FINAL REPORT

Waianiwaniwa Reservoir Feasibility

Prepared for

Central Plains Water Enhancement

Selwyn District Council
Private Bag 1
Leeston

7 November 2002

48685 002 4100 R1161

URS

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Contents

Acknowledgement

URS New Zealand would like to acknowledge the input into the Environmental Effects Assessment by NIWA.

1.1 Introduction

This report provides an assessment of the feasibility of establishing a storage reservoir in the Waianiwaniwa Valley, taking into consideration the social, environmental, technical and financial aspects. It also makes a comparative assessment of the Waianiwaniwa Valley site to the proposed reservoir site in the Wairiri Valley. Details of the Wairiri Valley reservoir are contained within the URS feasibility study report dated 31 January 2002.

The URS report dated 11 October 2002 provided a geotechnical assessment of the proposed Waianiwaniwa dam site. That report concluded that it would be possible to construct a dam in the valley with a storage volume of 290MCM. The top water surface level would be RL280m, which is considerably less than the previously estimated level of RL291m. This has had a significant impact on the cost of the reservoir, as it now will be approximately 10m lower than previously estimated.

The location of the dam and the approximate top water level contour are shown in Figure 1-1.

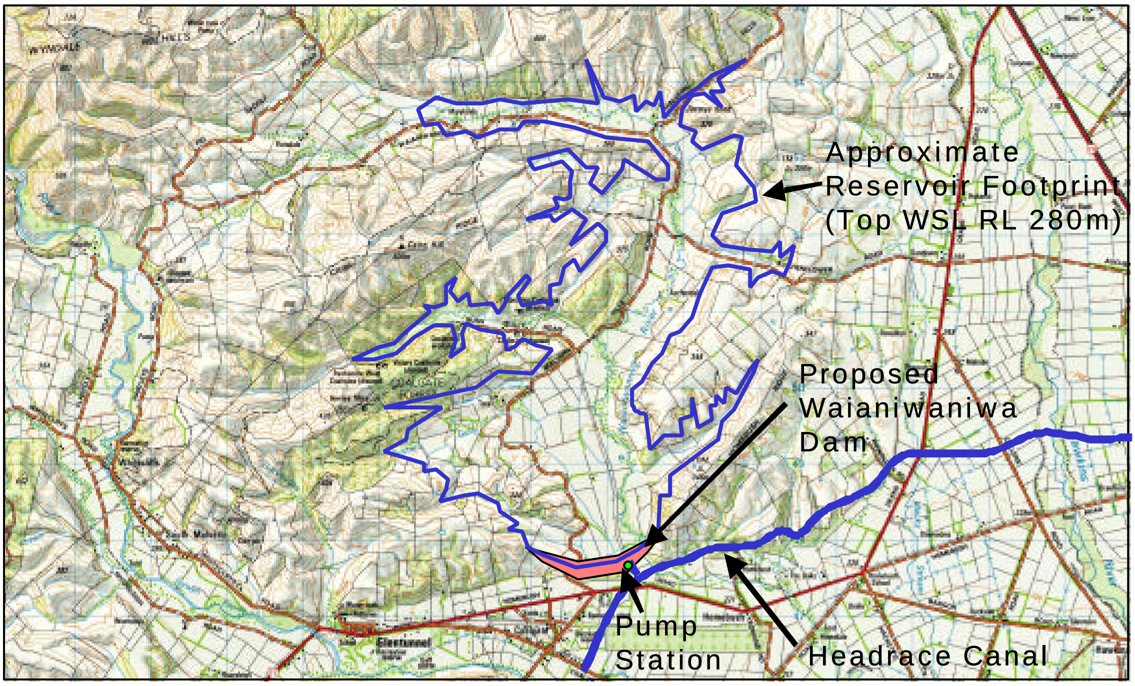


Figure 1-1: Waianiwaniwa Dam and Reservoir Location.

Figure 1-2 is an aerial photograph of the valley with contours and the top water surface level shown.

Figure 1-2: Aerial Photograph of Waianiwaniwa Valley

2.1 Description of the Waianiwaniwa Valley

Basically, the Waianiwaniwa catchment constitutes a broad, flat valley, surrounded by gently rolling hills dominated by pasture, with trees (willows, poplars) and shrubs (kanuka, gorse, broom) in the gullies and some pine plantations on the slopes (Figure 2-1). With the exception of the valley floor, which is quite fertile with lush pasture growth, the topsoil layer is thin and overlies clay subsoils. The Waianiwaniwa River rises in the pasture-dominated foothills, then traverses through gullies (some of which are heavily overgrown with broom) before meandering along the valley bottom where the margin is dominated by willows and poplars, and finally flows onto the plains, where the bed is coarse and porous, to join the Selwyn River. The flow on the plains is subsurface, although during major floods, surface flow is likely. The river appeares to be stable, with no evidence of major flooding, and had good periphyton growth and an abundance of benthic invertebrates and fish.

2.2 Water Quality

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

2.2.1 Water level fluctuations

Based on the availability of water from flow data for the Rakaia River (1972-2000) and estimated irrigation demand, it is predicted that either reservoir would go completely dry in two out of 28 years, and be drawn down to less than 50% capacity in 17 out of 28 years. Mean water volume of the reservoir over the 28-year period would be 220 MCM, or 78% of full capacity. The lowest volume would occur during periods of high irrigation demand (January-April), with the reservoir being near full from May through to December. It is estimated that a mean 173 MCM of water/year would be exported from the reservoir for irrigation (based on data for the period 1972-2000), resulting in a residence time of water in the reservoir of about two years.

Figure 2-1: Views of Waianiwaniwa Valley:

Upper – headwaters rising in pastoral hills; *middle* – pastoral hills with scrub growth in the gullies and few pine plantations on the slopes; *lower* – valley floor with lush pasture.

2.2.2 Limnological properties

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

Table 2-1: Some predicted limnological features of the Waianiwaniwa and Wairiri Reservoirs and fetch at varying reservoir capacities (% full).

	Waianiwaniwa Reservoir			**Wairiri Reservoir**		
Parameter	**100%**	**50%**	**25%**	**100%**	**50%**	**25%**
Volume (MCM)	290	145	70	250	125	64
Area (km^2)	12	7	5	10	6	3
Mean depth (m)	24	19	13	25	21	21
Thermocline (m)	14	12	11	13	11	10
Fetch (km)	5.9	5.1	4.7	6.2	4.5	3.6

2.2.3 Water clarity

Water supplied from the Rakaia River and Waimakiriri rivers would be quite turbid, as water would be extracted from the river primarily during freshes and floods. Water level fluctuations in the reservoir are likely to be pronounced due to variations in river flows and irrigation demands. The predictions of sediment inputs to the Waianiwaniwa Reservoir are assumed to be the same as those predicted in the previous study for the proposed Wairiri Reservoir (Glova et al. 2001).

