 260 L35: 320-583 Kowai River Water Race near Minchins Road
- Map reference NZMS 260 L35: 317-579 Kowai River Water Race near “Fairleigh”
- Map reference NZMS 260 L35: 308-569 Kowai River Water Race near SH 73

Roads and railway lines

The canal route crosses some roads and the West Coast railway line. Bridges will be constructed to carry the roads or railway line over the canal. The approximate location of these crossings are as follows.

- Map reference NZMS 260 L35: 322-583 Woodlands Road, northeast of Sheffield
- Map reference NZMS 260 L35:308-569 Curve Road, State Highway 73, and the West Coast Railway Line at Sheffield
- Map reference NZMS 260 L35: 303-563 Malvern Hills Road, 300 m south of Sheffield.

Terrace traversing

In the approximately 6 km section between Tipapa Farm (just south of the Kowai River) and Gorge Hill, the canal will traverse across an ~ 80 m high terrace face. This will require significant engineering to provide a platform for the canal and its outer embankment, and stable slopes above and below the canal.

Gorge Hill cutting

The canal will have 'climbed' to near the top of the Waimakariri Terrace when it is a few hundred metres west of Gorge Hill. A cutting will be required to take the canal through the plains surface. At Gorge Hill it will be about 20 m deep, tapering to reach the plains surface about 1.9 km southeast at Waimakariri Gorge Road. The cutting will be about 110 m wide at the upstream end.

3.5.4 Canal earthworks

The inlet canal will be constructed in alluvial outwash gravel and sand deposits along its entire length. It is expected that materials encountered along the alignment will mainly form suitably low permeability canal lining. This will entail compaction of in-situ materials to minimise leakage, and over time fine silts and clays will be carried into open pore spaces between large particles, further improving the sealing. Where particularly coarse framework gravels occur, some extra lining of the canal may need to be imported. This may be necessary as the canal traverses the Waimakariri terrace face. Lining material could include imported silt and/or clay sediments, or plastic lining material.

3.5.5 Tunnel

The final ~ 3 km of the gravity route from the upper Waimakariri River intake to the Waianiwaniwa Reservoir will require a tunnel through the Malvern Hills. The entrance would be on Malvern Hills Road at about map reference NZMS 260 L35: 300-561, about 1.2 km southwest of Sheffield.

The tunnel would be up to about 6 m in diameter, depending on the eventual design flow and may need to be lined depending on rock characteristics, and groundwater inflows.

It is expected that the tunnel route would encounter gravel, Tertiary sediments, and greywacke. Engineering design will need to take account of the stability of the materials that will be encountered and potential groundwater inflows. There may need to be appropriate internal support structures.

An estimated 100,000 to 110,000 m^3 of spoil will need to be disposed of, although some may be suitable for construction of the Waianiwaniwa Dam. Spoil disposal from the tunnel will be within the Waianiwaniwa Valley as the tunnel would be constructed from the southern end.

3.6 Waianiwaniwa Dam

An important component of the Central Plains Water Enhancement Scheme is the ability to provide farmers with a reliable water supply even during dry periods when river flows are low, and water is not available from either the Rakaia or Waimakariri Rivers. To achieve this, it is proposed to store sufficient water in a reservoir. This reservoir will be filled with water abstracted from the Waimakariri River during periods of higher river flow. However if a pumped reservoir supply option is eventually adopted instead of the presently preferred gravity supply it could also be filled from the headrace with water from the Rakaia River. The proposed reservoir will be located in the Waianiwaniwa valley, 1.5 km north east of Coalgate, as shown in Figure 3-8.

Creation of the Waianiwaniwa Valley reservoir will require damming the valley at the point where the river leaves the Malvern Hills between the Homebush Ridge and the unnamed ridge to the north of Coalgate. This is the point at which the river flows out onto the inner margin of the Canterbury Plains. The mouth of the valley is about 350 m wide at river level (230 - 235 m contour), and broadens to be 1.85 km wide at the 280 m contour. The river channel and associated shallow valley is situated close to Homebush Ridge. To the west is a higher terrace surface at 250 – 270 m above sea level that extends ~1.2 km across to the unnamed ridge. The proposed dam will take advantage of this topography.

The proposed impoundment structure will be approximately 2 km long, extending from just above the 280 m contour level on Homebush Ridge to the same level on the unnamed ridge. The maximum height of the structure will be about 55 m, with a basal footprint width of ~250 m, and 10 m wide crest constructed to give a minimum freeboard of 2 m above the highest storage water level. This extra 2 m of freeboard will allow for seiching (wind driven build up of water at one side of the lake) and rainstorm events.

At this stage the volume of storage required, assuming the worst-case scenario of water availability and demand is 280 million cubic metres. This will require a full storage water level of 280 masl, and a maximum dam height of 55 m. However, at the detailed design stage, it may transpire that less storage is required in which case a lower dam would be needed. It may be possible to provide all the necessary storage with a 270 m above sea level reservoir level, and this would be preferred as it would require less capital expenditure. However, given the uncertainties surrounding these issues at this stage, it is considered advisable to seek resource consents for the maximum potential reservoir size.

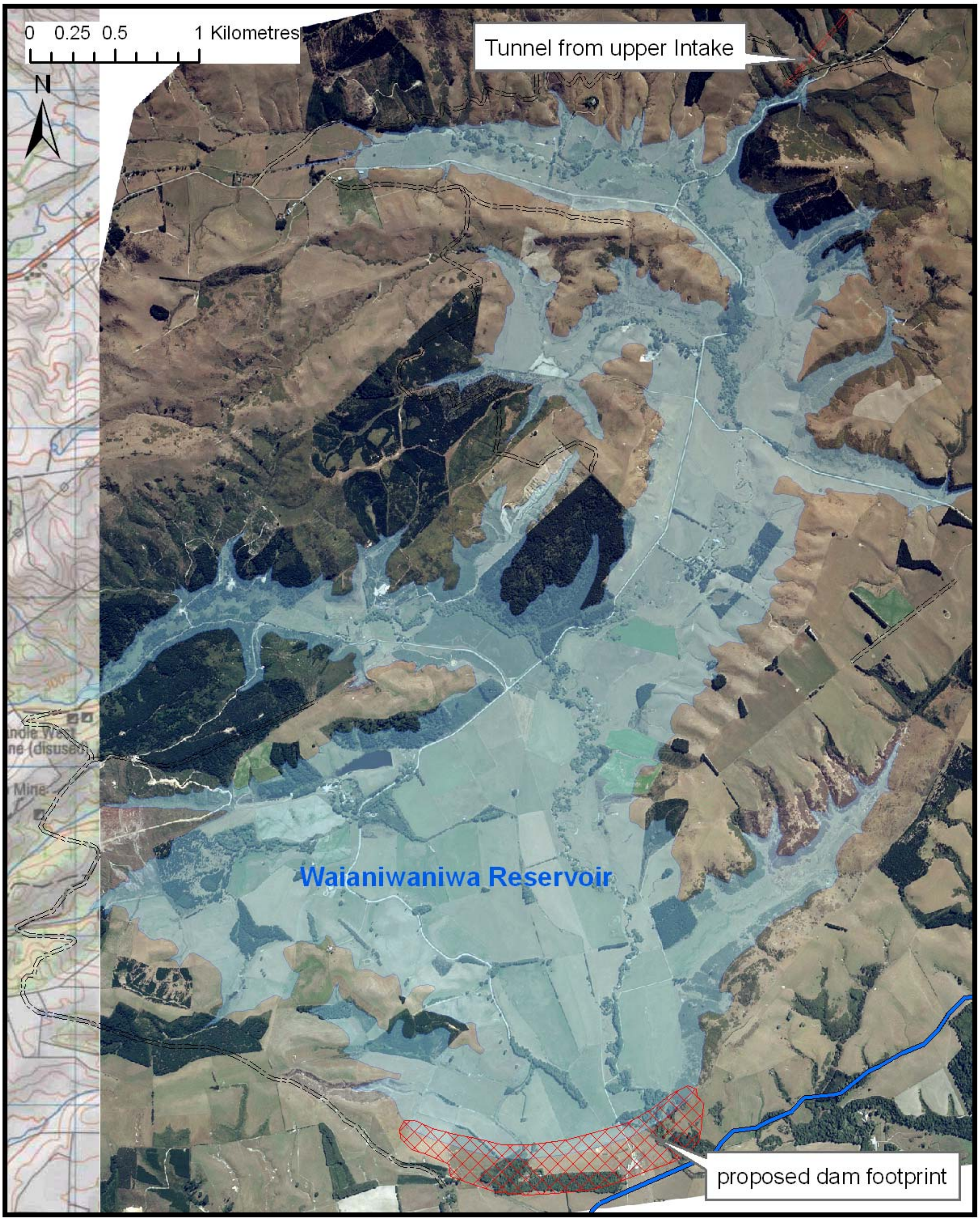


Figure 3-8: Proposed Waianiwaniwa Dam and Reservoir

3.6.1 Embankment design

The proposed dam design incorporates a zoned earthfill embankment comprising locally borrowed mainly gravel materials. In cross section, the dam will comprise six elements:

- *Foundations* will require removal of the 10 m deep loess silt layer on the terrace, and elsewhere a cut 3 m below existing ground level.
- *Cut off system* incorporating a 5 m deep cutoff trench with a 10 m deep slurry trench in the base of the core trench, extending down through the gravels to bedrock. This is to prevent excessive flow through the gravels under the embankment.
- *Core* of compacted clayey gravels with slopes of 0.5 horizontal to 1 vertical, being about 75 m wide at the base, and extending up to the dam crest level.
- *Sand filter drain* against the downstream face of the core to provide filter protection.
- *Shoulder* material of greywacke gravel and sand against the upstream and downstream faces of the dam. The outer construction slopes will be 2 horizontal to 1 vertical.
- *Outlet tower* of reinforced concrete to allow water to flow to the outlet canal towards the headrace.
- *Spillway* to former bed of Waianiwaniwa River which will most probably be a combination of the outlet tower and bypass gates from the headrace.

Figure 3-9 shows a typical cross section through the embankment, and the location of the dam is shown in Figure 3-10. The upstream face of the dam will require riprap protection from wave erosion as the reservoir water levels will vary significantly. Suitable riprap materials should be available locally.

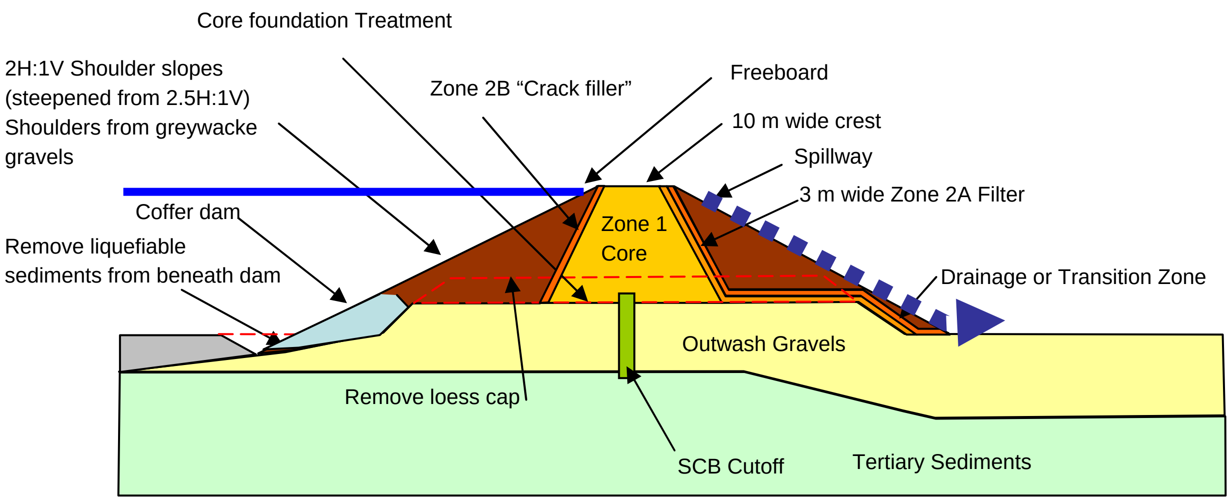


FIGURE 3-9: Typical cross section of the embankment dam

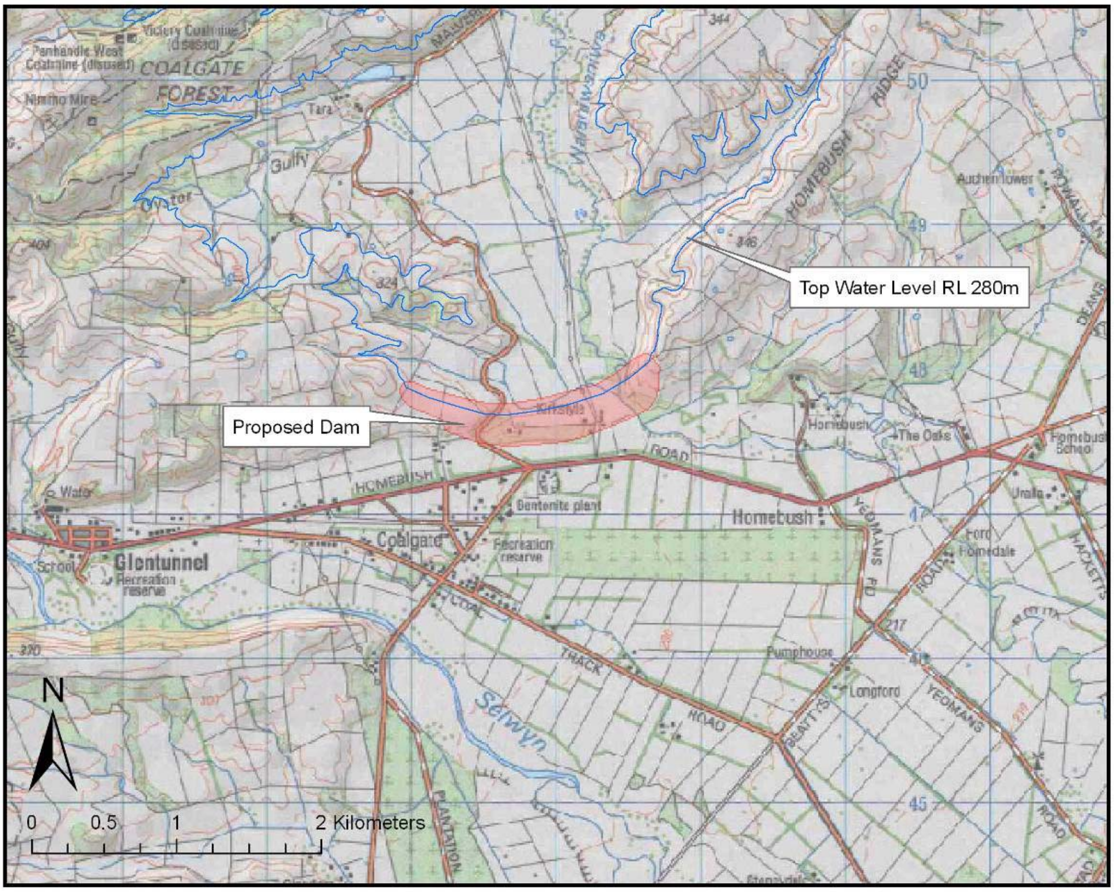


FIGURE 3-10: Location of the Waianiwaniwa Dam

Design, construction, and maintenance of the dam will be governed mainly by the RMA (1991), and Building Act (2004). Given the probable Potential Impact Category (PIC) classification of the dam, it is likely that the dam will need to be constructed to a standard that will allow it to safely pass inflows from a 1 in 10,000 year flood event, and to be able to withstand a 1 in 10,000 year earthquake event without uncontrolled release of water.

3.6.2 Construction materials

The total volume of material required for the embankment has not been accurately estimated. A crude approximation can be derived as follows. Assuming a 2000 m long embankment, 55 m high, and 250 m wide would require a total of ~ 17 million cubic metres. However, the terrace feature will form part of the base, and as this is ~ 1350 m long by 250 m wide and 25 m high it would reduce the material needed by ~8.5 million cubic metres, giving an approximate requirement of 8.5 million cubic metres.

A variety of materials are needed, including clayey gravels, sand, and sandy gravels. These are all available locally within about 2 km of the dam site. Clayey gravels for the core could be sourced from terrace remnants to the north of the dam in the Waianiwaniwa Valley in areas that would be flooded. Sandy gravels and sand for the filter material and shoulders could be sourced from the valley floor in front of the dam. If this option were taken up, once the construction phase was completed the resulting gravel pit could be suitably landscaped and filled with water as a recreation resource for Coalgate.

3.7 Reservoir

The purpose of the embankment dam is to impound the Waianiwaniwa reservoir. The top water surface level is proposed to be at RL 280 m, although as explained above, it may be possible to achieve the necessary storage with a lower water level of around RL 270 m. However, all descriptions and assessments in this report will be with respect to the higher water level.

It is necessary to provide a storage volume of 280,000,000 m^3 (280 MCM). The reservoir footprint required to achieve this is shown in Figure 3-8. When full, the reservoir will flood 12 km^2 of the valley, and have a mean depth of 24 m. The maximum depth of 50 m would occur along the southern margin of the reservoir next to the dam. Characteristics of the reservoir at 50 % and 25 % capacity are shown in Table 3-1.

Table 3-2: Characteristics of the Waianiwaniwa Reservoir at varying capacities

Parameter	100 %	50 %	25 %	Minimum
Volume (MCM)	280	140	70	35
Area (km^2)	12	7	5	3.7
Mean depth (m)	24	19	13	9
Fetch (km)	5.9	5.1	4.7	3

Based on hydrological data for the years 1967 – 2001, it is predicted that the reservoir would go completely dry in one year out of 34, and be drawn down to less than 50 % capacity in 12 years out of 34. The mean volume of water in the reservoir would be 239 MCM, or 85 % of capacity. Seasonally, the lowest water volumes in the reservoir will be from January to May, which is typically a period of high irrigation demand coupled with reduced river flows. It will be near full from June to end of December. It is estimated that the mean annual discharge from the reservoir will be 120 MCM, resulting in a residence time of water of about 2 years.

The inundated area will need to be prepared prior to filling the reservoir. All trees will be cut down, buildings, bridges and fences removed. The shoreline of the lake will largely be left to form naturally. However, a geotechnical survey of the shoreline area will be carried out to identify areas that could be potentially affected by slope stability problems once the lake is filled. Standard geotechnical works will be carried out to stabilise these slopes.

Surveys of the former coal mines in the valley will be carried out to determine whether any will be affected by the reservoir, and potential discharges of acid mine drainage or other toxic materials will be remediated.

Several roads will be flooded including 1.7 km of Auchenflower Road, 9.5 km of Malvern Hills Road, 1.5 km of Bush Gully Road, and 2.0 km of Waianiwaniwa Road.

3.8 Reservoir Outlet

The outlet canal between the Waianiwaniwa Reservoir and the headrace will be designed to pass peak flow volume of 45 m^3/s in a 4.5 m deep channel, with water level width of 27 m. Embankments will be designed for seismic stability with side slopes of 2.5 (H) to 1 (V), and a total footprint width of 50 m. The canal will be lined with compacted locally derived weathered gravels. At the junction with the headrace the canal outlet will be fed into a stilling pond to reduce flow velocity. At the discharge point from the outlet tower, energy dissipation will be provided to reduce the potential to scour canal linings.