2.2.4 Suspended sediment inflows

Final details of the intake structures for the races feeding the Waianiwaniwa Reservoir from the Rakaia and Waimakariri Rivers are not available at this time. In all likelihood, the efficiency of the sediment traps would be similar to that of the Rangitata Diversion scheme. This trap has been found to be highly efficient (84-92%) in trapping sand-size suspended sediments, but not those of the finer silt and clay particles (Waugh 1983). For the purpose of determining suspended sediment inflows to the

Waianiwaniwa Reservoir, it was assumed that 84% of the sand and none of the silt-clay fractions would be trapped in the settling basin at the intake. It is assumed that the intake structures would be adequately designed to divert bedload.

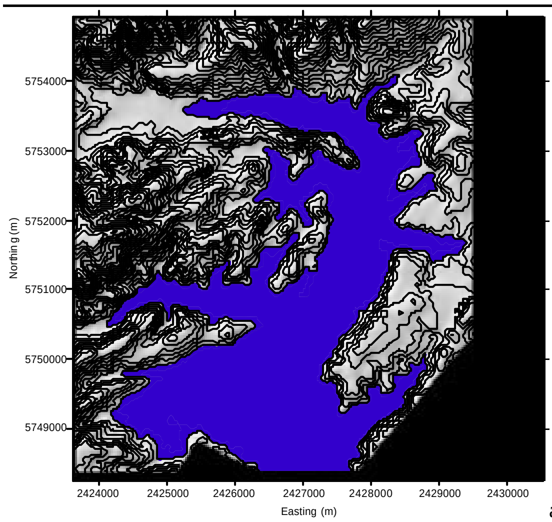
Suspended sediment sampling was undertaken in the Rakaia at the SH1 Bridge in 1995 during a 2844 m^3/s flood flow when the suspended sediment concentration was 5627 mg/l. Table 2-2 gives the sand, silt and clay fractions by mass based on particle-size analysis results. Since there are no major tributaries of the Rakaia River between the Gorge and SH1 Bridge, the particle size distribution of the suspended sediment at the Rakaia intake is expected to be similar to that at the SH1 Bridge, and we therefore used the former results without modification. In the absence of any particle-size information for the Waimakariri River, we also assumed the same distribution for the Waimakariri intake. This assumption is reasonable given the similar geologies of the Rakaia and Waimakariri catchments. The mass fractions for the Waianiwaniwa inflow show the proportion of the sand, silt and clay fractions, after allowing for removal of 84% of the sand fraction within each of the intake structures.

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

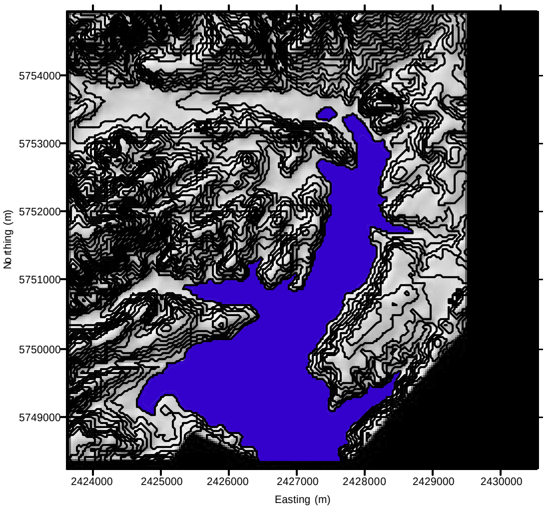
The amount of sand trapped at the intakes is expected to be between 5880 and 6440 t/year for the Waimakariri intake and between 1890 and 1840 t/year for the Rakaia intake (assuming a trap efficiency of 84-92% for the sand fraction of the input load.

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

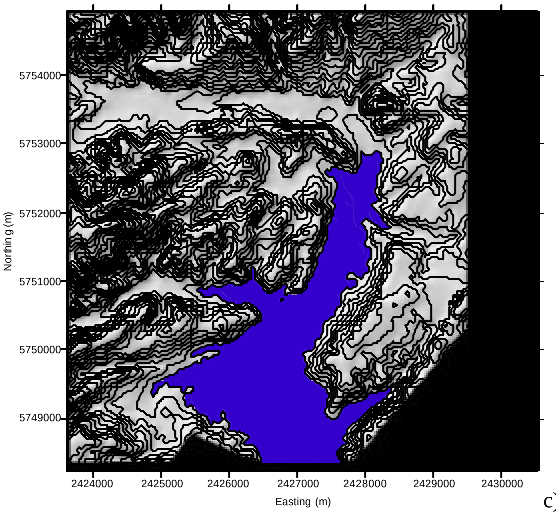
	Mass fraction (%)	
	Rakaia at SH1 bridge	**Waianiwaniwa inflow**
Sand (63 – 2000 µm)	26.7	5.5
Silt (4 – 63 µm)	37.7	48.6
Clay (<4 µm)	35.6	45.9



a) Lake Height 280 m, ~290 million m^3



b) Lake Height 263 m, ~145 million m^3



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

Figure 2-2: Plan views of the Waianiwaniwa Reservoir at a) 100% capacity, b) 50% capacity, and c) 25% capacity.

2.2.5 Sediment deposition and re-suspension

The sediment trap efficiency for the Waianiwaniwa Reservoir for long-term average inflows is estimated to be 95% for the reservoir between 50% and 100% full, reducing to 90% with the reservoir at 25% full. (Table 2-3). These estimates are based on Brune’s 1953 empirical relationship (Vanoni,1977).

Table 2-3: Sediment trapping efficiency for the Waianiwaniwa Reservoir

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

Assuming an average bulk trap efficiency of 95%, 24840 t of sediment would be deposited in the reservoir per year. This incoming sediment would be deposited largely in the shallow areas of the reservoir subject to periodic wetting and drying. For the predicted clay-sand-silt mix (Table 2-2), the specific weight of the depositing sediment is estimated by the Lara-Pemberton method to be 0.88 t m^{-3} (Morris & Fan, 1997). Loss of storage volume due to sedimentation is therefore expected to be approximately 28,300 m^3/year (0.028 MCM/yr).

The estimated settling time for 1-µm clay particles over an average depth of 24 m in the reservoir is 167 days. This is not considered long compared with the residence time for water of approximately 2 years. Thus, clay-size particles would have ample time to settle in the deeper areas of the reservoir and water clarity would be expected to improve over time.

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

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

Table 2-4: Wave base-depth for a 20 m/s wind for 1 hour duration at 10 m above the ground for the Waianiwaniwa Reservoir.

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

2.3 Eutrophication and Weed Growth

As was predicted for the Wairiri Reservoir, eutrophication is expected to be an issue during the initial period (3-4 years) of the Waianiwaniwa Reservoir. Inundated sediments and vegetation in lakes are likely to yield large quantities of nitrogen and phosphorus and promote phytoplankton growth (Viner and White 1987). The 20% greater area of flooded upland vegetation in the Waianiwaniwa Reservoir (12 km^2) compared with that of the Wairiri (10 km^2) is likely to result in greater initial inputs of nutrients and organic materials.

Water quality problems in reservoirs are frequently associated with high phytoplankton production (Hoare et al. 1987). However, in both the Wainiwaniwa and Wairiri Reservoirs, it is likely that phytoplankton production would be largely limited by low light penetration. Moderately high concentrations of suspended sediments in the reservoir would scatter down-welling irradiance and reduce light penetration (Davies-Colley 1989). Based on optical properties of glacial fed lakes in South Canterbury, light extinction coefficients for the reservoirs would probably be between those of Lake Pukaki (1.56 m^{-1}) and Lake Tekapo (0.63 m^{-1}), depending on the amount of time since the last freshet.

This would likely correspond to a euphotic zone (depth of phytoplankton growth, or 1% irradiance) of 3-8 m. However, the larger area and shallower overall depth of the Waianiwaniwa Reservoir would tend to result in greater phytoplankton production than that expected for the Wairiri Reservoir. The relatively short water residence time of both reservoirs (~2 years) would tend to reduce eutrophication problems because of the mass export of nutrients from decomposition of vegetation and soils. Over time, nutrient levels in the Waianiwaniwa Reservoir should approach those of the source (i.e., the Rakaia River), which would be relatively low and not support algal blooms.

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

2.4 Stratification and Anoxia

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

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

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

2.5 Drying of Reservoir

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

2.6 Water quality for irrigation

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

2.7 Fish populations

2.7.1 Sampling

A survey of the fish populations present in the Waianiwaniwa catchment was conducted on 16 October 2002 during moderate flows and good weather conditions. From the headwaters to within the vicinity of Glentunnel, a total of 11 sites (Fig. 3) was sampled qualitatively with the use of a backpack electric fishing machine, dipnet, and stopnet. At each of the sites, the species and numbers of fish caught were recorded. In addition, the general features of the river channel, substrates, bank conditions, habitats and relative abundance of benthic invertebrates were noted for each of the sites.

2.7.2 Results

Only three species of fish were found in the Waianiwaniwa catchment, with all of them being wholly freshwater resident – they comprised the Canterbury mudfish (*Neochanna burrowsius*), Canterbury galaxias (*G. vulgaris*) and the upland bully (*Gobiomorphus breviceps*). The upland bully was the most abundant fish, followed by the Canterbury mudfish, which was present at all but four of the headwater sites – at the uppermost site in the headwaters, only the Canterbury galaxias was found (Fig. 2-3). No fish were found at the lowermost site sampled (Site 11), where the river flows onto the plains.

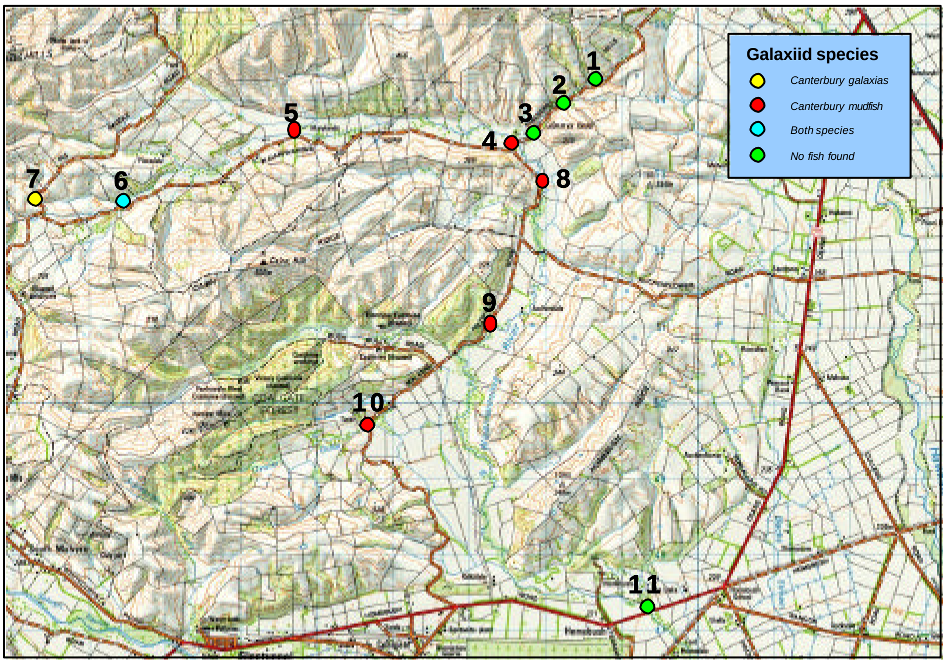


Figure 2-3: Waianiwaniwa River showing fish sampling sites conducted 16 October 2002.

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

The most significant aspect of the fish populations in the Waianiwaniwa River was the rather abundant and widespread nature of the Canterbury mudfish, a species that is on the rare and endangered list of freshwater fish in New Zealand. The species was found in all major habitats (Fig. 2-4; runs, pools, riffles), although its numbers were generally greater in slow-flowing runs and pools. This widespread occurrence of the species within a catchment has not been recorded elsewhere– hitherto, the species has been recorded to occupy swampy habitats not usually occupied by other species of fish (McDowall 1990).

Figure 2-4: Views of some of the habitats occupied by the Canterbury mudfish in the Waianiwaniwa River

In Figure 2-4, shown in order of preference: *upper* – slow-flowing run with cobble bed and lush riparian cover; *middle* – pool ~0.6 m deep with gravel and fines on the bed and riparian grasses overhanging the banks (the electric fisher is pointing to where several mudfish were captured); *lower* – shallow (0.1-0.2 m deep) and tumbling flows (~0.3-0.5 m/s) in a cobble-bedded riffle with some slack water pockets along the banks covered with a moderate growth of riparian grasses.