3.9 Headrace System

Water from the various river intakes and the Waianiwaniwa Reservoir will be fed into a level headrace that will follow the 235 m contour between the Waimakariri and Rakaia Rivers. The design allows it to be filled with water from the reservoir, or either of the two rivers, depending upon availability. This is part of the scheme's philosophy of carefully balancing flexibility, water use efficiency, and reliability of supply. The headrace system will comprise the canal and embankments, siphons under rivers, pipes for stream and water race crossings, and bridges for roads and railway crossings. There will also be embankments, cuts around and through hillsides, and traverses across terrace faces. These are described below.

Although the headrace will be essentially level, water can enter it from either end, or the middle. Thus, water may flow in both directions in the headrace, depending on different supply and demand conditions. Flow is induced by raising the water level at the inflow locations and drawing outflows into the distribution network. Flow velocities will be kept below 1 m/s to minimise potential for scour or erosion of embankments.

3.9.1 Headrace route

The headrace route will generally follow the 235 m contour elevation. In places where the surface topography is irregular, or where farm management needs require a shift, the canal may be moved laterally from this contour by several 10s of metres or more for short distances, and to avoid following every twist and turn it will be possible to achieve more direct alignments by adjusting cut and fill ratios. However, it will not be possible to precisely locate the headrace route until detailed design work and consultation with individual landowners has been completed.

The alignment of the headrace described below is based on available topographic information, in particular the NZMS 260 series of 1:50,000 scale topographic maps, a photogrammetric survey carried out by New Zealand Aerial Mapping Ltd, and ground surveys by Eliot Sinclair and Partners surveyors. The various road, stream, water race, and other crossings identified below are expected to be required, but the precise location will be subject to refinement as the design phase progresses.

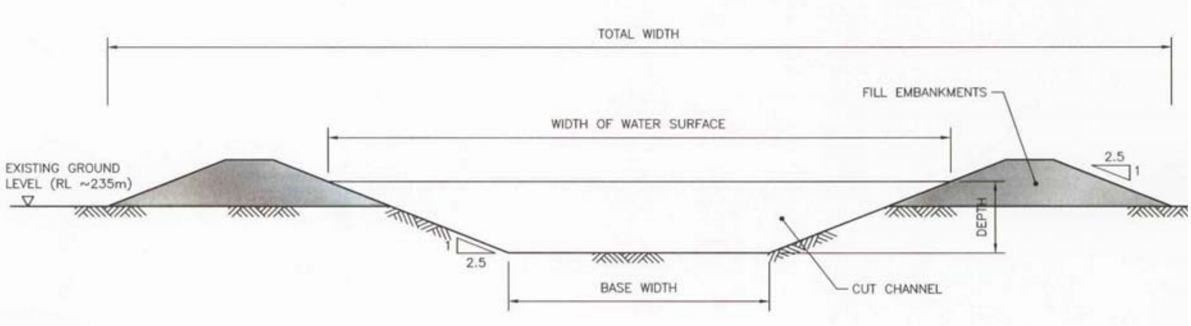
In the Rakaia Valley, the headrace canal starts at the 235 m contour about 3 km downstream of the intake, and it follows this contour across the plains for about 53.4 km to the Waimakariri Valley, to a point about 5 km downstream of the Waimakariri intake. The proposed route runs southeast and then east along the north bank of the Rakaia River, gradually 'climbing' a series of terraces and reaching the main plains surface about 11.5 km from the start. It then turns north to run ~ 10 km towards the Harper Hills, and then skirts ~ 11 km along the inner margin of the plains to the northeast to Coalgate, where the Waianiwaniwa Reservoir supply canal joins it. From here it skirts for ~ 4 km around the base of the Homebush Ridge, before heading for ~10 km east and northeast across the plains to be above the Waimakariri River, where it turns to the northwest and traverses about 8 km 'down' the terrace face to the riverbed. The route is shown in Figure 3-12 and 3-13, and in more detail in Appendix B.

3.9.2 Canal size

The headrace has a trapezoidal cross-section as shown in Figure 3-11, a bottom width of 5 m, and side slopes of 2.5 (horizontal) to 1 (vertical) will remain constant along the entire length. The embankment height and water surface width will vary along the length according to required flow capacity in each reach. Typically the canal will be designed to carry flow depths of 5.0 m, with a top water width of approximately 30 m and a freeboard of approximately 1 m. The total footprint width of the canal and embankments will be commonly 40 to 50 m, or wider where the alignment deviates significantly from the 235 m contour.

3.9.3 Canal earthworks

The headrace channel will be excavated into the plains surface, and the cut material used to form embankments on either side. Cuts and fills will be balanced to achieve the most effective use of on-site materials. Embankments will be designed to maintain stability and integrity under anticipated maximum seismic loads and fault movements.



FLOW m^3/s	DEPTH (m)	BASE WIDTH (m)	WATER SURFACE WIDTH (m)	FREEBOARD (m)	EMBANKMENT SLOPE (H:V)	TOTAL WIDTH (m)
20 – 40	5.0	5.0	30	1.0	2.5:1	50 – 60

FIGURE 3-11: Cross section of the headrace

Expected ground conditions

It is likely that the whole headrace route will be across or through gravel materials. These will have varying properties related to their topography, age, origin, and loess cover, and these will affect the detailed earthworks requirements that will control the headrace route.

Recent river gravels will underlie a total of about 2.5 km of the intake and headworks areas before the start of the headrace proper in the beds of the Waimakariri and Rakaia Rivers. These will be very free-draining gravels, and the headrace will be lined to restrict seepage to an acceptable level as described below.

Young river terrace gravels of the Springston Formation will underlie about 25% of the headrace route, as it crosses the older parts of the river beds, and traverses up the terrace faces and out of the Waimakariri and Rakaia riverbeds. There are also short sections of these gravels associated with the Hororata, Selwyn, and Hawkins Rivers. These are likely to be free-draining gravels, and it may be necessary to import some fine material to form a suitable lining to reduce leakage through these sections.

River terrace gravels of the Burnham and Windwhistle Formations are slightly older gravels that have some silt content and loess cover, and these will comprise about 51% of the headrace route. They underlie the main Canterbury Plains surfaces that slope east away from the Rakaia River, and southeast away from the Waimakariri River. Topography is generally flat, and it is expected that the silt content and loess cover will generally provide suitable materials for mixing to form the lining for the headrace in these sections.

Old river and glacial moraine gravels of the Woodlands and Hororata Formations should mostly have higher silt and clay content, and are in places overlain with thick loess cover (up to 15 m deep). They underlie about 24 % of the headrace route. They underlie the lower footslopes of the Harper Hills and Homebush Ridge. Surface topography is undulating to rolling, and the headrace route will need to follow these irregularities. Good lining should be achieved from the higher proportion of fines in these gravels.

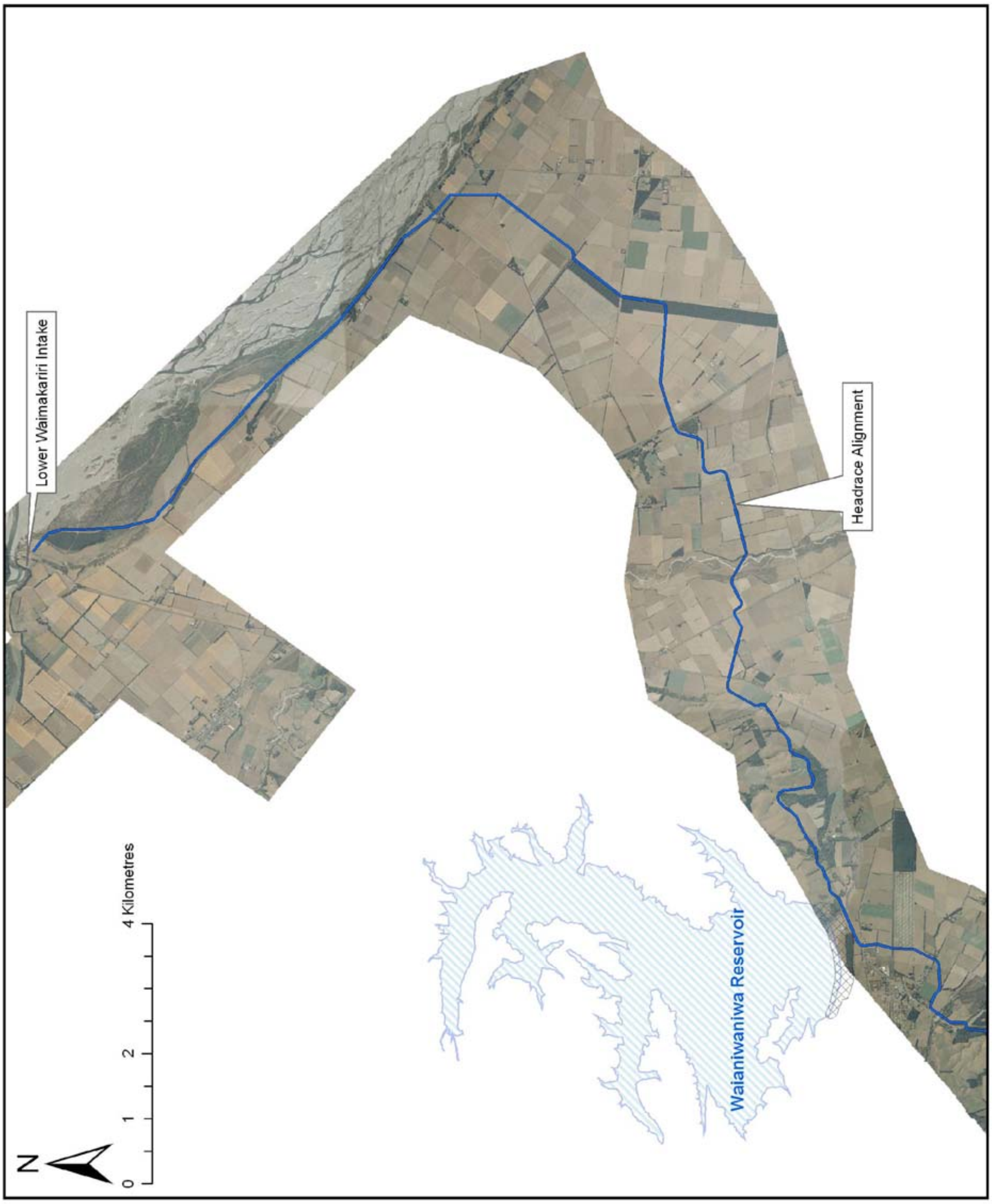


FIGURE 3-12: Headrace alignment – northern part

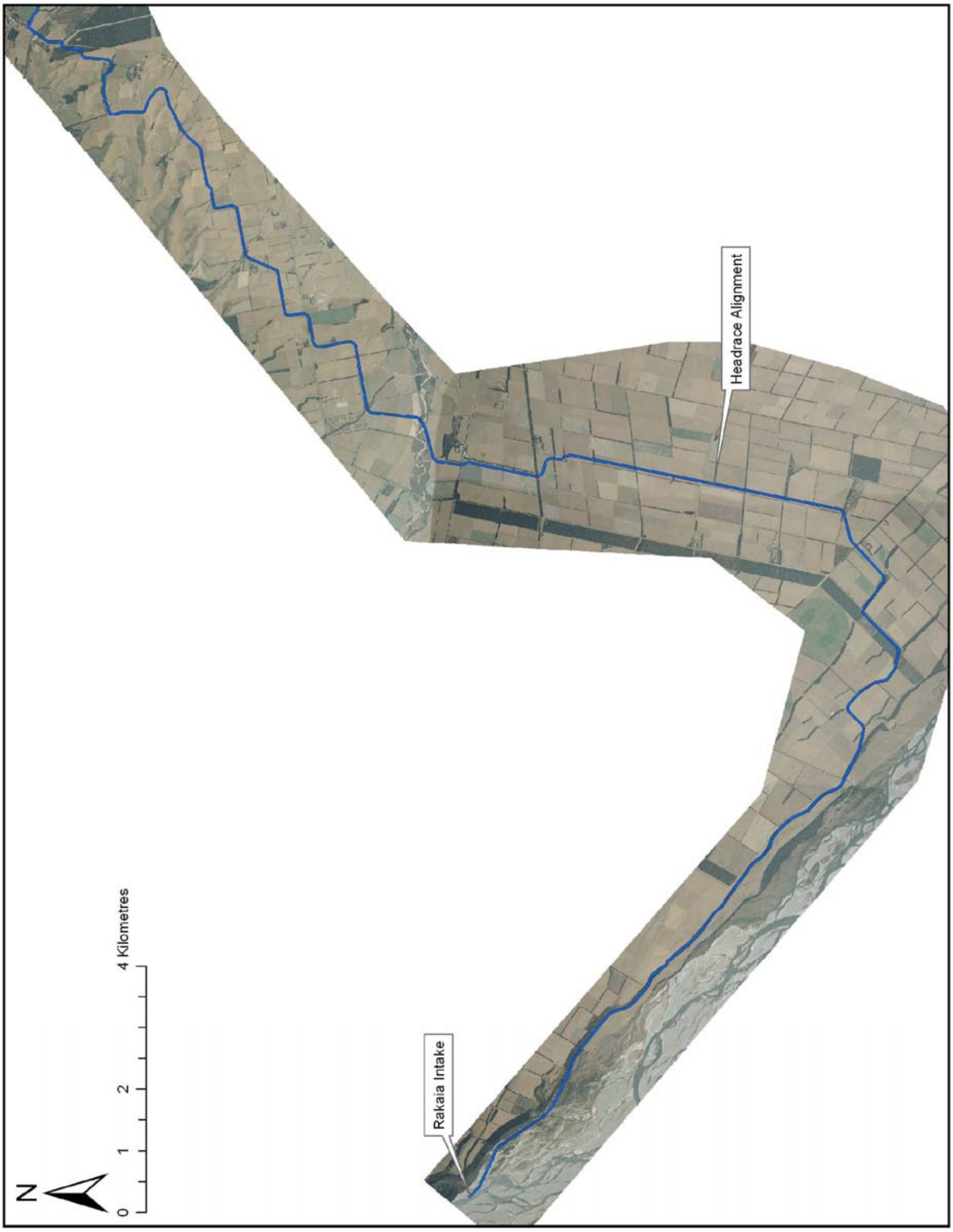


Figure 3-13: Headrace alignment – southern part

Headrace lining

An important aspect of the earthworks for the headrace will be the lining to prevent significant leakage to groundwater. A number of approaches are possible, including no lining at all rather relying of fines in the water to settle out over time to seal the headrace. This was the approach followed with the Rangitata Diversion Race, and over time this has become well sealed due to the settling out of fine materials. Alternatively, the headrace can be lined with a ~ 30 cm layer of compacted in-situ materials. If there is 5 – 10 % silt and clay, permeability of 10^{-8} – 10^{-7} m/s can be achieved (Macfarlane, 1988; Lewthwaite, 2001). Such materials may be won from within the headrace excavations, but could also be obtained from borrow pits in weathered gravels adjacent to the headrace. A further alternative could be to line the headrace with synthetic impermeable material. Previous experience of irrigation canal construction in the Amuri Basin, the Rangitata Diversion Race, and Lower Waitaki areas shows that low permeability can be achieved from the compaction of in-situ gravels with very similar characteristics to those present in the Central Plains project area. Thus, it is expected that the compaction of in-situ gravels should achieve total seepage losses of no more than about 1 m^3/s along the whole headrace route, irrespective of the canal construction method. The effects have been based on this seepage loss.

3.9.4 Traverses

Major traverses will be needed where the headrace 'climbs' out of the Rakaia and Waimakariri riverbeds. At the Rakaia River there will be one main traverse, and four small ones, as the headrace 'climbs' 35 m out of the river bed along a total distance of approximately 9 km. The main terrace traverse starts at about map reference NZMS 260 K36: 093-375, and runs for 7.1 km south east as it 'climbs' ~ 20 m from the river bed to the top of the terrace at about map reference NZMS 260 L36: 144-327. There are three further small terraces of about 2 to 3 metres, at approximate map references NZMS 260 L36: 146-327, a traverse of 1.1 km between map reference NZMS L36: 150-329 and L36: 157-322, and the final traverse of 0.7 km up an ~ 8 m high terrace between map references NZMS 260 L36: 165-327 and L36: 172-324.

In the Waimakariri sector, the headrace 'climbs' a single ~ 30 m high terrace in a 3 km long traverse from approximate map reference NZMS 260 L35: 358-563 to L35: 379-544.

An ~ 50 m-wide platform will be constructed into these terrace faces to accommodate the headrace. This will require slopes above and below the platform to be engineered to maintain stability, and material cut from the upper slopes will be used to fill the lower slopes.

3.9.5 Siphons

The Hororata, Selwyn, and Hawkins Rivers will be crossed with concrete culvert siphons running beneath the river bed. Siphons will be constructed from pre-cast concrete box-culvert units installed at least 3 m below bed level to allow for erosion and scour. The length of the siphons may be up to 400 m. The proposed siphons will be at the following approximate locations:

- Hororata River at map reference NZMS 260 L36: 196-398;
- Selwyn River at map reference NZMS 260 L35: 259-461; and
- Hawkins River at map reference NZMS 260 L35: 328-493.

3.9.6 Embankments

The proposed route of the headrace will follow the 235 m contour line. However, in some places following this line will result in difficulties, including long detours from the general route to follow topographic irregularities, passing through or too close to buildings, or close to sites of cultural, social, historic, or environmental value. In these cases it will be necessary to make embankments or cuttings to maintain grade where the headrace route must deviate from the 235 m contour on the ground.

Embankments will be needed where the ground surface needs to be raised at river crossings, and near Coalgate. The height of the embankment will depend on the topography being crossed, but will generally be no more than 5 m high, and the width at the base will be up to 85 m. Embankments at the minor river crossings will be located approximately as follows.

- Hororata River at about map reference NZMS 260 L36: 196-398
- Selwyn River at about map reference NZMS 260 L35: 259-461
- Hawkins River at about map reference NZMS 260 L35: 328-493

The length of the embankments at these river crossings cannot be accurately estimated until detailed design is carried out. The final length will be a trade off between the costs of an embankment , costs of the siphon, and width of river fairway necessary to safely contain flood flows without causing downstream erosion of the banks.

The longest embankment structures will be required between the Selwyn River and Homebush Ridge where the headrace will need to be located so as to avoid Coalgate township, and Homebush Station, on land that is ~ 5 m below the necessary grade. An embankment will be required running 1.3 km southeast from map reference NZMS 260 L35: 260-463 to map reference L35: 269-464. A further long embankment structure will be required starting at map reference NZMS 260 L35: 270-470 and running north for 0.4 km to map reference L35: 271-474, and then northeast for 0.75 km to map reference L35: 278-478. This will take the headrace from the eastern outskirts of Coalgate, across the Homebush – Glentunnel Road to the Waianiwaniwa River, and then to the base of Homebush Ridge west of the Homebush Station buildings.

Short sections of embankment may be required as the headrace crosses the lower slopes of the Harper Hills and Homebush Ridge. Along these sections the 235 m contour winds in and out of the mouths of shallow valleys, and it will be practical to cross these directly on embankments approximately 5 to 10 m high. There are 13 small streams mapped along the lower slopes of the Harper Hills, and 5 along the foot of Homebush Ridge. It is expected that the required grade can be maintained by allowing for a combination of cut and fill sections where small cuttings supply the necessary material for nearby embankments. Consideration will also be given to blocking off some small valleys with a single-sided impoundment structure, thereby creating a small water body of a few hundred square metres.

3.9.7 Cuttings

In places the headrace will need to be routed in a cutting through low hills or ridges. As with the embankments above, the need for this will arise where the route needs to be shortened, or to avoid farm buildings, sites of cultural, social, historic, or environmental value. Two significant cuttings will be required, southeast and northeast of Coalgate.