The Canterbury mudfish (Fig. 2-5) caught in the Waianiwaniwa River ranged in body length from 60-136 mm, with the larger fish found mainly in runs and pools, with some of them from riffles in which some slackwater was present along the banks or amongst the cobbles. Upland bullies of all sizes were captured with some darkly coloured males in spawning condition being around 100 mm in length. A total of four Canterbury galaxias (70-125 mm long) was found in the headwaters (Site 7) in a slow-flowing run ~0.4 m wide and 0.3 m deep, with a silt-covered bottom and an abundance of riparian grasses overhanging the banks; also, a single specimen was found further downstream in the headwaters (Site 6) – these were the only specimens collected of this species in the Waianiwaniwa catchment.

Figure 2-5: An adult Canterbury mudfish in good condition sampled in the Waianiwaniwa River 16 October 2002.

2.7.3 Implications of fish findings

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

The presence of a major population of the Canterbury mudfish in the Waianiwaniwa catchment has significant ramifications for the Central Plains irrigation scheme. While the proposed reservoir would eliminate riverine habitat in the lower reaches of the valley, there would still be considerable riverine habitat upstream of the reservoir. Screening migrating eels from entering the intakes of the Rakaia and Waimakariri Rivers would be impractical because of the small mesh (~2 mm) required for the small elvers. Excluding eels from entering the habitat upstream of the reservoir would be very difficult, as elvers are known to get out of the water and crawl up through the vegetation and amongst the substrates along the banks during rains. A desktop study would be needed to consider various possibilities in greater detail of excluding eels from the upper catchment and preserving the area for the benefit of the mudfish population, or finding alternative mitigation measures.

3.1 Introduction

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

3.2 Land Ownership and Use

Figure 3-1 shows the property boundaries taken from the Selwyn District Council GIS (geographic information system) cadastral database. Table 3-1 lists the property owners associated with each of the identified properties.

3.3 Flooded Residences

Within the Waianiwaniwa valley there are 14 residential buildings (12 inundated) that will be significantly affected by the reservoir. The impact on these residents will be large as there is no mitigation measures available other than relocation outside the catchment area. The location of the potentially affected residences is shown on Figure 3-2.

3.4 Loss of Productive Land

With the flooding of the valley, there will be the loss of approximately 1300 ha of agricultural land. This would be offset by the increased productivity from the land to be irrigated, such that while there is a loss of productive land, on balance the productive capacity of the Central Plains would be considerably enhanced.

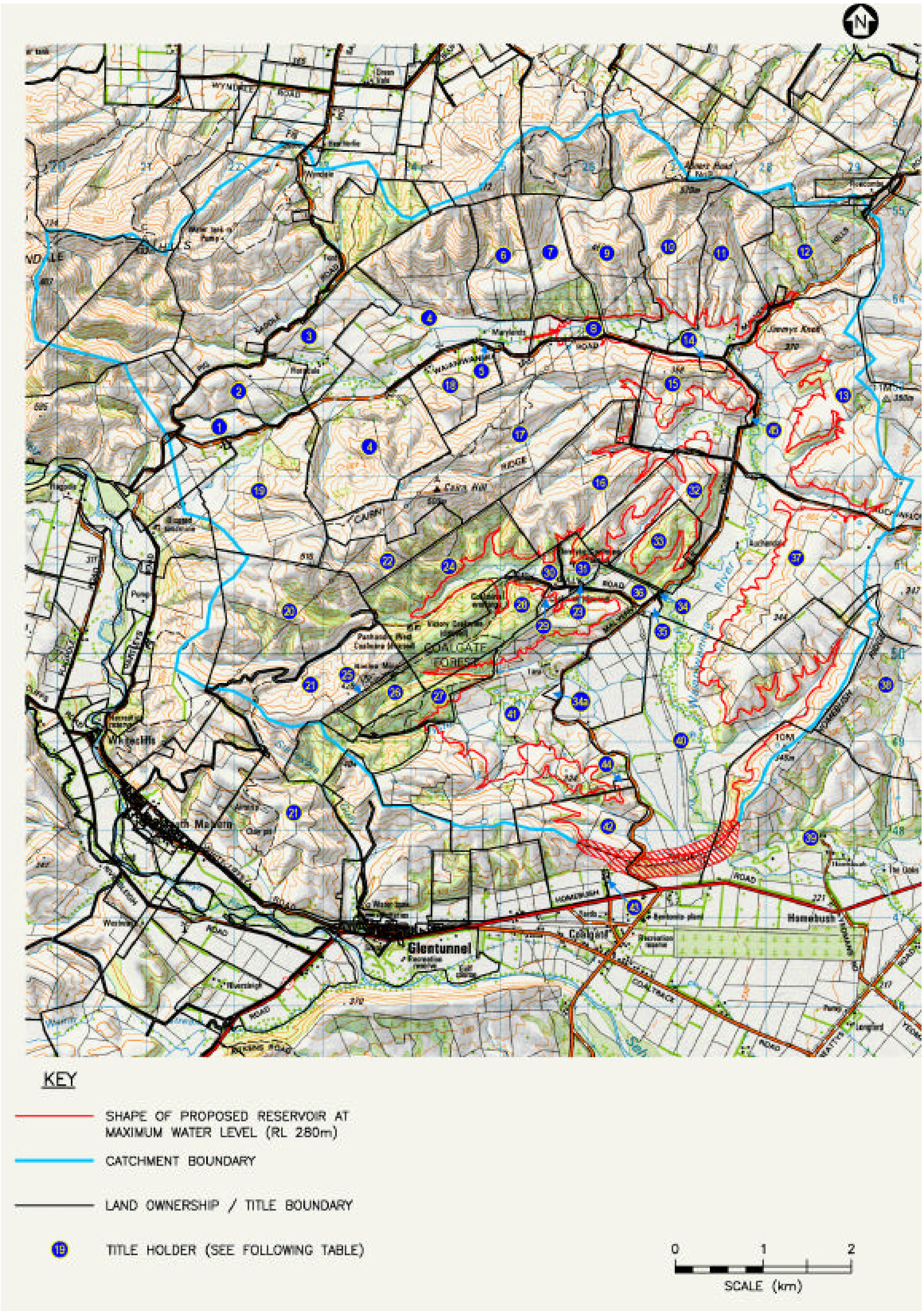


Figure 3-1: Land Ownership within the Waianiwaniwa Valley

Table 3-1: Land Ownership of Waianiwaniwa Valley Properties

Map Code	Title Holder
1	REED, Ian.
2	CULLEN, Michael and Warren.
3	BUTCHARD, John; MACKENZIE, Val; WRIGHT, Nesslea.
4	WILSON, Peter and Tony.
5	CANT, Alister and Dianne.
6	BROUGHTON, Barbara and Gordon.
7	DUNCAN FORESTRY Ltd.
8	PHILLIPS, Alfred and Ina.
9	GILMOUR, Sandra.
10	LUCAS, Annette and Martin.
11	ROBERTSON, James and Maureen.
12	ROECOMBE FARM Ltd.
13	DEANS, William; SAUNDERS, Geoffrey; SHACKLETON, David.
14	BURIT, Richard; LOGAN, Andrew; SLATTERY, James.
15	ROBERTSON, Craig, James and Maureen; HARRIS, Roger.
16	HIDDEN VALLEY TIMBER Ltd.
17	DAVEY, Helen; THOMPSON, Brian.
18	INCH, Geoffrey and Phyllis.
19	WILSON, Bernard, Janice and Tony.
20	WAKAEPA FARM Ltd.
21	WAKAEPA FARM Ltd; SELWYN PLANTATION BOARD; McSKIMMING INDUSTRIES Ltd.
22	SELWYN PLANTATION BOARD.
22	SELWYN PLANTATION BOARD.
23	THE PUBLIC TRUSTEE; NIMMO COLLIERIES.
24	SELWYN PLANTATION BOARD; DEANS, Charles.
25	McSKIMMING INDUSTRIES Ltd.
26	SELWYN PLANTATION BOARD.
27	SELWYN PLANTATION BOARD.
28	SELWYN PLANTATION BOARD; NIMMO COLLIERIES Ltd.
29	BENNETT, William; NIMMO COLLIERIES Ltd.
30	NORTH, Nelson and Suzanne; NIMMO COLLIERIES Ltd.
32	SELWYN PASTURES Ltd.
33	SELWYN PLANTATION BOARD.
34	SELWYN DISTRICT COUNCIL (esplanade reserve).
34a	SELWYN DISTRICT COUNCIL (gravel extraction gazette).
35	SELWYN DISTRICT COUNCIL.
36	NORTH, Nelson and Suzanne.
36	THWAITES, Adrian and John.
37	LOE, Richard and Felicity.
38	DEANS, George and Gillian.
39	DEANS, James.
40	KIRKSTYLE FARM Ltd.
41	TARA FARM Ltd.
42	CHAPLIN, Carole.
43	SCOTT, David; STANLEY, Stewart.
44	WATTS, Alan and Jennifer.
45	COLVILLE, Lewis; COUPER, Christian and Mitchell.

Figure 3-2: Residences, Coal Mines and Heritage Sites in the Waianiwaniwa Valley

3.5 Coal Mines

Coal mines were operated in the Malvern Hills throughout the late 1800's and early 1900's. The majority of mines were located in Bush Gully and in Surveyors Gully, though other mines were located where coal seams were found to outcrop. Figure 3-2 shows the locations of coal mines throughout the Waianiwaniwa Valley. The underground mining was extensive in places, particularly in the case of the Klondyke mine, which followed seams up to "1500 feet down dip" (approximately 300 m below ground level), and up to about 600 m along strike (personal communication, Ken Shearer, Canterbury Coal Ltd). Klondyke Mine was unusually extensive, and many mines were discontinued because they were overwhelmed by groundwater or because the coal seams were faulted out. In some circumstances the coal seam was found again, and mining continued. The faults responsible for displacing the coal do not have large throws as the coal seams generally follow a line of strike, that is not radically offset.

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

There is not considered to be a significant likelihood of underground coal mines forming a continuous conduit out of the reservoir. The Homebush Mine is located in Surveyors Gully, west of the proposed reservoir. The entrance to this mine is at least 2 km from the nearest point in the reservoir and it is considered very unlikely that the Homebush mine reached to the proposed reservoir footprint.

3.6 Designations, Heritage and Cultural Sites

Designations are provisions within the District Plan to give effect to a specific purpose, and are provided for under the Resource Management Act 1991. Designations can be considered as an alternative to a resource consent. The designation usually relates to public works or utilities such as roads, airports, sewage treatment plants, quarries etc. Activities on the sites that have designations on them become permitted activities, provided the purpose of the activity meets with the scheduled activities for that designated site. Within the inundated area of the Waianiwaniwa Valley there is only one designated site, and that is for a quarry on Malvern Hills Road – reference D339. The location of this site is shown on Figure 3-2.

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

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

There is one heritage site potentially affected by the Waianiwaniwa reservoir, and that is a bridge on the Homebush Station - reference H133. In addition to the heritage site mentioned, there are approximately 6 trees with heritage status. These heritage sites are shown on Figure 3-2.

A cultural site is scheduled within the District Plan as a site of Waahi Taonga. There is one scheduled cultural site within the inundated area of the valley, an oven – reference C20. This is listed as near Auchenflower Rd, however the planning map location of this site is not "near Auchenflower Rd". This site is shown on Figure 3-2.

The designations, heritage and cultural sites are listed in Table 3-2.

Table 3-2: Schedule of Heritage Sites affected by the Reservoir

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

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

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

These sites do not in themselves become fatal flaws to the establishment of a reservoir in the valley. Under the District Plan, activities which impact upon such sites are not likely to comply with the permitted activity status. In general, within the rural section of the plan, activities such as earthworks, removing heritage trees, buildings, roading and utilities that impact adversely upon such sites, would become limited discretionary activities, provided no other rules are contravened within the Plan which would require a different status. Therefore in so far as these sites are concerned, the construction of the reservoir would have little significance in relation to the status of the activity under the plan. Other rules will make the activity either discretionary or non-complying. A full assessment of the planning documents and provision of a legal opinion in relation to heritage orders and sites is not within the scope of this report.

There is a need to further identify these sites and their exact location with respect to the inundated area, whether or not they are subject to heritage orders, and if so, which is the relevant heritage protection authority.