A cutting is proposed through a spur of the Harper Hills from map reference NZMS 260 L35: 250-443 to L35: 246-444. This will be ~ 0.4 km long and up to 20 m deep, and will shorten the route by over 1.5 km, and allow the headrace to avoid farm homesteads at The Bend and Glendore.

A cutting is also proposed through a spur on the lower slopes of Homebush Ridge from map reference NZMS 260 L35: 287-482 to L35: 293-486. This will be ~ 0.8 km long, up to 30 m deep, and will allow the headrace to avoid the historic Homebush homestead.

3.9.8 Other crossings

The headrace route will cross numerous small streams, water races, roads, farm access tracks and a railway line. Bridges will be constructed to carry roads over the headrace, while culverts will be constructed to carry streams and water races under the headrace.

Most of the stream crossings will occur along the lower slopes of the Harper Hills where there are 12 small streams that are tributaries of the Hororata River, and 3 tributaries of the Selwyn River. There are also 6 stream crossings along the front of Homebush Ridge. Concrete box or steel plate culverts will be constructed to carry flows in these mainly ephemeral streams beneath the headrace. The approximate locations of these stream crossings are listed below in order along the headrace from the Rakaia to the Waimakariri Rivers.

- Unnamed tributary of Hororata River at about map reference NZMS 260 L35: 198-408
- Unnamed tributary of Hororata River at about map reference NZMS 260 L35: 204-409
- Unnamed tributary of Hororata River at about map reference NZMS 260 L35: 205-409
- Unnamed tributary of Hororata River at about map reference NZMS 260 L35: 209-414
- Unnamed tributary of Hororata River at about map reference NZMS 260 L35: 211-417
- Cordys Stream at about map reference NZMS 260 L35: 215-421
- Unnamed tributary of Hororata River at about map reference NZMS 260 L35: 220-422
- Unnamed tributary of Hororata River at about map reference NZMS 260 L35: 223-427
- Unnamed tributary of Hororata River at about map reference NZMS 260 L35: 226-428

- Unnamed tributary of Hororata River at about map reference NZMS 260 L35: 227-428
- Unnamed tributary of Hororata River at about map reference NZMS 260 L35: 233-433
- Unnamed tributary of Hororata River at about map reference NZMS 260 L35: 237-434
- Unnamed tributary of Selwyn River at about map reference NZMS 260 L35: 247-448
- Unnamed tributary of Selwyn River at about map reference NZMS 260 L35: 247-250
- Unnamed tributary of Selwyn River at about map reference NZMS 260 L35: 252-415
- Unnamed tributary of Waianiwaniwa River at about map reference NZMS 260 L35: 276-476
- Unnamed tributary of Waianiwaniwa River at about map reference NZMS 260 L35: 283-480
- Unnamed tributary of Waianiwaniwa River at about map reference NZMS 260 L35: 287-482
- Unnamed tributary of Waianiwaniwa River at about map reference NZMS 260 L35: 294-486
- Unnamed tributary of Waianiwaniwa River at about map reference NZMS 260 L35: 297-481
- Unnamed tributary of Waianiwaniwa River at about map reference NZMS 260 L35: 306-488
- Blacks Stream at about map reference NZMS 260 L35: 309-494

In addition, there will be a discharge to the Waianiwaniwa River downstream of the headrace at map reference NZMS 260 L35: 275-475. In this reach it will be largely dry as it is only a few hundred metres downstream of the dam, however environmental flow releases will be required to maintain the recharge to groundwater that naturally occurs.

Twenty water race crossings will occur along the headrace route, and the races will be piped beneath the headrace at the following approximate locations listed in order along the headrace from the Rakaia to the Waimakariri Rivers.

- Map Reference NZMS 260 L36: 159-321
- Map Reference NZMS 260 L36: 175-328
- Map Reference NZMS 260 L36: 184-340
- Map Reference NZMS 260 L36: 186-353
- Map Reference NZMS 260 L36: 187-379
- Map Reference NZMS 260 L36: 258-457
- Map Reference NZMS 260 L36: 189-385
- Map Reference NZMS 260 L35: 316-492
- Map Reference NZMS 260 L35: 336-493
- Map Reference NZMS 260 L35: 342-494

- Map Reference NZMS 260 L35: 346-498
- Map Reference NZMS 260 L35: 349-501
- Map Reference NZMS 260 L35: 354-504
- Map Reference NZMS 260 L35: 361-504
- Map Reference NZMS 260 L35: 379-521
- Map Reference NZMS 260 L36:382-524
- Map Reference NZMS 260 L36: 385-529
- Map Reference NZMS 260 L36: 381-540
- Map Reference NZMS 260 L36: 335-583
- Map Reference NZMS 260 L36: 332-599

Bridges will be constructed where the headrace crosses roads. There are 22 crossings of road reserves, and two lane bridges will be required for most of these. The approximate locations of these are listed in order along the headrace from the Rakaia to the Waimakariri Rivers.

- Map Reference NZMS 260 L36 084-378 Track onto Rakaia River bed
- Map Reference NZMS 260 L36: 165-326 Headrace adjacent to Steelers Rd for ~ 870 m
- Map Reference NZMS 260 L36 176-328 Rakaia Terrace Road
- Map Reference NZMS 260 L36 188-380 Leaches Road
- Map Reference NZMS 260 L36 189-392 Rockwood Road
- Map Reference NZMS 260 L35 214-418 Headrace adjacent to Downs Road for ~570 m
- Map Reference NZMS 260 L35 223-427 Maffeys Road
- Map Reference NZMS 260 L35 244-438 Aitkens Road
- Map Reference NZMS 260 L35 258-457 Headrace adjacent to Bridge Street for ~990 m
- Map Reference NZMS 260 L35 268-462 Coal Track Road
- Map Reference NZMS 260 L35 270-473 Homebush Road
- Map Reference NZMS 260 L35 307-488 Rowallan Road
- Map Reference NZMS 260 L35 311-494 Deans Road
- Map Reference NZMS 260 L35 321-493 Cullens Road

- Map Reference NZMS 260 L35 343-497 Headrace adjacent to Clintons Road for ~ 900 m
- Map Reference NZMS 260 L35 348-498 Clintons Road
- Map Reference NZMS 260 L35 350-502 West Coast Road
- Map Reference NZMS 260 L35 370-510 Auchenflower Road
- Map Reference NZMS 260 L35 376-517 Tramway Road
- Map Reference NZMS 260 L35 385-513 Bleak House Road
- Map Reference NZMS 260 L35 385-536 Old West Coast Road
- Map Reference NZMS 260 L35: 357-564 Track onto Waimakariri River bed

In addition, there will be approximately 20 single lane bridges required for farm access tracks. The locations of these will be decided in consultation with affected land owners.

Farm access bridges will be constructed using pre-cast concrete bridge units mounted on concrete abutments, and fabricated on-site. For the larger roads, the standard of construction for bridges will be commensurate with the class of road.

The headrace will cross the main West Coast railway line near The Oaks, about 4.5 km north northwest of Darfield at approximate map reference NZMS 260 L35: 350-502. Here the railway is adjacent to State Highway 73, and the crossing structures for both will be designed to avoid hazards for road and rail traffic. A bridge will be used for both crossings unless there are special installation or design requirements for the railway that necessitate a siphon.

3.9.9 Outlet structures

Water will be delivered from the headrace to the distribution network through radial gate outlets. Ten of these are proposed, five between the Rakaia River and Selwyn River, and five between the Waimakariri River and Selwyn River. The locations of these are shown on Section 3-11. Flows within the headrace and distribution canals will be fully controlled. Gates will be actuator operated steel radial gate assemblies (or similar) within a reinforced concrete structure.

3.10 Pump Stations

The design of the Central Plains scheme has attempted to make use of gravity for most of the water supply to farmers. However, two areas are included in the scheme that will require pumped water. These are between the western end of the Harper Hills and towards the Rakaia Gorge (the Windwhistle area), and the Sheffield to Springfield sector to the Waimakariri Plains (the Sheffield area). Thus with the Base Scheme concept as proposed, there will be three pump stations to service these areas.

In addition for resource consenting purposes application has been made for a pump station to fill the Waianiwaniwa reservoir, if it is decided that the reservoir will not be filled via the upper Waimakariri River intake, canal, and tunnel. This maintains the maximum degree of flexibility to provide the optimum design solution during the design and implementation phases. If pumped storage is the final solution, there will be no upper Waimakariri intake and a pump station for the Sheffield area will have to be located downstream of the Gorge Bridge intake. It would also be likely that a second pumping stage would be required from the upper plains level to pump water back up to the Springfield area.

Pump stations would as far as practical pump directly from the canals or stilling basins, as these sites minimise the amount of structural work required for the pump inlets.

3.10.1 Coalgate pump station

If a pump station was required to supply the Waianiwaniwa Reservoir from the headrace, this would be situated just below the dam, beside the headrace. The capacity of this pump station depends upon the ultimate scheme design reliability and storage volume provided in the reservoir. The maximum pumping capacity will be 20 m^3/s. If a top water surface level of 280 m is provided there will be a maximum pumping head of 55 m, which would require a pump station of approximately 13.8 MW capacity. When the dam was only half full the lift from the headrace would be less and the power demand would be significantly reduced.

3.10.2 Upper Waimakariri pump station

The Upper Waimakariri pump station would be situated just downstream of the Kowai River confluence, at approximate map reference NZMS 260 L35: 269-637 and would lift water ~ 70 m out of the Waimakariri River floodplain, up to the plains surface east of Springfield. The size of this pump station cannot be determined until the demand is determined from the farmer uptake. There could be an uptake of between 2,000 – 3,000 ha in this area between the upper intake canal and Springfield, which if supplied water at a peak rate of 0.6 L/s/ha would require a pump station with a capacity of up to 1.8 m^3/s. A pump station of approximately 2 MW would be required for this duty.

3.10.3 Lower Waimakariri pump station

The Lower Waimakariri pump station would be situated just downstream of the primary intake structures below the Gorge Bridge at map reference NZMS 260 L35: 335-584, and would lift water ~ 70 m out of the Waimakariri River floodplain, up to the plains surface east of Sheffield. The area serviced by this pump station would be much larger than the upper Waimakariri pump station as it would include the land north-west to Springfield and south-east to the main headrace canal. A pump station with a capacity of up to 3.6 m^3/s could be required at this site, which would require a pump station of approximately 3.5 MW.

It would also be possible that booster pump stations are required to take a portion of this volume from the upper terrace level of RL 300 m to RL 380 m at Springfield. This could be achieved in one or many pump stations. The feasibility study of 2002 identified the need for two additional booster pump stations at map references NZMS 260 L35: 283-590 and NZMS 260 L35: 252-612.

3.10.4 Rakaia pump stations

Two pump stations will be needed in the Rakaia Sector to service the Windwhistle area. One will be near river level at about map reference NZMS 260 L36: 120-348, and will have a capacity of approximately 2.5 MW. An underground pipe will take the pumped water 55 m up, and 4.2 km northeast to the second pump station. The second station of approximately 3 MW is at about map reference NZMS 260 L36: 141-386 at the junction of Leaches and Rockwood Roads. Water would be pumped from here a further 135 m up, and 9.4 km northwest up Leaches Road to the start of the piped gravity distribution area at map reference NZMS 260 K36: 057-424.

3.11 Water Distribution Network

The distribution of irrigation water from the headrace will be via a network of open surface water canals. For the purposes of description, the network is divided into 6 areas as shown in Figure 3-14. They are listed below in order from north to south and then west. The letters in brackets after each area name are the codes used to identify races in each area on the accompanying figures, and the descriptions below.

- Springfield (SP)
- Sheffield (SH)
- Central (C)
- Hororata (H)
- Te Pirita (T)
- Windwhistle (W).

The Springfield and Windwhistle areas will be served by a pumped water supply, while the others will be served by gravity flow from the headrace.

The races within each area are coded hierarchically with main races designated by integers (1, 2, etc), and subsidiary races as decimal numbers (1.1, 1.2 etc, and 1.1.1, 1.1.2 etc).

The distribution network will run along roadsides as well as running through private land. The stream crossings will be piped and road crossings will be constructed using culverts or bridges depending on the size of the canal. Residential and farm access points will be constructed using culverts or concrete bridges for larger canals. If required at certain race sections siphons could be constructed. If it is necessary to run races through farmland, the alignment would follow wherever possible existing boundaries/fence lines and would be subject to appropriate purchase agreements, final design and negotiation with landholders.

The races will have side slopes of 2.5 horizontal to 1 vertical with a bottom width of 1.2 to 3.0 m, and water surface widths ranging from 6 to 13 m, depending on the required design capacity. The races will be constructed by cut and fill excavation using the spoil for embankments. The total footprint of the races (including both embankments and the water surface) will generally be from 14 to 27 m across, with most being 14 to 16 m across.

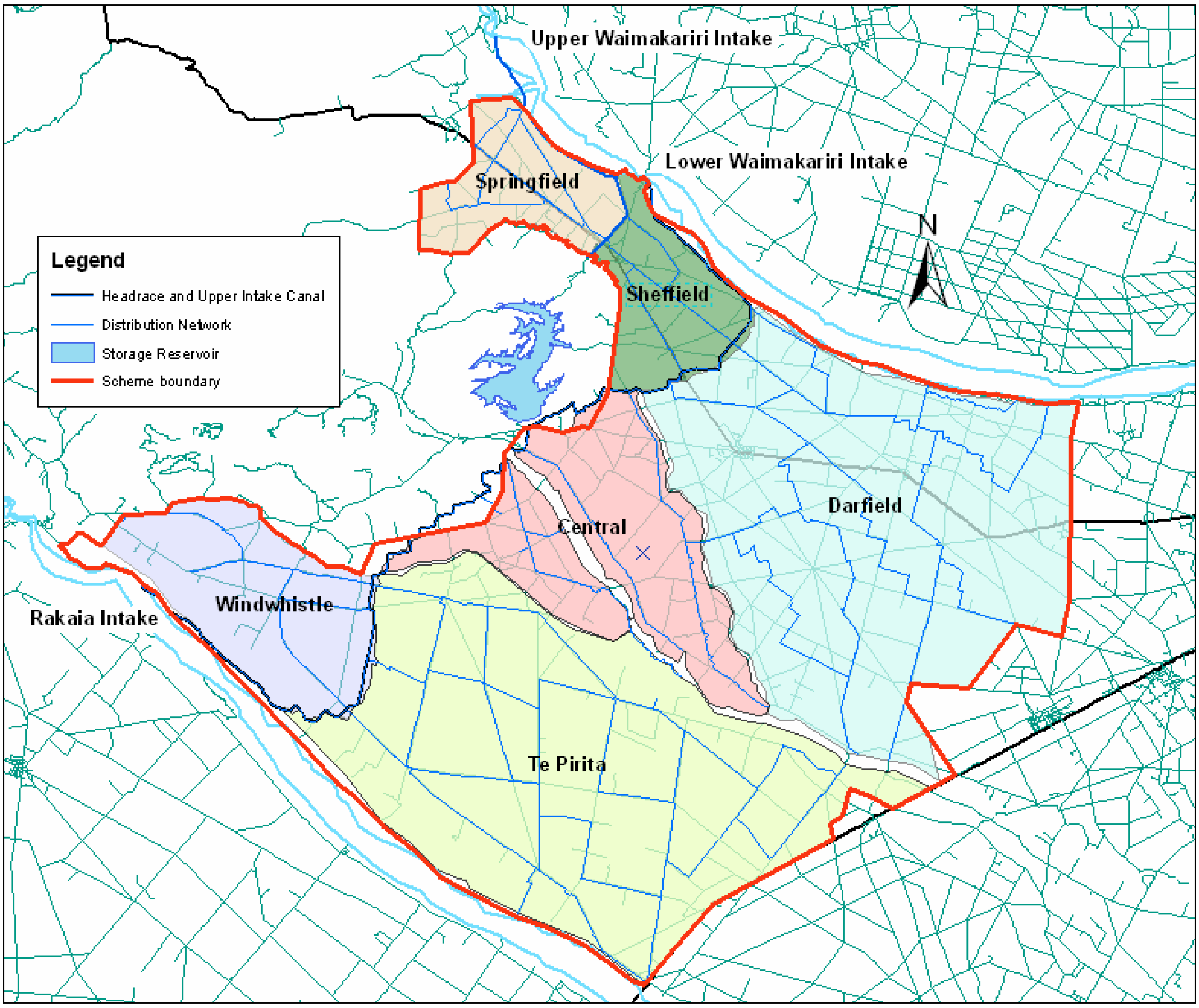


FIGURE 3-14 Irrigation areas within the Central Plains Scheme

3.11.1 Springfield area

The Springfield area is supplied by the Waimakariri pump station and will service the land south from the Kowai River to Sheffield, and between the Waimakariri River and the base of the Malvern Hills. This 5,000 ha area will be serviced by 32 km of races. The area including the distribution network is shown in Figure 3-15. The pump station will be located at about map reference NZMS 260 L35: 269-637 and takes water from the upper Waimakariri River intake canal to pump it 70 m up on the plains. The pumped water will be discharged into the Springfield distribution network at about map reference NZMS 260 L35: 266-637, and will be carried across the plains either by race SP1 or race SP2 (only one of these will be constructed), depending on irrigation requirements in this area. However if the Springfield area is supplied by a pump station from the lower Waimakariri intake it is likely that piped reticulation would be considered for this area. In that case it is also likely that properties particularly at the downstream end of the Springfield area will be supplied with pressurised water.