3.7 Roading

Access to the Selwyn Plantation Board forests is at present from Bush Gully Road within the valley. Similarly access to the proposed coal mine of Kenroll Services is also from this road. An alternate route would be needed to each of these areas and costs have been included in the estimates for this. There is an area of plantation approximately opposite Auchenflower Rd that also belongs to the Selwyn Plantation Board. Access to this area from the west for logging purposes is included within the cost estimates, however alternatives such as acquisition of the asset may be more favourable. Access through the valley will not be possible once flooded, but access into the reservoir will be available from Auchenflower Rd, Malvern Hills Rd, and Waianiwaniwa Rd from the west.

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

3.8 Recreation

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

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

3.9 Risks to Residents

There is concern within the community in relation to dam collapse, triggered by an event such as upland flooding or an earthquake. The catchment of the Waianiwaniwa Valley is small (5,600ha) compared to the surface area of the reservoir (1300ha) and the outlet capacity of the dam. The maximum probable rainfall event is able to be contained within the reservoir with a controlled outlet of up to 60 m^3/s (the capacity of the outlet for peak irrigation demand). The outlet structure would therefore also be the overflow structure for these events. Therefore the risk of dam failure from flooding and overtopping will be negligible.

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

3.10 Construction Effects

There will be impacts from construction activities at the dam site on the environment, organisations and people. Experience with other dam construction projects shows that they can require considerable workforces, possibly including a construction camp or other temporary accommodation. Potential adverse effects can include dust and noise on the everyday activities of the residents of Coalgate, disruption of farm management and operation, increased heavy traffic volumes on local roads and associated safety concerns. Stress from construction activities can be alleviated by a phased approach, and keeping people informed.

4.1 Introduction

This section presents the capital and operating costs for storage in the Waianiwaniwa Valley, as well as indicative costs for alternatives such as gravity inflow to the valley and hydro electric power (HEP).

4.2 Previous Cost Estimation

A preliminary assessment of storage in the Waianiwaniwa reservoir was reported in URS technical memorandum dated May 2002. Of the two sites considered at this early stage, the north site was discounted due to unfavourable foundation conditions and hence excessive costs. The south site was recommended as the favoured alternative. On this basis, costs estimates were prepared comparing the Waianiwaniwa and Wairiri reservoir options. These are presented in Table 4-1.

Table 4-1: Previous Cost comparison between the Waianiwaniwa Storage and Wairiri Storage Options

Item	Waianiwaniwa North Site Storage ($M)	Wairiri Storage ($M)
Total Costs	145.2	124

This table showed that the total cost of the Waianiwaniwa storage scheme exceeds the Wairiri scheme by about $21.2M. However when considering the reduced pumping costs for this option (pumping head of 56m compared to 85m) there was a negligible cost difference between the two options on a net present value (NPV) basis. This provided an economic justification to further investigate the feasibility of constructing a reservoir in the Waianiwaniwa Valley.

4.3 Waianiwaniwa Reservoir Costs

Now that the preliminary geotechnical investigations and topographical survey have been completed, it is possible to provide more accurate cost estimates for a dam in the Waianiwaniwa Valley. The updated cost estimates for the Waianiwaniwa reservoir are presented below.

4.3.1 Dam costs

Reservoir and dam crest levels have been reduced to give a new storage-volume curve calculated from the new digital terrain model. This has lead to a significant reduction in storage costs. Earthworks volumes for the embankment dam have been revised with improved accuracy from the 0.5m contours in the vicinity of the dam site. The contingency on these volumes has correspondingly been reduced from 30% to 20%.

4.3.2 Pump station costs

A 17 cumec pump station in the Rakaia River bed for the Wairiri option has been replaced with a 17 cumec pump station below the Waianiwaniwa Dam. The cost of the pump station below the dam is significantly less than the pump station in the Rakaia River due to a lower pumping head and by using the dam outlet structure as pipes into the reservoir instead of large steel riser pipes up the terrace scarp into the inlet canal. The Waianiwaniwa pump station would cost approximately $16.5M compared to $24.5M for the Wairiri pump station.

The estimated annual pumping costs were developed using the volume of water pumped to meet the demand for 84,000 ha from 1967-2001 (33 years). The analysis used the base scenario with 290MCM of storage and a peak pumping capacity of 17.2 m^3/s. The pumping costs were calculated on a monthly basis.

The pumping costs assumed a constant pumping rate for the month. The average monthly pumping rate was developed using the total volume pumped each month. The average monthly price for electricity accounted for variations in price for evening and weekend operation. The average monthly prices for electricity are shown in Table 4-2.

Table 4-2: Average monthly electric prices (cents/kW-hour)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4.63	4.86	5.35	6.03	6.91	7.58	7.20	6.61	5.75	5.46	4.93	4.65

The pumping costs were based on the following assumptions:

- Required Head = 55 m
- Pump System Efficiency = 85%

The annual pumping costs ranged between $320,000 and $3.4 M / year. The average for the 33 years was $1.87 M. Approximately 70% of the annual pumping costs are incurred between March and August.

The analysis does not include restrictions in demand. Restrictions would require less water to be pumped in some years. However, it is expected that the reduction in pumping would not reduce the annual pumping costs significantly.

These pumping costs are approximately half those for the Wairiri Option.

4.3.3 Gravity Flow from Waimakariri River

If water was taken just from the Waimakariri River to fill the reservoir, the reliability of the storage would decrease slightly from the scenario of having water available from both the Rakaia and the Waimakariri Rivers. Therefore to provide the same level of service to the CPWE scheme, either additional storage would be required or the filling rate would need to be increased.

To maintain the filling rate of 17 cumecs, the storage would need to increase to 360 MCM to maintain reliability, or alternately to maintain the storage provided of 290 MCM, then the filling rate would need to increase to 21 cumecs. For the gravity fill option, the costs of increasing the Kowai race from 17 cumecs to 21 cumecs would not be significant, therefore no increase in storage will be required.

Two options have been considered for gravity filling the Waianiwaniwa reservoir from the Waimakariri River above the Kowai at 21 cumecs along the RL 300m contour. These involve climbing the Waimakariri terraces with either an earth canal or steel pipe. Each option would then include a 20m-deep cut across the plains behind Waimakariri gorge, an earth canal across the plains through Sheffield, and a tunnel through the Malvern Hills into the Waianiwaniwa reservoir. Figure 4-1 Shows the location of the intake above the Kowai and the canal and tunnel route into the Waianiwaniwa Valley.

A preliminary cost estimate shows the capital costs for gravity filling the reservoir to be approximately $41M more than pumping to storage. This does not include an allowance for a HEP station to take advantage of generation potential. A power station would cost an additional $16M (similar cost to the pumpstation to fill the reservoir).