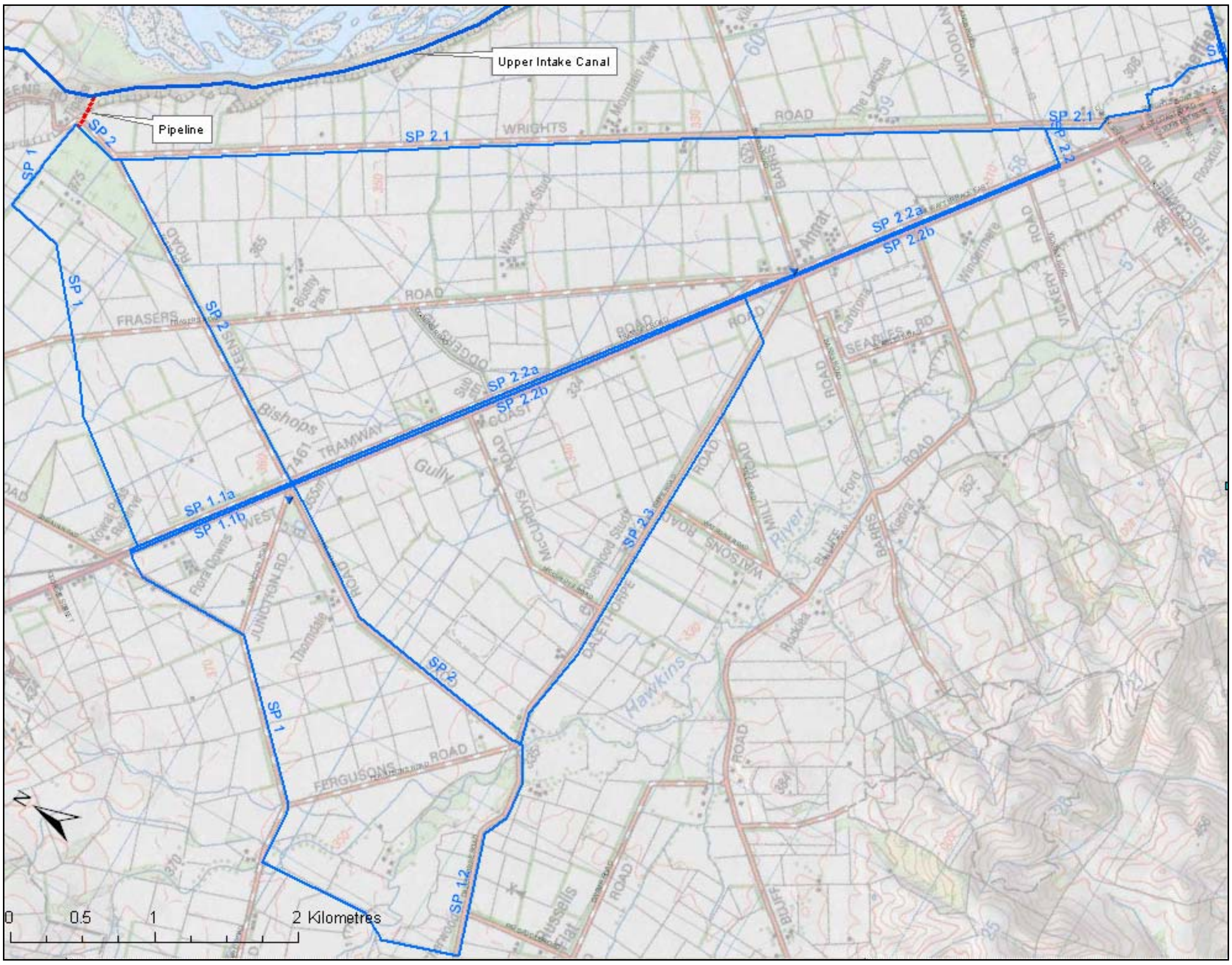


FIGURE 3-15: Springfield water distribution race network

Race SP 1

Race SP1 has a maximum total width of 14 m, will be 7.5 km long, and starts at about map reference NZMS 260 L35: 266-637 approximately 0.4 km north of the corner of Wrights and Keens Road. It will run generally south west through farmland for the first 3.5 km following wherever possible existing fence lines/boundaries, it will feed either race SP 1.1a or SP 1.1b at map reference NZMS 260 L35: 242-620. For the next 2.5 km the canal would first follow Domain Road, it then cuts across private property for 1.5 km ending at Dalethorpe Road at about map reference NZMS 260 L35: 229-586 where it drains into race SP1.2.

Stream crossings will occur at the following approximate locations:

- Map reference NZMS 260 L35: 248-627 unnamed stream.
- Map reference NZMS 260 L35: 233-601 unnamed stream.
- Map reference NZMS 260 L35: 230-601 unnamed stream.
- Map reference NZMS 260 L35: 229-599 unnamed stream.
- Map reference NZMS 260 L35: 228-592 Hawkins River.

Race SP 1.1a

Race SP 1.1a is fed by race SP1 and is only an option if race SP 1.1b does not go ahead, and has a maximum total width of 14 m. It starts at about map reference NZMS 260 L35: 242-620, and runs south east along Tramway Road for 1.1 km where it feeds race SP 2.2 at the junction with Coxs Road, Junction Road and Keens Road at map reference NZMS 260 L35: 252-612.

Race SP 1.1b

Race SP1.1b is fed by race SP1, and has a maximum total width of 14 m. It starts at about map reference NZMS 260 L35: 242-620, and runs south east between West Coast Road and the railway line for 1.1 km where it feeds race SP 2.2 at the junction with Coxs Road, Junction Road and Keens Road at map reference NZMS 260 L35: 252-612.

Race SP 1.2

Race SP 1.2 is fed by race SP 1, has a maximum total width of 14 m and starts at about map reference NZMS 260 L35: 229-586. It will run east along Dalethorpe Road for 1.6 km and discharge into SP 2.3 at map reference NZMS 260: L35 244-590.

A river crossing will occur at the following approximate location:

- Map reference NZMS 260 L35: 244-589 Hawkins River.

Race SP 2

Race SP2 will have a maximum total width of 14 m, be approximately 5.4 km long, and starts at about map reference NZMS 260 L35: 266-637. It will run south east along Keens Road for 3.0 km, then for 2.4 km along Coxs Road. This will feed races SP2.1, SP2.2a, SP 2.2b and SP2.3.

A stream crossing will occur at the following approximate location:

- Map reference NZMS 260 L35: 257-619 unnamed stream.

Race SP 2.1

Race SP2.1 is fed by race SP2, will have a maximum total width of 14 m, be approximately 7.9 km long, and starts at about map reference NZMS 260 L35: 266-634. It will run roughly south east along Wrights Road for 6.8 km where it is fed by race SP 2.2, it runs for a further 0.7 km along Wrights Road and then north east of Sheffield for 0.7 km until it discharges into the upper Waimakariri intake canal at about map reference NZMS 260 L35: 310-571.

Race SP 2.2a

Race SP2.2a is fed by race SP2 and is only an option if race SP 2.2b does not go ahead, will have a maximum total width of 14 m and starts at about map reference NZMS 260 L35: 252-612. It will run south east along Tramway Road for 3.4 km where it receives water from race SP 2.3, it continues running along Tramway Road for a further 2.4 km before crossing across private land for approximately 0.3 km to meet race SP2.1 at about map reference NZMS 260 L35: 300-579.

A stream crossing will occur at the following approximate location:

- Map reference NZMS 260 L35: 260-606 unnamed stream.

Race SP 2.2b

Race SP2.2b is fed by race SP2, will have a maximum total width of 14 m and starts at about map reference NZMS 260 L35: 252-612. It will run south east between West Coast Road and the railway for 3.4 km where it receives water from race SP 2.3, it continues running between West Coast Road and the Railway for a further 2.4 km before crossing across private land for approximately 0.3 km to meet race SP2.1 at about map reference NZMS 260 L35: 300-579.

A stream crossing will occur at the following approximate location:

- Map reference NZMS 260 L35: 260-606 unnamed stream.

Race SP 2.3

Race SP2.3 is fed by race SP2, will have a maximum total width of 14 m and starts at about map reference NZMS 260 L35: 244-590. It will run east along Dalethorpe Road for 3.3 km where it cuts across private land for approximately 0.3 km to meet race SP 2.2 at about map reference NZMS 260 L35: 279-591.

A stream crossing will occur at the following approximate location:

- Map reference NZMS 260 L35: 253-589 unnamed stream.

3.11.2 Sheffield Area

The Sheffield area is defined as the area between the upper Waimakariri inlet canal (south east of Sheffield), Waimakariri River, around the Malvern Hills – Homebush Ridge to the main headrace. This 5,100 ha area will be serviced by approximately 20 km of races. The area is shown in Figure 3-16. It will take water from the Waianiwaniwa inlet canal via two outlets.

Race SH 1

Race SH1, will have a maximum total width of 14 m and starts at about map reference NZMS 260 L35: 322-583. It will run south east along Woodlands Road for approximately 0.1 km and then run along Minchins Road for 3.9 km and then south west down Pinegrove Road for 1.2 km until it drains into SH 2.1.

Race SH 2

Race SH2 is fed by the upper Waimakariri inlet canal, will have a maximum total width of 14 m and starts at about map reference NZMS 260 L35: 310-571. It starts as a piped section for 0.3 km around Sheffield School, it then runs 1.8 km down Waddington Road and feeds race SH 2.1, cuts across private land for 0.6 km to join up with West Coast Road which it follows for 5.9 km discharges into the main headrace canal.

Race SH 2.1

Race SH2.1 is fed by race SH2, will have a maximum total width of 14 m, and starts at about map reference NZMS 260 L35: 324-577. It runs south east down Tramway Road for 2.1 km where it receives water from race SH 1 at the junction with Pinegrove Road, it then continues to follow Tramway Road for 4.4 km before it drains into the main headrace channel.

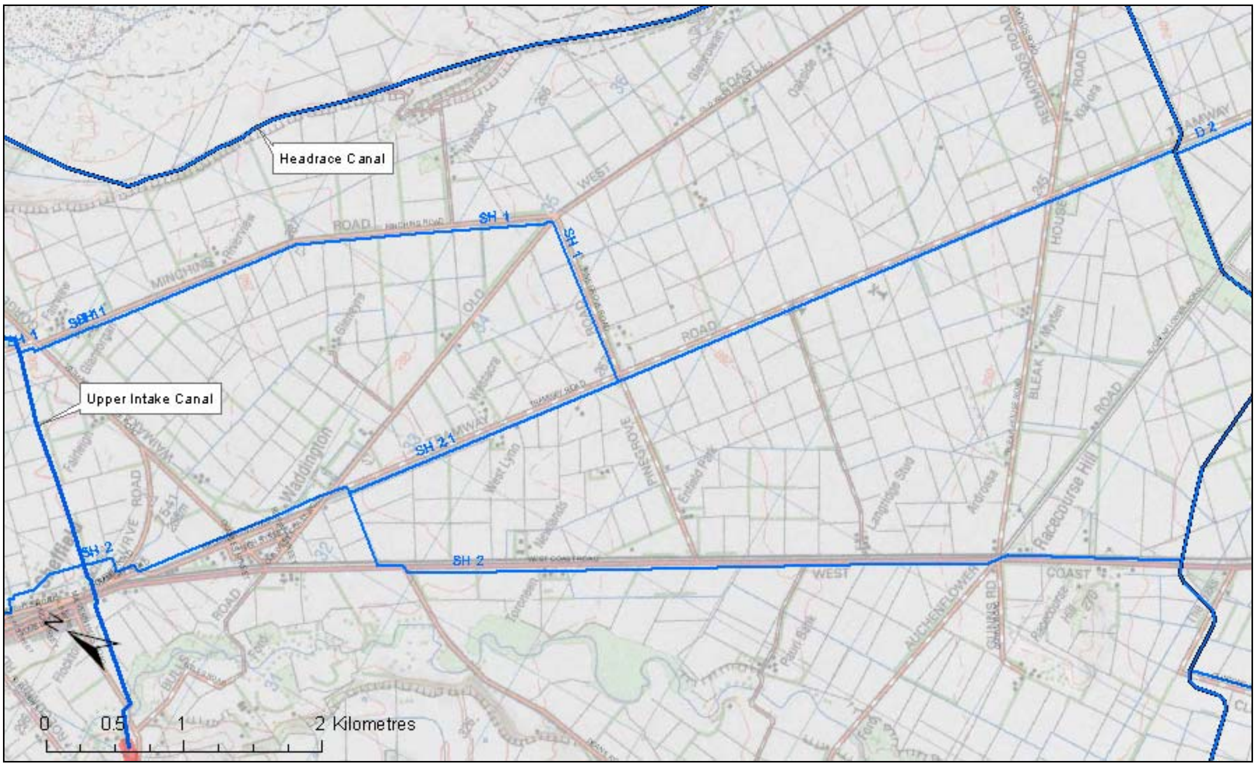


FIGURE 3-16: Sheffield water distribution race network

3.11.3 Darfield area

The Darfield area is between the Waimakariri River, Hawkins/Selwyn River, the main headrace canal and the eastern scheme border. This 32,500 ha area will be serviced by 130 km of races. The area including the distribution network is shown in Figure 3-17. The whole area will be supplied by gravity taking water from the main headrace.

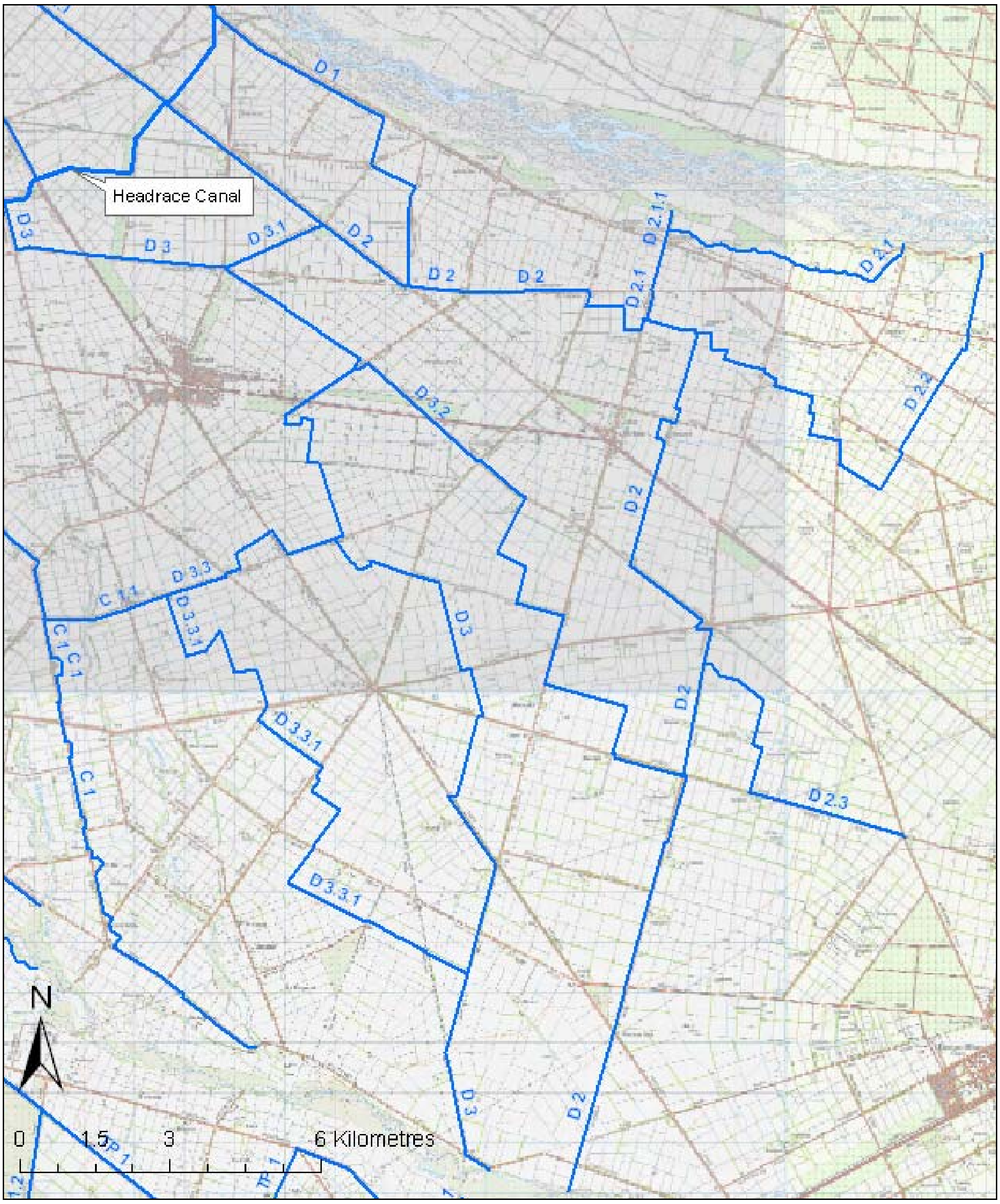


FIGURE 3-17: Darfield water distribution race network

Race D 1

Race D1 is fed by the main headrace and will be approximately 8 km long, it will start at about map reference NZMS 260 L35: 385-535 and will be up to 14 metres wide. It will run generally south east along Old South Road for 4 km, before crossing private land for 1 km where it crosses Auchenflower Road and then runs for a further 1 km along private land until it meets Addingtons Road. It then runs south down Addingtons Road for approximately 2 km where it drains into D 2 at the intersection with Homebush Road and Tramway Road.

Race D 2

Race D2 is fed by the main headrace, starting at about map reference NZMS 260 L35: 375-517. This race will vary in width between 14 m and 25 m. It will be between 22m and 25 m at the start and runs south east along Tramway Road for 4 km where it receives water from race D 3.1 and then continues for another 2.1 km where it is fed by race D 1 before running east up Homebush Road for 3.6 km and then down Ansons Road for 0.3 km. It cuts across private land for 1.6 km until it meets up with Courtenay Road which it follows for 0.2 km and then feeds race D 2.1. It then runs on private land for 1 km around the backs of smaller sections and feeds race D 2.2. The rest of the race will be between 14 m and 22 m in width. It follows private land for another 1.9 km and then meets up with Hoskyns Road along which it travels for 0.3 km. Subsequently it will run through private land for 1.3 km before crossing West Coast Road and then runs for a further 1.8 km where it meets with Miles Road along which it runs for 1.8 km. It then crosses private land for 0.2 km to join with Bealey Road along which it runs for 0.3 km until it meets Highfield Road. It runs generally south down Highfield Road for 11.6 km ending at the discharge location in the Selwyn River at about map reference NZMS 260 L36: 456-300 (see below in Section 3.12).

Race D 2.1

Race D2.1 is fed by race D2, and will start at about map reference NZMS 260 L35: 472-474. Initially it will be between 22 m and 25 m wide and runs north along Courtenay Road for 1.8 km where it discharges into race D 2.1.1. From here on it will be less than 14 m wide and runs eastward along the backs of private sections for 5.4 km before discharging into the Waimakariri River at map reference NZMS 260 M35: 523-490 (see below in Section 3.12).

Race D 2.1.1

Race D2.1.1 is fed by race D2.1 and starts at map reference NZMS 260 L35: 476-492. It will be between 22 and 25 metres in width and follows Courtenay Road for 0.6 km until it reaches its discharge point into a wetland by the Waimakariri River at map reference NZMS 260 L35: 477-495 (see below in Section 3.12)..

Race D 2.2

Race D2.2 is fed by race D2, and will start at about map reference NZMS 260 L35: 481-471. It will be up to 14 m wide, and runs along private land for 1.9 km where it crosses Highfield Road and continues on private land for 2.7 km until it meets Station Road. It follows Station Road for 0.5 km runs along private land for 1.8 km until it meets Painters Road it follows Painters Road for less than 0.1 km and then runs northward along private land for 4.5 km crossing Hawkett Road and the Old West Coast Road on the way to it discharge point into a wetland by the Waimakariri River at map reference NZMS 260 M35: 539-488.

Race D 2.3

Race D2.3 is fed by race D2, and will start at about map reference NZMS 260 L35: 483-405 on Highfield Road. It will be up to 14 m wide and runs along private land for 3.5 km and then runs eastward down

Wards Road for 3.3 km until it reaches its discharge point to either ground or stock water race at map reference NZMS 260 M36: 523-370.

Race D 3

Race D3 is fed by the main headrace starting at about map reference NZMS 260 L35: 343-498 it varies in width and will be up to 25 metres in width. It starts with a width between 22 m and 25 m and runs south along Clintons Road for 1 km and then eastward along Homebush Road for 4.2 km where it feeds race D 3.1, it cuts south east across private land for 3.4 km to meet with Creyke Road where it feeds race D 3.2 and then runs south west down Creyke Road for 1.7 km. It runs across private land for 3.5 km until it meets with Essendon Road which it runs down for 0.2 km and feeds race D 3.3. For the remainder of its length the race will be between 14 m and 22 m across. The race cuts across private land for 2 km crossing Ansons Road and then runs down Barrys Road for 0.6 km and then across private land for a further 1.8 km to meet Bealey Road. It runs along Bealey Road for 0.2 km cuts across private land for 1 km where it meets Wards Road, it follows Wards Road for 0.1 km and cuts across private land for a further 1.8 km to meet with Telegraph Road. It runs generally south east along Telegraph Road for 1.7 km and runs roughly southward down Courtenay Road for 3.9 km, it meets with Stranges Road along which it follows for 2.1 km and then runs south east for 0.6 km along Coaltrack Road to carry the water to the discharge location into a wetland adjacent to the Selwyn River at about map reference NZMS 260 L36: 441-304 (see below in Section 3.12).