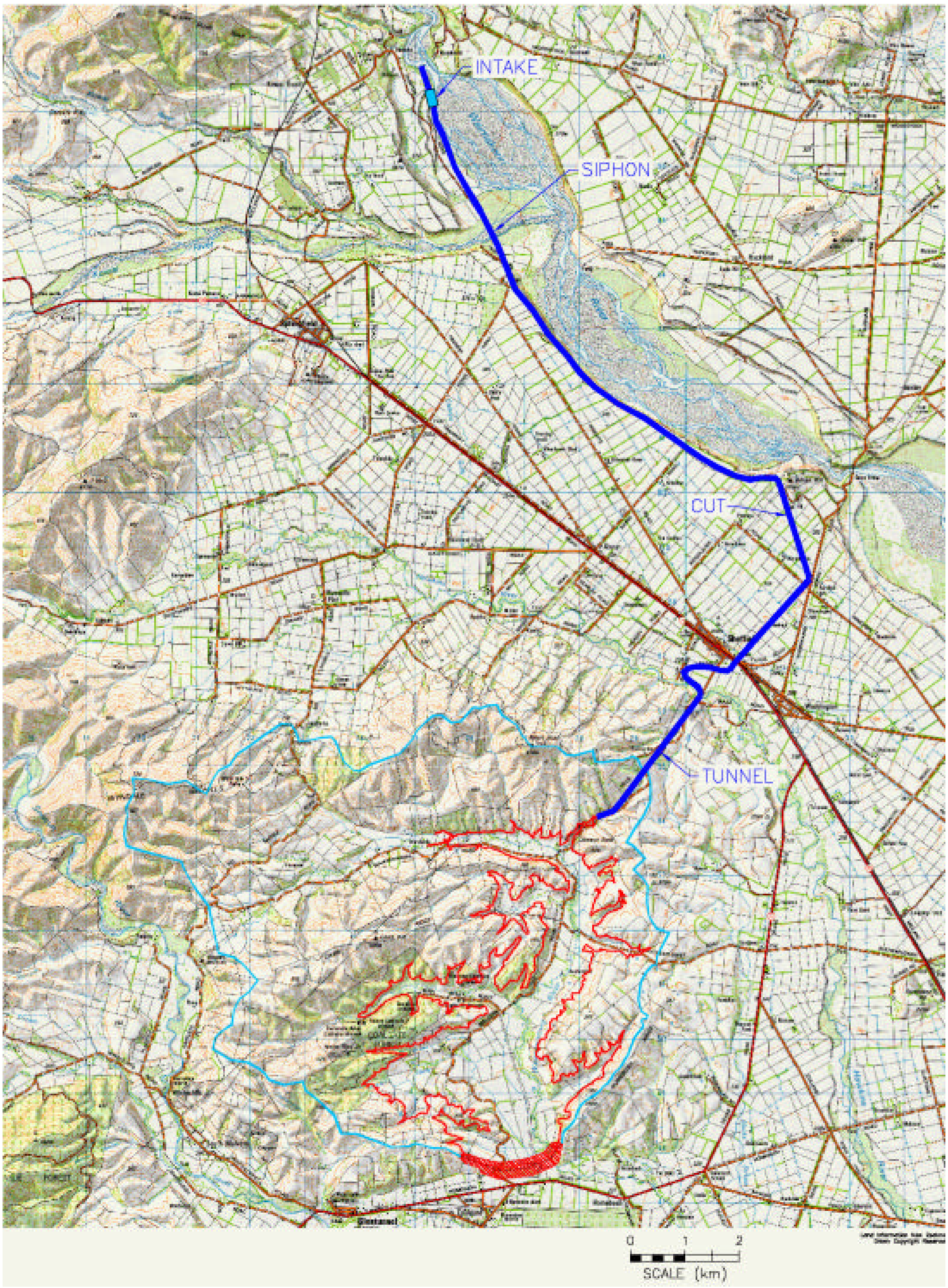


Figure 4-1: Gravity intake to Waianiwaniwa Reservoir

4.3.4 Pumped distribution to Windwhistle

A 4 cumec pump station, steel riser pipes and canal have been costed to supply the Windwhistle area, which was previously supplied from the Rakaia canal feeding the Wairiri reservoir.

4.3.5 Cost summary

Table 4-3 presents the cost comparison for the Waianiwaniwa and Wairiri options. The pumped Waianiwaniwa storage option, when considering all the components necessary to make a valid comparison, is the same capital cost as that for the Wairiri option. However the pumping costs for the Waianiwaniwa option will be approximately 50% of those for the Wairiri option.

All costs are based on irrigating 84,000ha, and provision of 290 MCM of storage. In addition, approximately $11.4M has been added to the Waianiwaniwa option to enable provision of irrigation to the Windwhistle area, that would have been served from the feed canal into the Wairiri Valley with that option. It does remain an alternative to not include this area, much in the same way as the Springfield/Sheffield areas could be included or excluded.

Table 4-3: Cost comparison between the Waianiwaniwa Storage and Wairiri Storage Options

Item	Waianiwaniwa Pumped Storage ($M)	Waianiwaniwa Gravity Storage ($M)	Wairiri Storage ($M)
Pump station in Rakaia River	0	0	24.5
Pump station below Dam	16.5	0	0
Rakaia Windwhistle Canal	0	0	4.9
Outlet Canal	0.2	0.2	10.7
Dam Embankments	82.5	82.5	64
Land Purchase	Not included	Not included	Not included
Roading and other costs	1.3	1.3	9.6
Spillway	0.01	0.01	0.01
Outlet Structure	4.5	4.5	4.5
Sub Total	105.0	88.5	118.2
Windwhistle Canal	2.2	2.2	0
Rakaia Pump Station	9.2	9.2	0
Waimakariri Gravity Canal	0	57.8	0
Total Capital Cost	**116.4**	**157.7**	**118.2**

4.4 Whole of Life Costs

To enable the costs for Wairiri and Waianiwaniwa to be compared, the capital and operating costs need to be combined. This is done on the basis of assuming a discount rate of 8% over a period of 20 years to reduce the capital cost to an equivalent annual cost allowing all annual costs to be added. These data are presented in Table 4-4.

Table 4-4: Annual cost comparison of reservoir options

Item	Waianiwaniwa Pumped Storage ($M)	Waianiwaniwa Gravity Storage ($M)	Wairiri Pumped Storage ($M)
Capital Cost	116.4	157.7	118.2
Annual pumping cost	1.87	0	3.60
Annual O&M Costs	1.04	.40	1.40
Annual Cost at (8%, 20yrs)	14.8	16.4	17.0

Note: This table only compares costs for comparable portions of each option.