Race D 3.1

Race D3.1 is fed by race D 3 and will start at about map reference NZMS 260 L35: 388-484. It will be up to 14 m wide. It runs north east for 2.1 km along Boultons Road discharging into race D 2 at the intersection with Tramway Road and Boultons Road at map reference NZMS 260 L35: 407-493.

Race D 3.2

Race D 3.2 is fed by race D 3 and will start at about map reference NZMS 260 L35: 414-465. It will be up to 14 m wide. It runs along Creyke Road for 0.3 km before running south east down Miles Road for 4.1 km, it then cuts across private land for 2.6 km, it runs roughly south east down Barrys Road for 1 km until it joins with Courtenay Road which it follows for 1.4 km. It then runs across private land for 2.6 km to meet Wards Road which it runs east down for 1.4 km and discharges into race D 2 at the intersection with Highfield Road and Wards Road at map reference NZMS 260 L36: 479-383.

Race D 3.3

Race D3.3 is fed by race D 3 and will start at about map reference NZMS 260 L35: 409-430. It will be between 14 m and 22 m wide. It runs roughly south west down Essendon Road for 1 km and then north west down Telegraph Road for 0.5 km. It runs across private property for 1.2 km and then runs roughly south west down Essendon Road for a further 1.6 km where it discharges into race 3.3.1 at map reference NZMS 260 L35: 376-419.

Race D 3.3.1

Race D3.3.1 is fed by race D 3.3 and will start at about map reference NZMS 260 L35: 376-419. It will be between 14 m and 22 m wide. It runs down the backs of private sections for 4.2 km crosses Bealey Road and travels south west down Ansons Road for 0.3 km. It cuts south east across private property for 1.6 km, runs south west down Ridgens Road for 0.2 km and then cuts south east across private property for 6.8 km crossing Clintons Road and Miltons Road before discharging into race D 3 at map reference NZMS 260 L36: 436-344.

3.11.4 Central area

The Central irrigation area is defined as the area between Hawkins River, Hororata River and the main headrace canal. This approximately 12,000 ha area will be serviced by 56 km of race and 1.2 km of pipe. The area including the distribution network is shown in Figure 3-18. The whole area will be supplied by gravity taking water from the main headrace.

Race C 1

Race C1 is fed by the headrace and starts at about map reference NZMS 260 L35: 322-492, it will have a maximum width of 14 m. It will run south along Cullens Road for 6 km, along Elmhurst Road for 1.5 km and then down Greendale Road for 1.2 km where it feeds race C 1.1, it continues down Greendale Road for 0.8 km until it is piped through private property for less 0.3 km and then follows Greendale Road for approximately 5.3 km running round the back of the recreation reserve. It cuts across private land for 0.2 km, joins with Adams Road for 0.2 km and then cuts across private property for 0.6 km where it meets with Coaltrack Road. It then runs roughly south east along Coaltrack Road for 3.6 km where it reaches its discharge point into a wetland adjacent to the Hawkins River at map reference NZMS 260 L36: 394-329 (see below in Section 3.12).

Race C 1.1

Race C 1.1 is fed by race C 1 and starts at about map reference NZMS 260 L35: 351-414 and will have a maximum width of 14 m. It runs generally south east down Essendon Road for 2.5 km and discharges into race D 3.3.1.

A river crossing will occur at the following approximate location:

- Map reference NZMS 260 L35: 360-414 Hawkins River

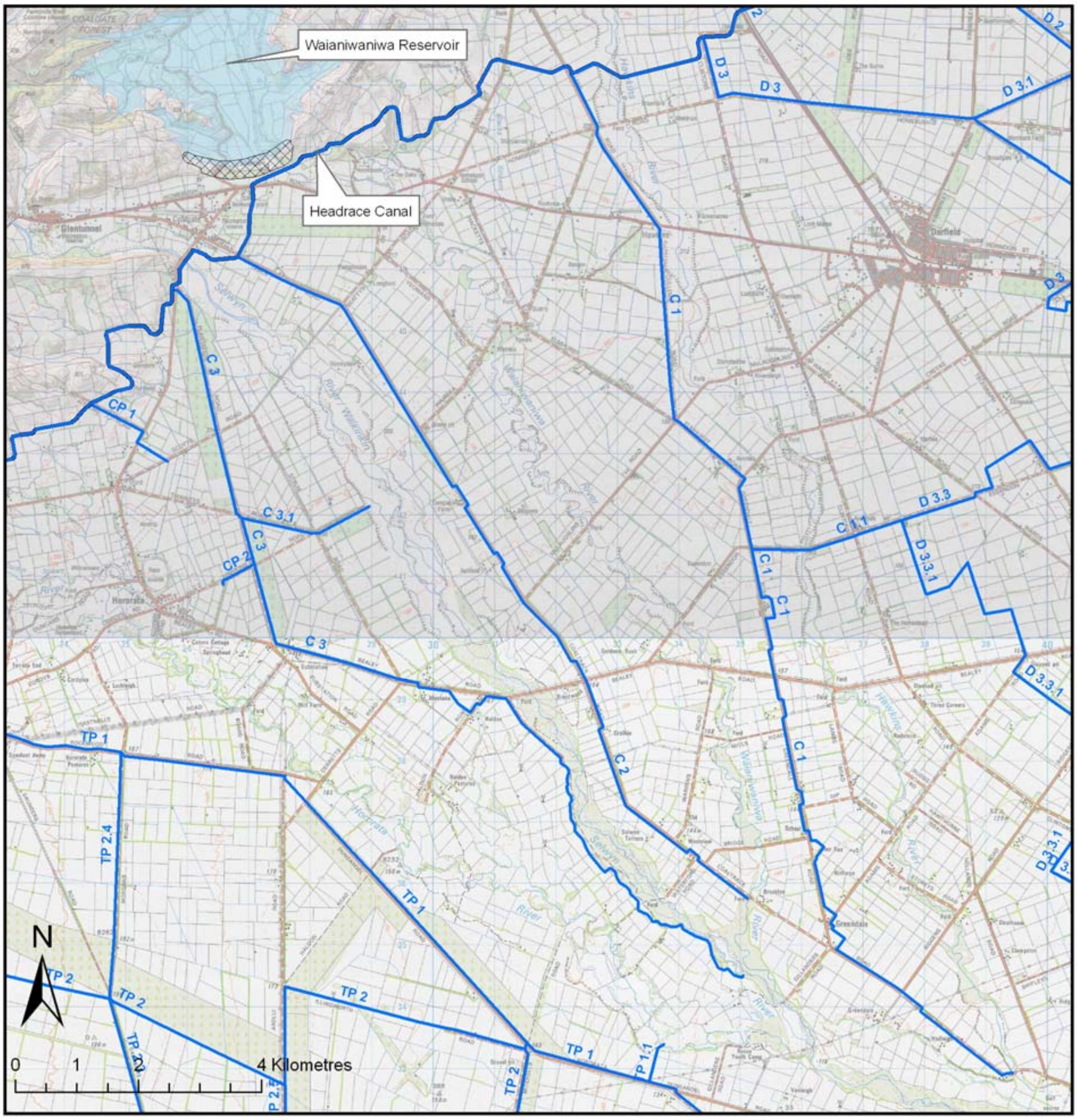


FIGURE 3-18: Central area water distribution race network

Race C 2

Race C 2 is fed by the headrace and will start at about map reference NZMS 260 L35: 267-462. The race will be up to 14 m wide and will run along Coaltrack Road for its total length of about 13.8 km and will discharge into a wetland adjacent to the the Waianiwaniwa River bed at map reference NZMS 260 L36: 351-357 (see below in Section 3.12).

Race C 3

Race C 3 is fed by the headrace and will be up to 14 m wide. It starts at about map reference NZMS 260 L35: 257-456. It runs generally south for 4 km down Plantation Road where it feeds Race C 3.1 at the junction with Thwaites Road and Plantation Road, it then continues east along Plantation Road for another 2.1 km until it meets Bealey Road, it runs along Bealey Road for 2.9 km and then cuts across private land for 0.5 km to meet Haldon Road. It follows Haldon Road for 0.4 km to meet back up with Bealey Road which it follows for another 0.4 km and then runs generally south east along an unnamed gravel road for 1.5 km down the edge of the Selwyn River. The last section of the race follows the edge of the Selwyn River for approximately 5.2 km where it reaches its discharge point into a wetland adjacent to the Selwyn River bed at map reference NZMS 260 L36: 350-345 (see below in Section 3.12).

Race C 3.1

Race C 3.1 is fed by race C 3, starts at about map reference NZMS 260: L35 268-420 and will have a maximum width of 14 m. It follows Thwaites Road for 2.2 km where it reaches its discharge point into a wetland adjacent to the Selwyn River bed at map reference NZMS 260: L35 289-421 (see below in Section 3.12).

Race CP 1

CP1 is a piped race that starts at map reference NZMS 260 L35: 244-438 and follows Aitkens Road for 1 km, follows Bealey Road for 0.2 km and then runs across private land for 0.6 km, crossing Scott Road and reaching its discharge point on private farmland at map reference NZMS 260 L35: 256-428.

Race CP 2

CP2 is a piped race that starts at map reference NZMS 260 L35: 270-412, follows Hawkins Road for 0.6 km, crosses the road and reaches its discharge point at the corner of Cottons Road and Hawkins Road on private farmland at map reference NZMS 260 L35: 265-409.

3.11.5 Te Pirita area

The Te Pirita area is defined as the area between the Hororata/Selwyn Rivers, Rakaia River, the main headrace and the State Highway 1. This 33,900 ha area will be serviced by approximately 153 km of races. The area including the distribution network is shown in Figure 3-19. The whole area is supplied by gravity from the main headrace via three outlets.

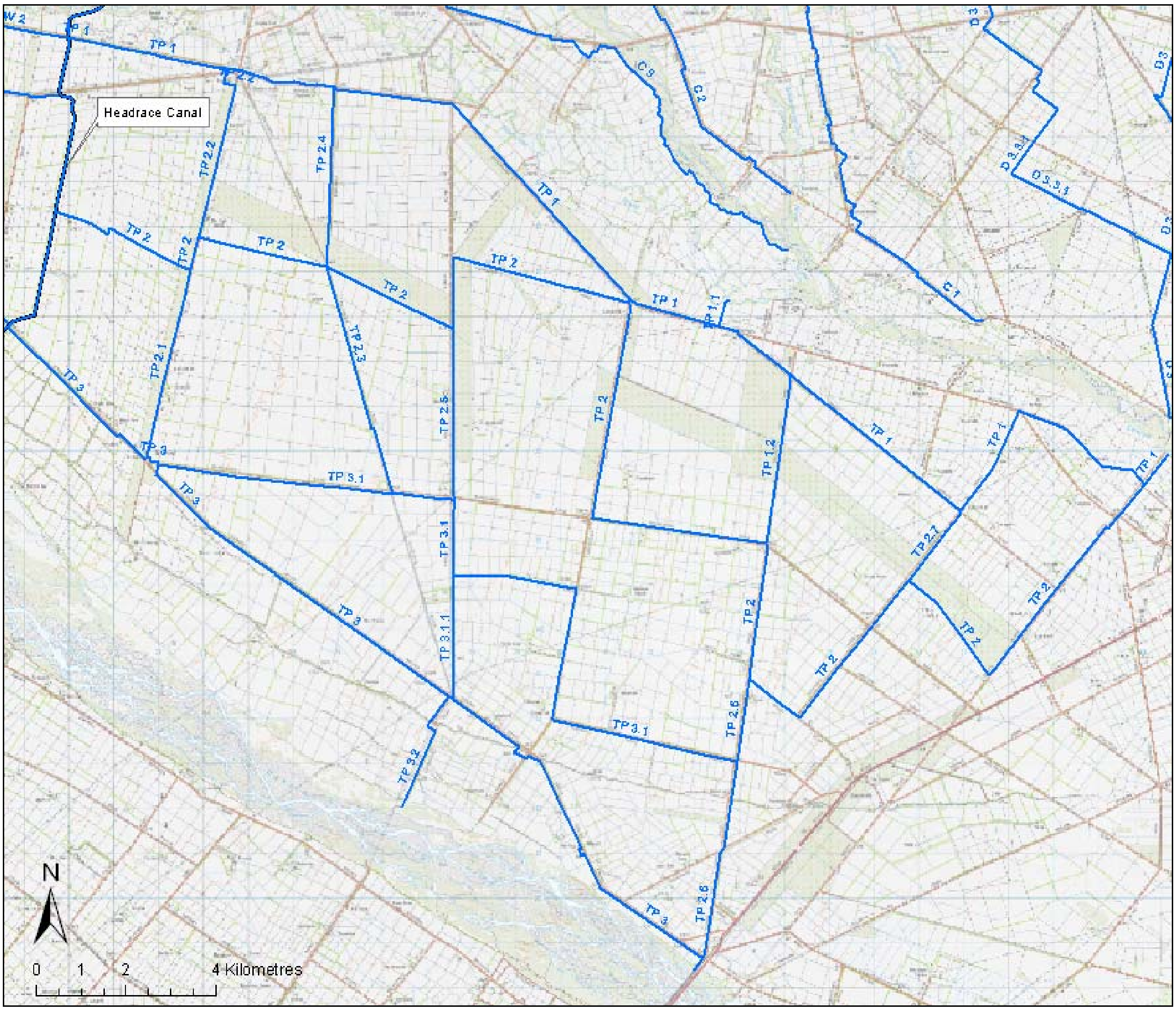


FIGURE 3-19: Te Pirita water distribution race network

Race TP 1

Race TP 1 will start at about map reference NZMS 260 L36: 189-392 at the headrace outlet. This race will be between 22 m and 25 m wide initially. It runs east along Rockwood Road for 3.7 km where it is fed by race TP 2.2, it follows Rockwood Road for another 2.4 km where it is fed by race TP 2.4, it continues to follow Rockwood Road for another 6.8 km where it is linked with TP 2, after another 0.2 km it joins with Hororata Dunsandel Road and runs generally south east for 1.9 km where it discharges into race TP 1.1. It follows Hororata Dunsandel Road for a further 0.5 km and then follows Wrights Road for 1.5 km and feeds race TP 1.2 at the junction of Wrights Road and South Two Chain Road. The race will be up to 14 m wide from here onwards; it runs south east down Wrights Road for another 4.8 km and is fed by race TP 2.7 at this point. It runs roughly north east up Hunters Road for 2.6 km and then follows an unnamed gravel road and along private land for 3.4 km to meet with Old South Road. At this point it joins with race TP 2 and runs north east along Old South Road for 0.9 km where it reaches its discharge point into a wetland adjacent to the Selwyn River at map reference NZMS 260 L36: 435-299 (see below in Section 3.12).

River crossings will occur at the following approximate locations:

- Map reference NZMS 260 L36: 420-296 Irwell River.
- Map reference NZMS 260 L36: 423-296 Irwell River.
- Map reference NZMS 260 L36: 425-296 Irwell River.
- Map reference NZMS 260 L36: 426-296 Irwell River.
- Map reference NZMS 260 L36: 432-295 Irwell River.

Race TP 1.1

Race TP 1.1 is fed by race TP 1 and starts at about map reference NZMS 260 L36: 335-327. It will be between 22 m and 25 m wide and carries water 0.7 km to a discharge point at the Hororata River at map reference NZMS 260 L36: 337-333 (see below in Section 3.12).

Race TP 1.2

Race TP 1.2 is fed by race TP 1 at the junction of South Two Chain and Wrights Road at map reference NZMS 260 L36: 351-316 and will be between 22m and 25 m wide. It runs south down South Two Chain Road for 3.8 km before it discharges into race TP 2 at the junction of South Two Chain Road and Sharlands Road.

Race TP 2

Race TP 2 is fed by the headrace canal and will start at about map reference NZMS 260 L36: 186-353 . It will be between 14 m and 22 wide at the start and runs generally eastward for 3.5 km through private land where it discharges some water into race TP 2.1 before running north alongside Te Pirita Road for 0.7 km where it feeds race TP 2.2. It decreases in width to a maximum of 14 m from here on and then cuts across more private land for 2.9 km. At the intersection of Saunders Road and Morgans Road it feeds races TP 2.3 and TP 2.4, it runs for a further 2.4 km along private land until it meets Ardlui Road where it feeds race TP 2.5 as well as running north along Ardlui road for 1.6 km, it runs east along Illingworth Road for 4.1 km and then south down Mitchells Road for 4.9 km where it reaches the intersection with Sharlands Road. It runs east along Sharlands Road for 4 km where it receives water from race TP 1.2 at the intersection with South Two Chain Road. It increases in size to between 22 m and 25 m at this point and then runs south along South Two Chain Road for 3 km, decreases in size to less than 14 m again and cuts across private land for 1.4 km meeting with Gales Road and then runs north east along Hunters Road for 3.9 km where it feeds race TP 2.7 and then cuts across private land for 2.8 km to meet Old South Road along which it runs north eastward for 1.3 km before discharging into race TP 1 at map reference NZMS 260 L36: 435-299.

Race TP 2.1

Race TP 2.1 is fed by race TP 2, is 2.3 km long, and starts at about map reference NZMS 260 L36: 218-348. It will be up to 14 m wide and runs south along Te Pirita Road until it discharges into race TP 3 at Rakaia Terrace Road.

Race TP 2.2

Race TP 2.2 is fed by race TP 2 and starts at about map reference NZMS 260 L36: 218-347. It will be up to 14 m wide and runs north along Te Pirita Road for 3.5 km before cutting across private land for 0.6 km until it discharges into race TP 1 at Rockwood Road.

Race TP 2.3

Race TP 2.3 is fed by race TP 2, and starts at about map reference NZMS 260 L36: 247-341. It will be up to 14 m wide, and runs south east along Saunders Road for 5.3 km until it discharges into race TP 3 at Sharlands Road.

Race TP 2.4

Race TP 2.4 is fed by race TP 2 and starts at about map reference NZMS 260 L36: 247-341. It will be up to 14 m wide, and runs north along Morgans Road for 4 km until it discharges into race TP 1 at Rockwood Road.

Race TP 2.5

Race TP 2.5 is fed by race TP 2, and starts at about map reference NZMS 260 L36: 275-327. It will be up to 14 m wide, and runs south along Ardlui Road for 3.8 km until it discharges into race TP 3 at Sharlands Road.

Race TP 2.6

Race TP 2.6 is fed by race TP 2, and starts at about map reference NZMS 260 L36: 341-249. It will be between 22 m and 25 m wide, and runs south along South Two Chain Road for 6.3 km where it receives water from North Rakaia Road. It then continues for another 0.3 km where it discharges into a wetland adjacent to the Rakaia River at map reference NZMS 260 L36: 329-184 (see below in Section 3.12).

Race TP 2.7

Race TP 2.7 is fed by race TP 2, and starts at about map reference NZMS 260 L36: 377-271, will be up to 14 m wide and follows north east along Hunters Road for 2 km where it feeds race TP 1 at the intersection of Wrights Road and Hunters Road at map reference NZMS 260 L36: 389-286.

Race TP 3

Race TP 3 is fed by the headrace canal and will start at about map reference NZMS 260 L36: 176-327 . It will be between 22 m and 25 m in width. It runs south east down Rakaia Terrace Road for 4.3 km where it receives water from race TP 2.1, it cuts across private land to join Sharlands Road for 0.2 km where it feeds race 3.1. It decreases in width to between 14 m and 22 m and then cuts across private land again for 0.2 km to meet back with Rakaia Terrace Road. It follows Rakaia Terrace Road for 8.2 km where it feeds race TP 3.2 by Darrochs Road, after another 0.1 km it receives water from race TP 3.1.1. It increases in width to between 22 m and 25 m and follows Rakaia Terrace Road for 1.8 km where it cuts onto private land for 0.5 km, runs north east along Burns Road for 0.1 km and generally south east back along Rakaia Terrace Road for 6.2 km cutting round the back of one property on the way. It discharges into race TP 2.6 at map reference NZMS L36: 331-186.

Race TP 3.1

Race TP 3.1 is fed by race TP 3, and starts at about map reference NZMS 260 L36: 209-296. It starts off with a maximum width of 14 metres and runs east along Sharlands Road for 5.3 km where it receives water from race TP 2.3 at the intersection with Sharlands Road and Saunders Road, it increases width to between 14 m and 22 m at this point. It carries on along Sharlands road for another 1.4 km where it receives water from race TP 2.5 at the intersection with Sharlands Road and Ardlui Road, it then runs south along Ardlui Road for 1.7 km where it discharges into race TP 3.1.1 and decreases width again to be less than 14 m wide. It runs along private land for 2.7 km to meet with Mitchells Road which it runs southward down for 3 km and then runs east down Terrace Road for 4.2 km where it feeds race TP 2.6.

Race TP 3.1.1

Race TP 3.1.1 starts at about map reference NZMS 260 L36: 275-272. It will be up to 14 m wide and will run south down Ardlui Road for 2.7 km long ending at the intersection with Rakaia Terrace Road at map reference NZMS 260 L36: 275-244 discharging into race TP 3.

Race TP 3.2

Race TP 3.2 is fed by race TP 3, and starts at about map reference NZMS 260 L36: 274-245. It will be between 14 m and 22 m wide and runs generally south west along Darrochs Road for 3.9 km before discharging into the Rakaia River at map reference NZMS 260 L36: 264-221. (see below in Section 3.12).

Stream crossings will occur at the following approximate location:

- Map reference NZMS 260 L36: 271-236 unnamed stream.
- Map reference NZMS 260 L36: 266-224 unnamed stream.

3.11.6 Windwhistle area

The Windwhistle area is defined as the area between Rakaia River, Washpen Creek and Hororata River, Windwhistle and the main headrace. This 9,200 ha area will be serviced by 32 km of races and 14 km of pipeline. The area including the distribution network is shown in Figure 3-20. It is supplied by a pump station taking water out of the headrace about 6 km downstream of the Rakaia River intake structure at about map reference NZMS 260 L36: 120-348. This pump station will lift water from the intake canal at the Rakaia terrace face about 55 m up to Leaches Road using a pipeline. The pipeline will carry the water on top of the river terrace and then follow Sleemans Road until Leaches Road. From there a second pump station at about map reference NZMS 260 L36: 141-385 will pump a proportion of the water further up along Leaches Road to about map reference NZMS 260 K35: 057-424. From there water will be discharged into an open race. It is likely that properties particularly at the downstream end of the Windwhistle area will be considered for supply with pressurised water.

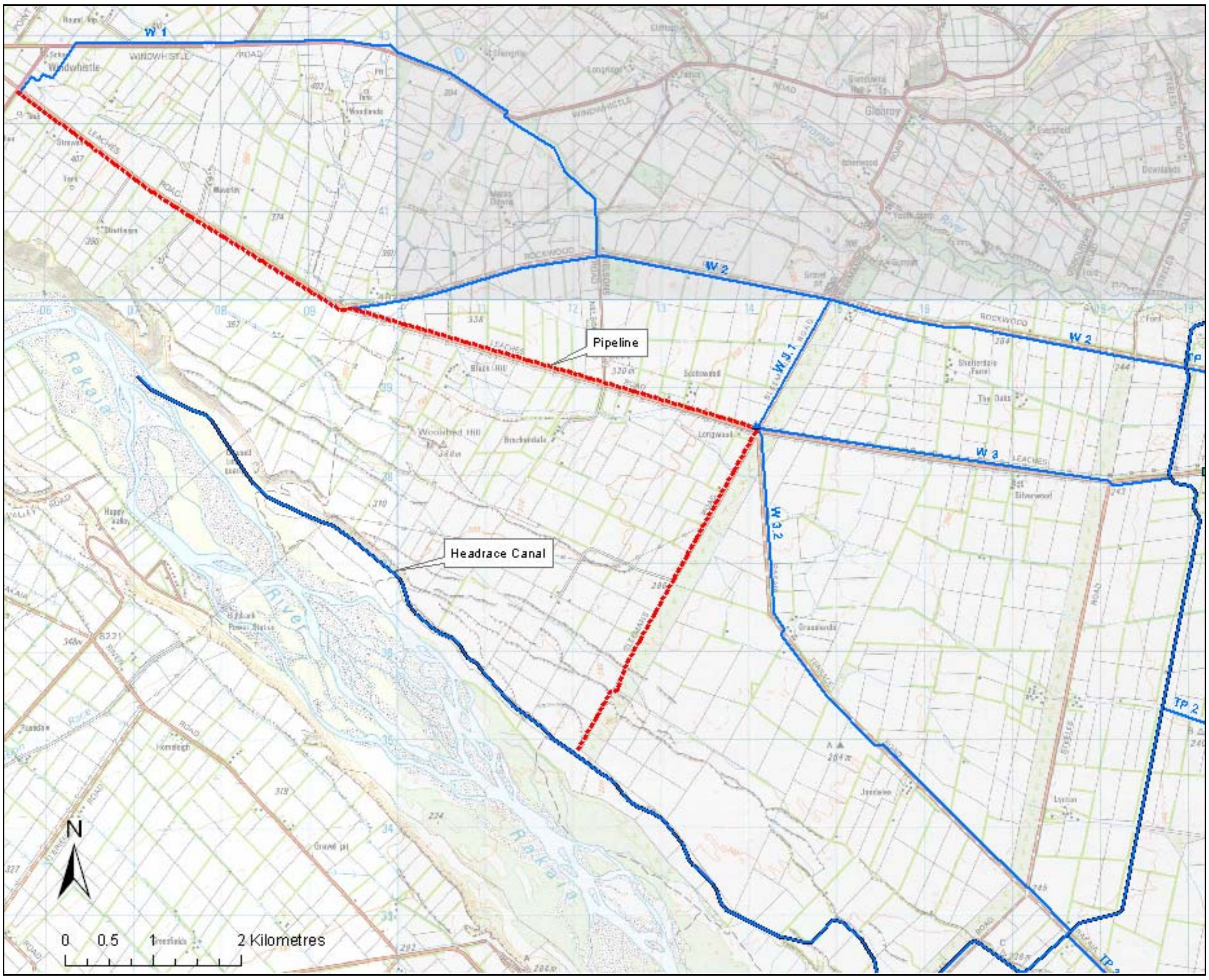


FIGURE 3-20: Windwhistle water distribution race network

Race W1

Race W1 will be up to 14 m wide and starts at about map reference NZMS 260 K35: 057-424, running a total of 8 km. It will run 0.2 km along Rakaia Gorge Road, then 0.8 km along private land and a further 7.3 km along Windwhistle Road and will drain into canal W2 at the junction of Rockwood Road and Nelsons Road.

Stream crossings will occur at the following approximate locations:

- Map reference NZMS 260 K35: 058-425 unnamed stream.
- Map reference NZMS 260 K35: 074-429 unnamed stream.
- Map reference NZMS 260 L35: 122-408 unnamed stream.

Race W2

Race W2 will be fed by the pipeline and starts at about map reference NZMS 260 K36: 094-399, will be up to 14 m wide and runs eastward along Rockwood Road for 9.8 km. It will drain into the main headrace.

Stream crossings will occur at the following approximate locations:

- Map reference NZMS 260 K36: 096-399 unnamed stream.
- Map reference NZMS 260 L35: 104-401 unnamed stream.

Race W3

Race W3 starts at about map reference NZMS 260 L36: 141-385, will be up to 14 m wide and runs east along Leaches Road for 4.8 km until it drains into the main headrace.

Stream crossings will occur at the following approximate locations:

- Map reference NZMS 260 L36: 154-383 unnamed stream.

Race W3.1

Race W3.1 is fed by race W3, and starts at about map reference NZMS 260 L36: 141-385, will be up to 14 m wide and runs north east along Sleemans Road for 1.7 km until it drains into race W2 at the intersection with Sleemans Road and Rockwood Road.

Race W3.2

Race W3.2 is fed from race W3, and starts at about map reference NZMS 260 L36: 141-385, will be up to 14 m wide and runs along Rakaia Terrace Road for about 7.1 km until it drains into the main headrace.

Stream crossings will occur at the following approximate locations:

- Map reference NZMS 260 L36: 141-378 unnamed stream.

3.12 Discharge points

Discharge points are required at the lower end of the distribution network to discharge surplus flow. Such flow is generated by operational bywash and emergency peak flow conditions. Figure 3-21 shows the discharge locations.

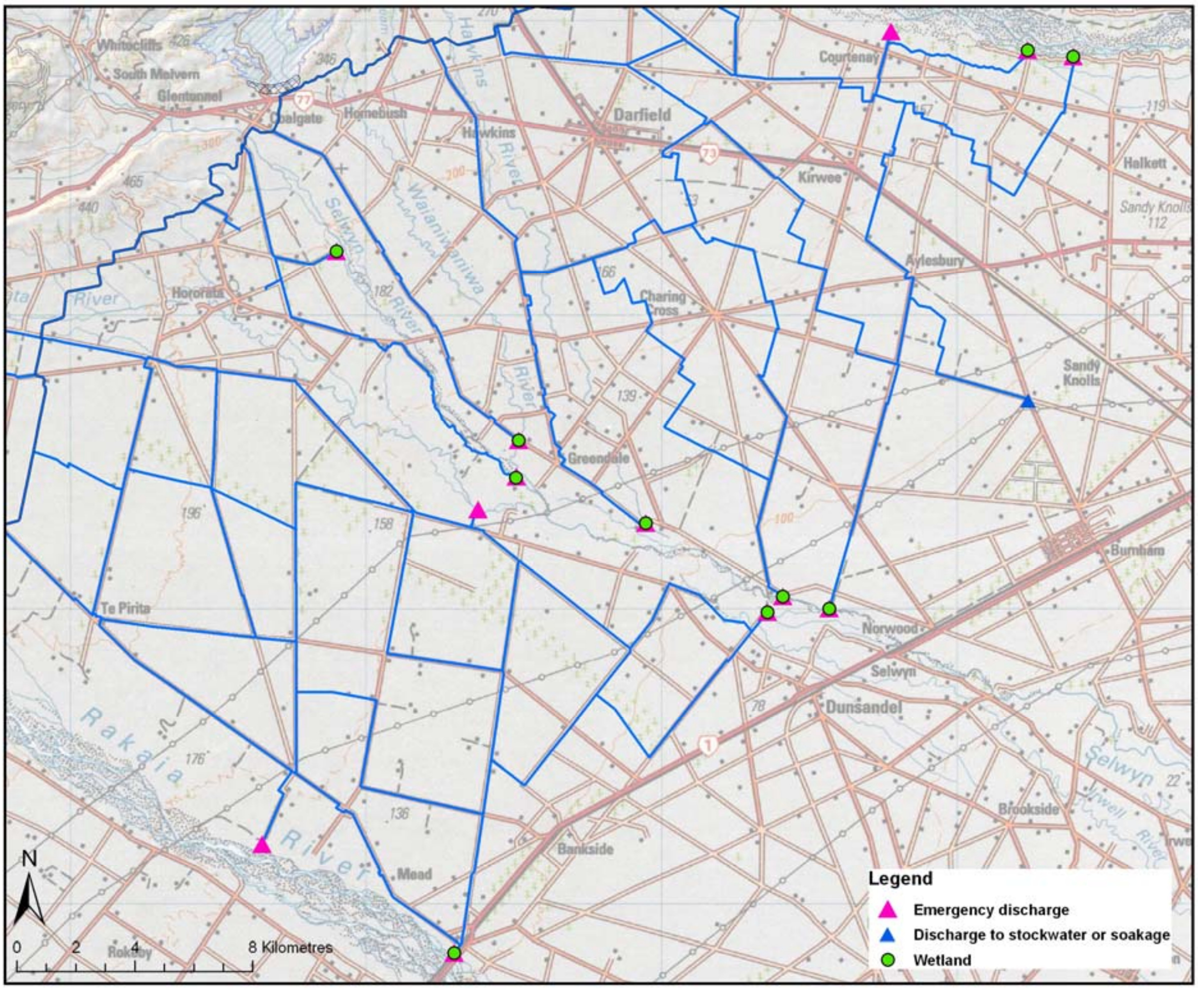


FIGURE 3-21: Discharge locations and wetlands

3.12.1 Operational bywash discharge

Under normal operations it will be necessary to discharge small volumes of surplus water at the end of the network branches. This is necessary to maintain flow past the last farmer taking scheme water on each race. This bywash will be minimised and in general discharged through ground soakage via wetlands, to existing stockwater races (race D2.3), or into the headrace or reservoir inlet canal.

The wetlands will be located adjacent to existing water courses but will not have any surface water connection to prevent overflow. Soils in the wetland will be permeable enough to absorb water through the soil profile to the groundwater table.

The characteristics and locations of the bywash sites are outlined below, and shown in Figure 3-21.

Springfield area bywash

All bywash from the Springfield distribution network will be discharged into the upper Waimakariri intake canal, which flows to the Waianiwaniwa Reservoir.

Sheffield area bywash

All bywash from the Sheffield distribution network will be discharged into the main headrace.

Darfield area bywash

Race D 2 in the southern Darfield irrigation area will discharge bywash at a maximum rate in normal operations of 0.8 m^3/s to a 0.2 – 0.4 ha wetland at about map reference NZMS 260 L36: 456-301, adjacent to the Selwyn River.

Races D 2.1 in the northern Darfield irrigation area will discharge bywash at a maximum rate in normal operations of 0.4 m^3/s to a 0.1 – 0.2 ha wetland at about map reference NZMS 260 M35: 523-490, adjacent to the Waimakariri River.

Race D 2.2 in the north-eastern Darfield irrigation area will discharge bywash at a maximum rate in normal operations of 0.4 m^3/s to a 0.1 – 0.2 ha wetland at about map reference NZMS 260 M35: 539-488, adjacent to the Waimakariri River.

Race D 2.3 is in the east of the Darfield irrigation area, and bywash could be discharged into existing stockwater races. Alternatively this minor flow could also be dispersed to ground using a soakage pit. The maximum bywash flow in normal operations will be 0.1 m^3/s and the discharge location will be at about map reference NZMS 260 M36: 524-371.

Race D3 in the southern Darfield irrigation area will discharge bywash at a maximum rate in normal operations of 0.8 m^3/s to a 0.2 -0.4 ha wetland at about map reference NZMS 260 L36: 441-305 adjacent to the Selwyn River.

Central area bywash

Race C1 will discharge bywash at a maximum rate of 0.4 m^3/s in normal operations to a 0.1-0.2 ha wetland at about map reference NZMS 260 L36: 394-330, adjacent to the Hawkins River.

Race C2 will discharge bywash at a maximum rate of 0.2 m^3/s in normal operations to a 0.1 ha wetland at about map reference NZMS 260 L36: 351-358 adjacent to the Waianiwaniwa River.

Race C3 will discharge bywash at a maximum rate of 0.4 m^3/s to a 0.1 – 0.2 ha wetland at about map reference NZMS 260 L36: 350-345, adjacent to the Selwyn River.

Te Pirita area bywash

Race TP 1 is in the north eastern Te Pirita irrigation area, and will discharge bywash at a maximum rate of 0.4 m^3/s to a 0.1 – 0.2 ha wetland at about map reference NZMS 260 L36: 435-299, adjacent to the Selwyn River.

Race TP 2.6 is in the south eastern Te Pirita irrigation area, and will discharge bywash at a maximum rate of 1.5 m^3/s to a 0.5 ha wetland at about map reference NZMS 260 L36: 329-184, adjacent to the Rakaia River.

Windwhistle area bywash

All bywash from the Windwhistle distribution network will be discharged into the main headrace.

3.12.2 Emergency peak flow discharge

At rare and brief times the full intake flow may have to be discharged. This could occur when there is a district-wide power cut when the canals were carrying full flow capacity, thus water can not be pumped out of the canals and has to be discharged. Also a sudden heavy rainfall could cause such conditions, as irrigators shut down their pumps before the intake race gates are closed. It is important to recognise that the full extent of the consents sought is for an extreme case that might never occur in the life of the scheme and, if it did, it would last for only a few hours.

As the wetlands can usually not take such flow rates without overflowing, other measures will be required to manage these situations. A risk analysis will be conducted with help from key stakeholders, including identifying the consequences of large surplus flows in relation to the variety of associated causes. A number of management measures will be investigated, including building series of small storage weirs within the races, or backup power supplies, or discharging to land. It is probable that none of these would need consenting. A fallback option, most likely as a partial solution to be implemented in conjunction with other measures, would be to build larger bywashes that could accommodate in total sum the full flow of the canals. To do this, separate races would be constructed at the discharge locations to bypass the wetlands that take normal operational bywashes, and transport water to adjacent watercourses. As this is the only option in view that is likely to need consenting, it is described in some detail in this report and consents are sought for this option. This is an important contingency move to cover the options available, pending further discussion with interested parties.

Additional sections of race will be constructed to accommodate these emergency bywash events at the following locations.

Waimakariri River emergency bywash

Race D 2.1.1 is in the northern Darfield irrigation area, and will take overflow water to the Waimakariri River. The maximum flow will be 9 m^3/s and the discharge location will be at about map reference NZMS 260 L35: 477-496.

Race D 2.1 is in the northern Darfield irrigation area, and will transport overflow water to the Waimakariri River. The maximum flow will be 1 m^3/s and the discharge location will be at about map reference NZMS 260 M35: 523-490.

Race D 2.2 is in the northern Darfield irrigation area, and will take overflow water to the Waimakariri River. The maximum flow will be 3 m^3/s and the discharge location will be at about map reference NZMS 260 M35: 539-488.

Selwyn River emergency bywash

Race D 2 is in the southern Darfield area, and will transport overflow water to the Selwyn River. The maximum flow will be 7 m^3/s and the discharge location will be at about map reference NZMS 260 M35: 456-301.

Race D 3 is in the southern Darfield area, and will transport overflow water to the Selwyn River. The maximum flow will be 8.5 m^3/s and the discharge location will be at about map reference NZMS 260 L36: 441-305.

Race TP 1 is in the northern Te Pirita area, and will transport overflow water to the Selwyn River. The maximum flow will be 3.5 m^3/s and the discharge location will be at about map reference NZMS 260 L36: 435-299.

Race C3 is in the Hororata area, and will transport overflow water to the Selwyn River. The maximum flow will be 2.5 m^3/s and the discharge location will be at about map reference NZMS 260 L36: 350-345.

Hawkins River emergency bywash

Race C1 is in the Central area, and will transport overflow water to the Hawkins River. The maximum flow will be 3 m^3/s and the discharge location will be at about map reference NZMS 260 L36: 394-330.

Waianiwaniwa River emergency bywash

Race C2 is in the Central area, and will transport overflow water to the Waianiwaniwa River. The maximum flow will be 2 m^3/s and the discharge location will be at about map reference NZMS 260 L36: 351-358

Hororata River emergency bywash

Race TP 1.1 is in the northern Te Pirita area and will transport overflow water to the Hororata River. The maximum flow will be 1 m^3/s and the discharge location will be at about map reference NZMS 260 L36: 337-334.

Rakaia River emergency bywash

Race TP 2.6 is in the southern Te Pirita area, and will transport overflow water to the Rakaia River. The maximum flow will be 16.5 m^3/s and the discharge location will be at about map reference NZMS 260 L36: 329-184

Race TP 3.2 is in the southern Te Pirita area, and will transport overflow water to the Rakaia River. The maximum flow will be 5.5 m^3/s and the discharge location will be at about map reference NZMS 260 L36: 264-219.

3.12.3 From headrace

The scheme has no plans for emergency discharge points from the main headrace canal. The most likely emergencies would derive from power cuts or sudden floods when river intake gates or the storage lake outlet had been left open, or if a stream underpass blocked during heavy rain. Enough gates will be provided to have a robust system of controls throughout the scheme to manage unexpected events, and the scheme races have enough capacity, including outlet capacity, to transport and discharge some 45 m^3/s. At each upstream end of the headrace canal there will be gates at the river intake and below the sediment settling pond, at the Waianiwaniwa lake outlet there will be a flow control structure, and there will also be some ten gates controlling outflows into the distribution system. These should provide the capacity to handle any reasonably foreseeable event. Further, to guard against effects of power cuts the scheme will provide emergency backup generators at larger key structures and backup manual controls at smaller structures. Regarding blocked culverts and other crossings it is anticipated that proper design and maintenance will be required to minimise the incidence of damage.

3.12.4 Release from Waianiwaniwa Reservoir

There will be a release from the Waianiwaniwa Reservoir to the bed of the Waianiwaniwa River immediately downstream of the headrace. This will be sized to release the mean annual flow primarily to provide groundwater recharge to that area of the Central Plains. It would also be possible to release significantly greater flows if there was some environmental or social benefit in doing so and if the lake had enough capacity. Given that currently this section of the river only flows during flood events, it may be that there are few ecological or environmental reasons to release such flood flows in the future.

3.13 Construction Activities

The construction of the Central Plains Water Enhancement Scheme is likely to take about three years. This is a large civil engineering project, likely to significantly affect the availability of resources within the local construction industry.

There is the possibility to stage construction to bring early water to parts of the plains should the shareholders want early water without the added security of a reliable supply from the reservoir. Staging construction is discussed later in this AEE.

3.13.1 Intakes and headworks structures

The construction of the intakes will involve the protection of the construction area from the river through the use of cofferdams, normally comprising sheet piling. If required, the river main stem would be diverted away from the intake site to minimise the amount of water that would have to be dealt with. The intakes by their very nature will be below current river water surface levels and therefore dewatering will be required from within the cofferdam structures. This water would be discharged back into the main river bed.

It is likely that only the intake at the Gorge Bridge will involve tunnelling. Alternatively it is possible that the upper Waimakariri intake could require pumping if detailed site investigations show that the location 5 km upstream from the Kowai River is the better site. The inlet and exit from the gorge tunnel will be protected from the river with sheet piling. Due to the short length of tunnel required, a drill and blast construction technique is most likely. The nature of the rock material has not been determined at this stage and therefore it is not possible to identify whether there is a need to line or otherwise protect the inside surface of the tunnel. Techniques such as rock bolting, grouting and lining would be used if required.

At the entrance to all intake structures there would be a radial (or equivalent) intake gate. This would be a substantial structure made from concrete with steel mechanical components. A concrete batching plant would be required in close proximity to the intake site. It is possible that a centralised concrete batching plant will be established on suitably zoned land in Selwyn District, or if necessary on land that will come under the control of Central Plains Water Ltd. A site close to the Waianiwaniwa reservoir would be most convenient.

The earthworks at the intake sites would initially involve stripping the site of vegetation and top soil. This material will either be disposed of or stockpiled for later restoration works. Detailed geotechnical investigations required for design will have identified the material at each site that is suitable for construction. Generally construction will involve balanced cut and fill, with canals excavated to grade with embankments constructed of compacted fill material on either side. Material identified as suitable for lining the canals would be mixed, placed and compacted to the required degree.

A wide range of equipment would be required for construction including but not limited to:

- Excavators
- Scrapers
- Cranes
- Pile driving equipment – impact and vibrating
- Concrete batching plants
- Gravel crushing and screening plant
- Bulldozers
- Compactors – vibrating and gravity
- Drilling equipment
- Blasting equipment
- Trucks – cartage and concrete
- Generators for site power
- Fuel storage and cartage vessels
- Miscellaneous small equipment and vehicles.

3.13.2 Waianiwaniwa Dam

The preliminary geotechnical investigations for the dam are reported in URS 2002[2]. This report details the geological sequences at the dam site and establishes the material most likely to require removal for construction of the dam. It is likely that a zoned earthfill embankment dam comprising of locally borrowed gravel materials will be constructed. At 55 m high, the dam is considered to be a large dam and would be subject to the Dam Safety Guidelines produced by the New Zealand Society on Large Dams (NZSOLD).

Construction Site

The construction site will extend out to the state highway in the east and well into the valley to the west. It is likely that the main construction staging area will be located within the valley behind the dam. This

[2] Geotechnical Investigations for the Proposed Waianiwaniwa Water Storage Dam. 11 October 2002, Prepared for Central Plains Water Enhancement Committee.

will accommodate the projects temporary construction facilities for the construction management team and the contractor. Facilities accommodated within the staging area include:

- Offices for construction management team and contractor management team and associated amenity facilities.
- Service buildings including workshops for plant repairs, storage, weighbridge, laboratory and amenity facilities.
- Aggregate screening and crushing plant
- Concrete batching plant
- Material stockpiles for the differing materials used to construct the various zones within the dam.
- Haul roads for the heavy machinery used to excavate and cart the construction materials.

Excavation and clearing

The site will require stripping the site of all vegetation, topsoil and other material down to competent foundation levels beneath the dam footprint. It also may be necessary to provide a cut off trench below the dam to provide a seal down to the tertiary bedrock or to less permeable gravels on the abutments. These details would be finally determined during the design geotechnical investigations.

Within the valley, gross vegetation such as trees would be removed by firewood contractors, and remaining rubbish burned.

To fully excavate the foundations, the site will require dewatering. A cofferdam will be built on the upstream side of the dam with water either piped or pumped past the dam foundation. Once the dam footprint has been isolated and dewatered, the excavation will proceed to the desired depth.

Material supply

The core of the dam would be constructed from weathered greywacke gravels with a relatively high clay content. This material can be sourced from within the valley. The filter zones would comprise of gravely sand, sourced either locally or from the Waimakariri River and processed on site. The shoulder material is bulk fill, comprising free draining gravels, either from the downstream area of the plains or from within the valley. Preliminary investigations indicate no shortage of suitable construction materials.

To minimise the construction time for the embankment, material stockpiles will be formed within the valley and then transferred to the dam for placement and compaction. The building of the earth embankment is likely to take 12 months, with the aim to place the core during the summer period to minimise the impacts of wet weather. The materials requiring stockpiling include:

- Weathered greywacke for the core

- Sand for the filter layers
- Bulk fill material for the dam
- Stripped topsoil and organic matter for reinstatement works
- Aggregate for concrete and shotcrete
- Cement
- Rock for rip rap protection.

Quarrying

The materials described above will be primarily sourced from within the Waianiwaniwa Valley, however some material such as the filter sand and concrete aggregate may be better sourced from the Waimakariri River bed. The land use consents and designations for the valley will enable quarrying within the valley. Consent will be required to take gravel from the river in the vicinity of the intakes.

It may be possible to excavate on the plains side of the dam to provide the bulk gravel fill required for the earth embankment dam. This could be used to create a separate recreational lake in the general area east of the state highway at Coalgate. This is a concept that requires development through public consultation with the local community.

Construction equipment

It is likely that much larger dump trucks will be used at this site compared to the canal and intake construction sites, with carrying capacities from 60 – 250 tonnes. Compactors are also likely to be larger with 10 -15 tonne steel wheeled vibrating rollers required on the dam. Other equipment will include those items of plant listed below:

- Excavators
- Scrapers
- Bulldozers
- Graders
- Cranes
- Trucks – cartage, concrete and water tankers
- Compactors – vibrating and gravity
- Pile driving equipment – impact and vibrating
- Concrete batching plants

- Gravel crushing and screening plant
- Compactors – vibrating and gravity
- Drilling equipment
- Blasting equipment
- Generators for site power
- Fuel storage and cartage vessels
- Miscellaneous small equipment and vehicles.

Workforce

It is difficult to be precise as to how many people will be working on the construction project, but it is likely to be less than 200, with 100 being a realistic estimate. Most of the workforce will be employed from the local area, with much of the work able to be undertaken by unskilled workers trained specifically for the job. There will of course be the need for skilled workers and some may be brought in especially for the project works. These workforce comments also apply for the headrace and water distribution race network construction programmes.

There will be no workforce residential accommodation provided on-site.

Hours of operation

For planning purposes it is essential to provide for work 24 hours per day and 7 days per week. It is likely that construction activities will be based on a 20 hour day (2 x 10hour shifts) with 4 hours available for maintenance works.

3.13.3 Reservoir supply canal

The intake and canal construction activities will be much the same as described above, however it is worth noting that the construction of the reservoir supply canal from the Kowai River siphon to the upper plains level will be a major civil engineering works. The canal will be constructed partly on fill and partly on cut so that the earthworks volumes can be minimised. While the canal footprint including banks and batters is approximately 50m, additional separation will be required to the cliff face, which in parts is approximately 80m high. The batters of the cut above the canal and the fill below the canal will need to provide for stability in all conditions. These will be determined through the design process.

The reservoir supply canal will also require a large cut to the southwest of Gorge Hill. This will be undertaken by excavators such as scrapers and diggers. Excavated material would be use to build canal banks in adjacent sections.

3.13.4 Waianiwaniwa Reservoir Tunnel

Overview

The tunnel length of 3 km is approximate at this stage of the project and represents the straight line distance between either side of the Malvern Hills on the proposed tunnel alignment. This length may require minor adjustment should subsequent site investigations identify reasons to move the alignment slightly or to relocate the tunnel portals.

The invert level of the tunnel has yet to be confirmed. The nominal water surface level in the canal supply approaching the reservoir is RL 300 to 305 m. The tunnel invert could be constructed to maintain a free water surface level through its whole length, or alternatively the tunnel could be constructed at a lower level such as an invert level below RL 300 m so that the tunnel always flows full. Each option has its advantages. The first is hydraulically more efficient (lower head loss), and the second would provide a tunnel that was not visible. For the latter option, the canal would flow to a head pond and the water would drop down through the tunnel and flow up onto the valley floor on the other side, with the water surface level governed by weirs and spillways within the valley. The later option would enable the Hawkins River to be crossed with a siphon connection to the tunnel without the need for embankments across the river bed. The costs and benefits of both options should be left to the design phase, and as such consent is required for any tunnel alignment in this general vicinity.

The tunnel will be constructed from the Waianiwaniwa Valley end through to the Sheffield end. All material excavated from the tunnel will be disposed of within the Waianiwaniwa Valley. If a tunnel of 40 cumecs capacity is built (~6m diameter), there will be approximately 100,000 to 110,000 m^3 of spoil to be disposed of. This would be placed in a stable contoured stockpile within the valley that would be above the top water surface level in the flooded valley.

In the tunnel, the rock will be supported with a pattern of rockbolts around the tunnel circumference and a 75 – 100 mm thick layer of sprayed concrete (shotcrete) will be applied as lining where required. The amount of rockbolt support and shotcrete lining required will be dependent on the quality of the rock encountered as tunnelling proceeds.

The tunnel will require reinforced concrete portal structures at each end, excavated by conventional drill and blast methods into the main rock. A hard rock Tunnel Boring Machine (TBM) may be used for the entire tunnel except the portals, with excavation proceeding upgrade from the Waianiwaniwa end. This machine will be sized to provide the tunnel capacity required for the final scheme concept adopted. Due to the short length of tunnel involved, a contractor may choose to tunnel using drill and blast techniques all the way. Consent is required for both methods of construction.

Tunnel spoil will be transported from the TBM or tunnel face by a continuous tunnel conveyor attached to the wall of the tunnel or wagons on a rail system. A precast concrete invert will be installed immediately behind the TBM on which temporary rails will be laid for the construction trains used to transport materials into the TBM. Rockbolts and shotcrete will be installed behind the TBM or drill and blast face as required.

The TBM would be expected to excavate in excess of 20 metres per day on average, operating 20 hours per day, 6 days per week. (The hours of operation may vary from this depending on the shift system the contractor chooses). It is therefore likely that the whole tunnel construction activities including the portals and head works will take less than one year.

Two staging areas will be required for this tunnel to accommodate the construction activities. At the Waianiwaniwa portal location, sufficient area will be required to construct the portal and associated permanent structures, assemble the TBM and accommodate tunnel services such as power supply, water supply, disposal of water from the tunnel, temporary tunnel spoil storage, tunnel locomotive operations, workshop and construction buildings. This is likely to be less than 1ha in area.

The second staging area will be located further from the tunnel portal and will accommodate an aggregate production area and batching plant for concrete production; spoil disposal area for all tunnel spoil; water supply and any settling ponds and water treatment facilities required for discharge water.

A brief description of the activities and facilities in the Waianiwaniwa portal area follows:

- Initial clearance and excavation of the footprint
- The perimeter buffer zone, catch drain and fencing will be established prior to any further construction work taking place.
- The TBM supply and delivery normally takes about 12 months and in this period the portal structures will be constructed, the initial length of tunnel into hard rock will be excavated by drill and blast and all buildings and other construction facilities will be established
- Diesel powered generators, substation, compressors and tunnel fans for the construction work. Up to 3 MW of power will be required to power the TBM, ventilation and other services. All diesel fuelled facilities such as these or storage tanks will be bunded off to capture any accidental spillage.
- A small workshop to service tunnel plant. TBM cutters need to be replaced daily and the workshop will include a cutter repair shop.
- The TBM will be assembled outside the portal on a substantial concrete pad, before it is jacked down the tunnel to commence tunnelling. Sufficient space each side of the pad is required to accommodate large cranes and the transporters bringing in components during the assembly.
- Tunnel spoil is likely to removed from the tunnel using a continuous tunnel conveyor, although this is normally the contractors choice. The rail system could be used. A stockpile area is required outside the portal to allow the TBM operation to proceed independently of any trucking operation to the spoil dump.

- A number of typical "Portacom" type construction buildings will be required in this area for offices, lunchroom, drying room, showers and toilets. Limited vehicle parking space will be necessary.

- Other miscellaneous buildings such as first aid and small tools will be located at the portal.

The second area is required for:

- Aggregate processing area for concrete supply. A small aggregate screening and crushing plant would be required to produce concrete aggregates and may also be used for other works in the project.

- A mobile concrete batching plant and testing laboratory will be required to produce concrete and shotcrete for the tunnel construction.

- The disposal area for tunnel spoil.

- A settling pond and water treatment plant will be required to treat dirty water from the tunnel and from the batching plant. Tunnel water would be piped into this settling pond from the portal.

- A temporary storage area for tunnel materials and plant such as rockbolts, steel sets, pipes, mesh, precast invert sections and any other materials required in the tunnel. A stockpile of materials is needed on site to ensure that no delays occur to the tunnel operation waiting on material deliveries. A small number of sheds or containers will be required to store perishable goods.

Water Supply

A modest supply of water will be required for general site operations, ablutions, tunnel operations and the concrete batching plant. It is envisaged that this will be pumped from the shallow ground water within the valley. Potable water for drinking will also be required on site and this will be obtained either from treatment of groundwater supply or will be brought from off site.

Power Supply

The TBM will require approximately 2 MW of power and with other load sources such as ventilation fans, lights, conveyor and aggregate and batching plant, the total demand is likely to be in the order of 3 MW. Power supply could either come from the existing supply lines suitably upgraded for the increased demand, or be provided by diesel generators feeding into a local site substation for distribution. The facility will be totally contained within a bunded area to contain accidental spillage of diesel.

Effluent and Waste Management and Disposal

With the main construction activities being undertaken from the Waianiwaniwa portal, this will be the source of most of the effluent and waste from the construction activities.

Potential effluent and waste can be categorised as follows:

- Tunnel discharge water. The tunnel will be driven upgrade from this end and any ground water encountered will flow out of the portal under gravity. It will be mixed with sediment and contaminants from the tunnel operations. This water will be collected in settling ponds, treated as necessary to achieve a stipulated standard before discharge into the Waianiwaniwa Stream.

- Discharge water from aggregate screening plant and concrete batching plant. These discharges will be discharged into settling ponds and if necessary treated to achieve a required water quality.

- Stormwater runoff. Runoff from surrounding farm land will be intercepted with perimeter drains and where possible will be diverted around the staging areas. Runoff from bare ground in the staging areas will be collected in perimeter drains and diverted through silt fences.

- Potential diesel spillage. Diesel will be used to power generators, compressors and other items of plant located at the site. Some diesel storage will be required on site. All storage facilities and permanent installations will be bunded to contain spillage and procedures will be developed to minimise the risk of spillage and for cleanup of any accidental spillage.

- An amount of construction waste and debris is unavoidable. This will include surplus construction materials, offcuts, packaging, office waste and household type waste from lunchrooms and ablutions. This will all be strictly controlled and will all be removed from the valley on a regular basis and disposed of in an approved disposal area.

- Waste water associated with the toilets, showers, washroom and lunchroom. A waste water treatment system will be constructed at the portal to service the construction facilities.

The construction contract specifications will include a very strict Environmental Management Plan and Environmental Specification to ensure that tight controls on all effluent, waste and potential spills are maintained.

Staff and Workforce

The portal works would be carried out by a relatively small workforce of about 12-18 people on a dayshift basis. Once excavation commences, a 24-hour, 7-day shift system is probable, with approximately 25 people per shift required, or a total shift personnel of about 75 to 80 people. These would be supported by about 15 to 20 people on dayshift including construction plant maintenance personnel and office staff. The peak workforce would be approximately 90 to 100 people for four months tunnelling duration.

For a large proportion of the works local subcontractors and labour will have the necessary skills and resources. The tunnelling work is specialised and a core of experienced tunnellers and supervisors will be required to come in for the project to augment the local labour. Accommodation would be in the local area.

3.13.5 Headrace

As discussed previously the typical dimensions of the headrace along the flat sections of the route will be 5 m wide at the base, and a top water width of 30 m, and 5 m deep. The total footprint of the canal and embankments will commonly be 50 - 60 m. Construction will be by cut to fill, such that in general terms the volume of material required to be excavated equals the volume of fill material required to build the embankments.

The construction process will commence with securing the site and construction lay-down areas by either temporary or permanent fencing. The route of the canal will then be stripped of topsoil, which will be placed alongside ready for restoration at the completion of the job. Depending on the geology at the particular section of canal, other materials may be collected and stored separately from the bulk excavation material. This in particular applies to any silt/clay material needed for the lining. Bulk excavation material is generally excavated, placed and compacted in a single operation, to minimise the need for double handling, long haul distances and general efficiency. As canal construction is an essentially linear process, the contractor will develop a construction plan to optimise the use of machinery, minimise haul distances, double handling of material etc. It is not possible at this stage to clearly identify the sequence of the work, nor the lengths of canal being constructed at any time. However it is likely that at each section being constructed will be a small number of kilometres, possible reaches between major siphon or stream crossings.

The bulk material for the embankment will be placed by scrapers, dump trucks or direct from excavators. Compaction with heavy steel vibrating rollers will be required. To obtain optimum compaction, moisture concentrations in the material will be controlled through the application of water by tankers. This large machinery will form the general shape of the canal, and then smaller excavators, bulldozers and graders will establish the profile.

Lining material is placed last, and this may include a compacted layer of low permeability material or a synthetic liner such as HDPE. The choice of lining material will be a design consideration depending on the availability of in-situ materials and cost.

The canal will be completed with the placing of topsoil on the outer embankments, which will then be sown down with grass.

3.13.6 Distribution network

The distribution network will be constructed in a similar way to the headrace canal, however due to the significantly smaller canal involved, the process can be simplified. In general the distribution canals are shallower and therefore leakage is less difficult to control. The route would be fenced as required, topsoil stripped generally with graders and then the profile constructed with the in-situ materials mixed, placed and compacted to provide the required permeability. The fall on the Central Plains generally exceeds that required for the canals, and therefore drop structures will be required at regular intervals. These can take a number of forms, including precast weir structures, in-situ concrete structures, or cascading concrete and rock lined spillways. These will be determined through the design process. The final construction activity will be replacement of the topsoil and sowing grass.

3.13.7 Siphons

The major streams and rivers will be crossed using siphons. The locations of these have been described previously. Siphons will be placed below the bed of the streams and therefore will require extensive works within the bed of the rivers. Generally the siphons will be pre-cast concrete box culvert units installed 3m below bed level. Following site clearing, the crossing route will be excavated to the required depth and the bedding material for the boxed units placed to grade. Box units will be placed and joined to the other units. Selected excavated material will be placed and compacted around the units with bulk fill used to restore the river bed to the existing grade. Excess material will be disposed of in fill areas or used as construction material for the headrace canal. The joins in the concrete units will be sealed and the structures water tested before final completion.

This process will proceed across the stream bed in a linear fashion. It is likely that the existing stream bed will be maintained at current levels so that any water can still flow past the site. Many of these stream crossings will be in dry streambeds – Hawkins, Hororata etc, but others may have flowing water – Selwyn, Kowai etc. In all cases provision will be made to enable minor flood flows to pass the site. Large floods will not able to be controlled and the construction site would be inundated. This is a construction risk that the contractor would take.

As the excavations will be below bed level, there will be a need to dewater the site. This is generally attained through the excavation of pits lower than the base of the siphon from which pumps remove the groundwater. In situations where groundwater inflows cannot be controlled in this manner, other techniques such as well pointing or sheet piling may be needed. Consent is required for all methods of construction.

At either end of the siphon, headworks will include earth embankments and concrete wingwalls or similar to provide a transition from the trapezoidal canal to the rectangular culvert without excessive head loss.

3.13.8 Stream Crossings

Stream crossings involve culverts being placed under the canal. These will be used where there are smaller flows, less sediment transport and generally shorter distances to travel. These will be constructed as part of the canal construction and will involve either pipes or box culvert sections being placed below the invert level of the canal.

3.13.9 Road and Railway Crossings

Road and rail crossings will be constructed to minimise the disruption to traffic flows. Road crossings will inevitably involve the construction of a temporary road around the crossing, so that the canal can be formed and the bridge units installed prior to restoration of the road. A number of construction techniques could be used for this, including using box culvert units or bridge beams across specially constructed bridge abutments in the canal embankments. The need for piles and central piers to support the bridge units will be determined as a design function. The final grade and alignment of the crossings will be determined through discussions with Transit and Selwyn District Council as the roading authorities.

The rail crossing has a higher requirement to remain open at all times and to maintain grade. Construction is therefore likely to involve “tunnelling” under the rail line while providing support to enable continued use of the tracks. This is particularly important given the use of this line for coal transportation.

3.13.10 Heavy Machinery

Given that the Central Plains Water Enhancement Scheme is a very large civil engineering project, virtually every type of construction plant conceivable could be used on the project. The main types of equipment have been described in other sections. In particular large dump trucks, excavators, scrappers and compactors will be required for the dam. Drilling and blasting will be required for the tunnelling operations. Quarrying and general winning of construction materials will be required. Extensive use of trucks, excavators, bulldozers, graders and compactors will be required on the canals. Typical roading construction equipment will be required for the road crossings. Cranes, piling equipment, pumps, generators, welding equipment and general engineering workshop activities will be required. Concrete batching plants, aggregate screening and crushing plant will be required at a number of sites. It is important that those reading this application understand the large scale of the works involved and the nature of the heavy machinery likely to be used.

3.13.11 Hours of Operation

The applications are for 24 hour/day, 7 day/week construction activities. However it is recognised that some activities do not need to have such open hours. In particular where parts of the canals are close to residential areas and local rural residences, reasonable hours of operation would be followed. This typically would be between the hours of 7am – 9pm Monday – Saturday for the heavy machinery operation and special arrangements can be made to accommodate other one-off events. It will be a requirement of the construction contracts for the contractor to develop a construction management plan that will identify the hours of operation in areas that could be particularly sensitive.

It will not be practical to limit the hours of operation for the dam construction nor the tunnelling works.

3.13.12 Contractors' Work Sites

The preceding sections have described the contractor work sites for the dam and tunnel construction. In addition to these, there will be other work sites established along the canal routes to provide amenity and office support to the contracting operations. These will generally involve the use of portable buildings and may include:

- Vehicle storage areas
- Material storage
- Office accommodation
- Amenity facilities such as toilets and lunch rooms
- General work areas.

3.13.13 Construction Timetable

It is not possible to provide a construction timetable at this point in time, other than to state that the construction works are likely to take about three years.

3.13.14 Health and Safety

As with any construction works, the tunnelling, canal construction, dam construction and other works must comply with the Health and Safety in Employment Act, which has generic requirements relating to these works. A number of specific tunnel industry standard requirements will also be mandatory to ensure that a safe work environment is achieved in this particularly risky activity.

A Health and Safety Plan will be required from the contractor which complies with all aspects of the Act and with current industry practice.

Emergency first aid and evacuation procedures will be required to cater for minor and serious harm injuries.

3.14 Scheme Operation

3.14.1 Surface water takes

Central Plains Water Trust has applied to take flows of up to 40 m^3/s at all three intake sites. The normal maximum at the Rakaia site will be 20 m^3/s. However by agreement with Ashburton Community Water Trust, and when the Rakaia allocation rules permit it, and when the Ashburton Trust does not need its allocation, and when Central Plains is short of water, water could be traded to take up to 40 m^3/s into Central Plains. For the Waimakariri intakes it is intended that a combined flow from both sites of no more than 40 m^3/s will be diverted for irrigation at any time, the distribution between the two intakes being governed by whether water is needed to go into storage. In addition a further flow of 2 m^3/s will need to be diverted and discharged at each intake to operate the fish passes. Flows into the intakes will be regulated according to scheme needs and according to the takes allowable under the relevant river allocation rules, and it is expected that ECan will provide information on the allowable takes each day. Gates at the intakes and downstream end of the sediment trap will be monitored and controlled remotely and generally automatically. However sluice gates will only be opened with a scheme operator present, as a safety measure to check for the presence of people around the sluice return channels. Scheme operators will also inspect the intakes and other headworks features frequently, at least daily during times of higher flows, to check for debris, river channel movements and potential damage to facilities.

River training works will be needed from time to time at the Rakaia and upper Waimakariri intake sites. They might also be needed at the lower Waimakariri site although less frequently because of the favourable location of potential tunnel intakes. Typically a bulldozer will be required to excavate an entrance to the intake channels to divert and maintain a strong flow. In addition a low weir might be erected to aid the diversion. It can be expected that this will have to be repaired after significant changes in the river bed, which occur typically when the river bed starts to mobilise during significant freshes. In the Rakaia these changes occur typically above a flow of 400 m3/s, and possibly at a lower flow in the Waimakariri. The site that is most vulnerable to changes in the river bed is likely to be the upper Waimakariri intake site. It can be expected that river training might have to be performed on average about ten times a year at each site.

3.14.2 Stilling basins and sediment removal

The upper and lower Waimakariri and the Rakaia intakes are proposed to contain suspended sediment traps of almost identical size. The traps, which will be built within 1 km downstream of the intake structure, will be designed to settle coarse suspended sediments (i.e. sands and a small proportion of silts). A capacity of approximately 80,000 m^3 per sediment trap is necessary to reduce intake flow velocities and to achieve the residence time required for settling. The sediment trap will be a widened canal section which will be approximately 100-150 m wide and 400 m long. We expect the traps to collect about 20,000 m^3 of sediment per year, total from all sources, depending on the level at which the gates will be closed. Further design refinements will be able to be made before construction following further river sediment sampling.

It is intended that settled sediments will be flushed periodically or they may be removed mechanically from time to time. These operations will be optimised after practical experience.

At this stage it is planned that each of the intakes will be designed for a peak flow rate of 40 m^3/s for irrigation, plus an allowance for a fish return flow from the fish screens. The initial flushing flow will be at least double that flow rate for the first few minutes when the sluice gates are first opened, sending a noticeable floodwave into the nearby river channel, but the flow rate will drop rapidly as the level falls in the sluicing channel. Sluicing operations are likely to take between half and one hour to complete.

Experience from other irrigation intakes on Canterbury rivers indicates the governing criterion for establishing the frequency of flushing operations will be consolidation of the sediments, as with time the sediments tend to become cemented in the sides and inverts of the channels and will not flush away. The volumetric capacity of the channel will not normally be an issue. The best practice will be established by experiment, and the frequency of flushing will vary depending on the amount of incoming sediment, but it could be expected that typically, flushing might be needed once a week to prevent sediments consolidating in the sluice race. More frequent flushing will be needed in times of higher flow as a higher concentration of sediment is drawn into the intake, perhaps as often as daily at the worst times, but at higher flows the scheme will prefer to shut the intake or at least limit the intake flow to reduce the amount of flushing and other maintenance required. Investigations suggest that the frequency of scheme closure to prevent excess sediment intake will occur on average about one day per year.

Sediment laden water that is returned to the river from the sluice channel could be expected to have a high sediment content compared with the river naturally. Sediment that is moved in the sluicing operations will be mainly the sand and gravel fractions as storage time in the sluicing race would be too short to settle much of the finer material. The only material returned to the river during flushing will be sediment that has been taken out of the river. This can be expected to deposit on the river berm or be returned to a main channel and be moved on from time to time by freshes and floods, being reincorporated into the river sediments.

Below the sediment trap there will still be some accumulation of remaining sediments, particularly in the headrace canal when it is full and there is little demand for water. It can be expected that the headrace canal will require mechanical cleaning every few years. This could be done by diggers or dredges, with the latter being more appropriate if the canal had to remain full throughout a winter. Within the distribution system fine sediments will wash out of race banks during the early years of operation and some of these will deposit in flatter sections of race, possibly requiring mechanical cleaning. But apart from this settling-in phase there should be minimal settling of sediments in the secondary distribution system as race grades will be steep enough and velocities high enough to keep all remaining sediments in suspension.

3.14.3 Fish Screens

Fish screens and fish bypasses will be in operation continuously and automatically. Bypasses will be open channels requiring no mechanical activities so will remain operative during power failures. Cleaning systems will also operate automatically, to clean debris and algae, either with continuously rotating drum screens with brush cleaners, or continually operating brushes on flat screens. It is likely to be necessary to do some fine tuning of fish return channels to the river from time to time to ensure that fish are able to return easily to a significantly flowing braid, and the details of this will need to be done with advice from fishery experts.

3.14.4 Reservoir filling and operations

Initial filling of the Waianiwaniwa reservoir will take one to two years, depending on available water flows. Dam safety parameters and environmental impacts will be monitored throughout this period.

Once filled, the lake will be used as a backup supply when the required flows are not available from the Rakaia and Waimakariri Rivers. Modelling of over 30 years of supply and demand has indicated that, if the scheme had been operating over that period, the lake would have been drawn down to its minimum operating level in only two season. Generally, very little water will be drawn before January, so storage levels will almost always be full for recreation during the peak of the Christmas holiday period. It is intended that the minimum operating level will be 246 m, i.e. with 35 MCM of water retained, as a means of reducing dust nuisance, maintaining the ecological health of the lake and its fauna and enhancing the visual impact.

For drawing water from the reservoir a tower will be constructed with inlets at multiple levels to enable the best quality water to be selected.

3.14.5 Canal operation

The headrace is a 61.4 km-long open canal designed to deliver the allocated flows of water across the width of the plains to distribution canals. Water will be supplied to the headrace from intakes on both the Rakaia and Waimakariri rivers, and from the Waianiwaniwa storage reservoir. Water will be able to flow both directions in the headrace depending on different supply and demand scenarios. The canal will be level across the entire width of the plains and water will be induced to flow in either direction by raising the water level at the inflow locations and drawing outflows into the distribution canal system. These operations will be controlled remotely. Flow velocities will be kept below 1 m/s to minimise potential for scour or erosion of embankments. The flat gradient and low velocities will lead to some deposition of fine sediments and these will need to be removed mechanically once every few years.

The headrace has been assumed to have a leakage rate of 1 m^3/s. This leakage water will come either directly from the rivers or from the Waianiwaniwa storage without any further contamination, and the rate of flow will have a small but noticeable impact on groundwater levels in comparison with other contributors to the groundwater. Scheme consent applications and storage design have allowed for this leakage loss in addition to on-farm water demands and other water losses. Initial site inspections indicate that suitable natural earth materials are likely to be available to achieve the required degree of impermeability and at the same time protect the canal banks against scour. However an alternative that might prove to be equally economic is to use a synthetic lining. The method of lining will be determined during detailed site investigation and design.

3.14.6 Delivery of water to farms

Simulations of water demands over a period of more than 30 years have indicated a peak scheme requirement of 35.6 m^3/s and an average requirement of 18.7 m^3/s taken over the irrigation season. This will be supplied from three sources in the following order of priority: the Rakaia River when run-of-river water is available from there according to the rules of the NWCO, then the Waimakariri River when run-of-river water is available from there according to the rules of the WRRP, and finally the Waianiwaniwa storage lake. The reason for drawing from the Rakaia first is that it is the larger of the two rivers and has the more environmentally robust allocation rules. The reason for drawing from the lake last is that it is important to keep its water in reserve for periods of shortfall from the run-of-river flows. It also maintains its level for recreational or fishery use. The design of the scheme hydrology, i.e. the canal sizes, storage lake capacity and take applications have been predicated on these assumed priorities. If the lake was to be used earlier it would need to be very substantially larger to be able to service the scheme adequately during periods of low river flow when run-of-river flows could be cut off for significant periods of time.

It has been assumed that the method of application of water on farms will be by automatically moving sprinkler irrigators. Farmers will therefore require a continuous flow, not an intermittent or rostered flow. Because of the size and complexity of the scheme, races will take a number of days to adjust their level to an altered flow so it is expected that farmers will be required to order their water at least three days in advance of needing it. They will then be required to take delivery of this water regardless of whether rain has fallen in the interim except in emergency. The alternative would be large bywash flows, and that is not likely to be acceptable.

Water deliveries will be activated generally remotely and only by scheme operators. Delivery times will be recorded and flow rates metered by automatic recorders. The method of delivery will generally be by suction pipe immersed in the canal and powered by an adjacent pump station. A range of suitable designs is available and selection will be made according to required on-farm flow rates and pump and irrigator specifications.

It has been assumed that there will be a loss of water from the distribution races equal to 10 % of the average on-farm water demand, and that this will be a constant loss throughout the season regardless of fluctuations in on-farm water demand. The 10 % loss is to account for evaporation losses and leakage to groundwater, and has been allowed for in the calculations of scheme water requirements and in the applications to take water, and over a season it amounts to an average of about 2 m^3/s. This is considered a reasonable rate of loss for the scheme to accommodate, leading to a small increase in operational race design capacity. It is also considered that it can be realistically achieved with the mix of materials that occur across the plains. It might require different measures from one location to another depending on the type of material encountered, such as importing fine material for sealing, or constructing from immediately available in-situ material, or allowing a period of time for races to seal naturally using fine material that washes down a race line.

3.14.7 Use of water on farms

It is expected that all irrigation will be by sprinkler methods, although a variety of other methods are possible including surface and sub-surface drippers, and hydroponic systems. Most farmers will use large automatically propelled sprinklers, with centre pivots and various types of moving booms currently being the favoured applicators for large properties. When these are properly designed, operated and maintained they can expect to achieve a water use efficiency of about 80 %.

Calculations have assumed farmers will irrigate 37,000 ha of pasture (with present markets it is assumed most pasture will be for dairying) and 23,000 ha of crops. Modelling has assumed a peak rate of supply of 0.6 L/s/ha and return periods would average 7 to 14 days depending on soil types and crops. Average application rate over an irrigation season has been calculated to be about 0.31 L/s/ha.

Farmers will be allocated water according to the number of shares purchased in the scheme share float of late 2004. Guidelines were given about a suitable number of shares per hectare but investors were able to purchase more or fewer shares, not tied to their farm area. They will then be able to apply more or less water than assumed in modelling calculations, but overall it can be expected that the modelling assumptions will be a realistic and fairly accurate representation of farming practice.

With a storage-dependent water supply irrigators will have a strong incentive to make efficient and effective use of irrigation water. To improve this it is likely that more farmers will adopt modern planning techniques such as water scheduling and soil moisture monitoring. The Trust has a Memorandum of Understanding agreement with Central Plains Water Ltd that requires sound environmental management practices, so it is required that the company will sell water to irrigators in Central Plains with conditions to ensure these are carried out. A proposal for such practices is currently being developed by a local team with assistance from the government's Sustainable Farming Fund. Farmers might want to sell, lease or temporarily trade their water shares depending on their selection of crops, current soil moisture levels and prices offered for both crops and water. In this way a water market could develop within the scheme, subject to resource consent and land management conditions, which should allow a more economically optimum use of water to be achieved

3.14.8 Bywash

Sprinkler irrigators require a continuous flow of an amount specified by the equipment supplier. It would be impossible to regulate the flow in a long supply canal sufficiently accurately to ensure that the final person on a supply race received exactly the right amount, no more and no less. Therefore all irrigating properties, including the last person on a line, require a surplus flow to pass by their supply point. These surplus flows will be collected and returned to the environment by way of a series of bywashes.

Calculations of scheme water requirements have assumed that the total flow in these bywashes under normal operating conditions will be 10% of the current instantaneous on-farm water demand, and this has been allowed for in the applications to take water. Bywash flows would be continuous from most of the outlet points identified in Section 3.12 of this report and it can be assumed they would fluctuate around the 10% level, with a seasonal average of 2 m^3/s. This 10 % figure has been established from experience in other major irrigation schemes in Canterbury and is a compromise between:

- a responsibility to minimise water takes from the rivers,
- the practicalities of engineering acceptable bywash designs,

- the extra capital costs of upsizing scheme components to accommodate yet larger flows,
- what is operationally achievable (a larger percentage bywash flow is easier to operate), and
- a desire to limit withdrawals of valuable water from the storage lake.

The need to limit bywash flows is the reason for insisting that farmers take and use water that they have ordered for their properties (see Section 3.14.6, Delivery of water to farms).

However the total planned bywash capacity is 66 m^3/s, which exceeds the total scheme intake capacity. This provides excellent operational flexibility and recognises comments from operators of other Canterbury irrigation schemes, who have listed adequate bywash capacity as their chief request from scheme designers. But more crucially the maximum capacity is dictated by the need to plan for emergency situations. Such situations would be most likely to occur in a district-wide power cut when the scheme is operating at full capacity. In that situation all irrigators would shut down and the full allocated flows would pass along the scheme distribution system and on through the canal bywashes. The system of bywashes or other management measures as described in Section 3.12 is intended to recognise this need. However bywash design and operation will have to be investigated, developed and refined during detailed design, in consultation with relevant stakeholders, to identify the risks from excess flows and, where higher flows may eventually have to be discharged via bywashes, to limit flows according to the capacities of individual bywashes and their receiving environments.