Table 4-4 shows that the Waianiwaniwa pumped option is the most economic, with a saving of approximately $2.2M/yr over the Wairiri pumped option. This translates to approximately $26/ha/yr for the 84,000 ha scheme.

4.5 Hydro Electric Power Generation

4.5.1 Pumped Storage Scheme

For the pumped storage option, water would be pumped from the headrace into the reservoir. During shortfalls in the availability of water from run of river sources, water will be discharged from the reservoir. This water has the potential to generate hydro electric power (HEP). The proposed pump station would be modified to provide for power generation, by utilising the pump motor sets as generator alternator sets when running in reverse. This generation would only occur during times of irrigation.

Pumped storage systems that provide an opportunity to generate power during the day and pump water to refill the reservoir at night, at current spot power prices during the winter months does not appear economical, although such an operation could be undertaken if spot power prices significantly changed in the future.

The following assumptions were used to estimate power returns:

- Maximum Head = 48 m
- System Efficiency = 85%

- Value of Electricity = 4.5 cents/kW-hour

The peak design discharge from the reservoir is 60 m^3/s. However, only a portion of this can pass through the power plant, up to 17 m^3/s. This results in a significant portion of the water not being used for power generation. The demand on water from storage for an average year is show in Figure 4-2. This figure also shows the portion of water not used to generate power.

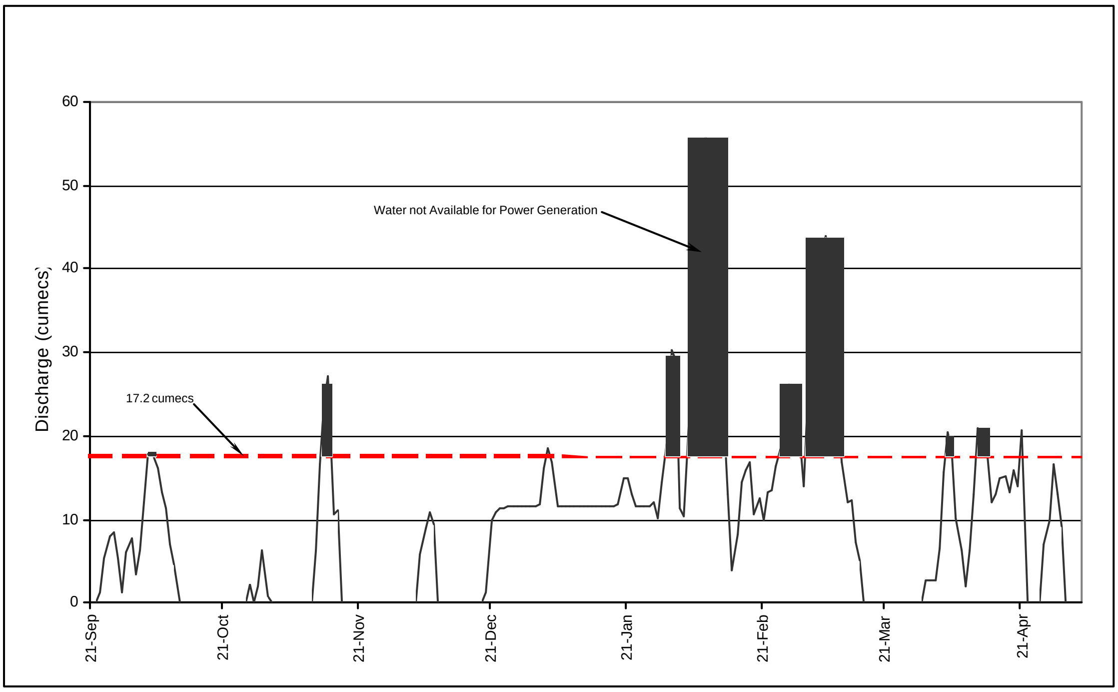


Figure 4-2: Water supplied from reservoir for an average year

The annual value of the HEP generated ranged between \$0.16M -\$0.61M with an average of \$0.39M over the period 1967 - 2001. If power prices increase above the 4.5 c/kWhr assumed, then so too will the return from HEP. For example, if the power price was 6 c/kWhr the average return would increase to \$0.52M/yr and at 8 c/kWhr the return would be \$0.69M/yr.

The increase in capital expenditure between a pump only and a pump/generator, is likely to be in the order of \$3M – \$5M, making this an option that is either slightly positive or neutral depending upon the value assigned to the generated power.

4.5.2 Gravity Filling of Reservoir

A gravity filling option provides an opportunity to run water through the reservoir for power generation. There are three options for this. The first is that all water required by the CPWE scheme up to the capacity of the inlet canal of 21 cumecs, would pass through the HEP station. The second option is that whenever the operating rules on the Waimakariri River allow abstraction, even when it is not required for the CPWE scheme, it would be passed through the HEP station up to a canal capacity of 21 cumecs. The third option is increasing the canal capacity to 40 cumecs and using all water available under the

Waimakariri operating rules, for HEP. The excess water used for HEP generation and would spill back into the Waimakariri River. The second and third options therefore provide longer periods of time that river water is used for HEP generation, compared to that where the reservoir supplies the irrigation scheme alone.

The annual value of the HEP generated over the period 1967 – 2001 (at 4 c/kWhr) for the first option ranged between $0.59M -$1.26M with an average of $0.92M, and for the second option between $0.93M - $3.19M with an average of $2.38M. This demonstrates that taking water from the Waimakariri River whenever it is available approximately doubles the HEP generation potential through the storage. Option 2 will always be more favourable due to the greater utilisation of the resource. For option 2, the average annual return would be $3.17M/yr at 6 c/kWhr and $4.23M/yr at 8 c/kWhr.

The additional capital cost for the gravity feed, plus the power station is approximately $57M, therefore the first two options do not appear to be economic. The revenue from HEP does not cover the cost of the generation station alone, therefore does not add value to the option for gravity filling of the reservoir.

The third option would generate power with an annual value of between $1.30M - $5.57M with an average of $3.99M. The average annual return would be $5.32M/yr at 6 c/kWhr and $7.09M/yr at 8 c/kWhr. Increasing the canal capacity to 40 cumecs for the third option would increase the capital cost by another $27.1M to an extra $84M. This also would be uneconomic.

4.6 Additional Storage for Other Schemes

An opportunity exists for the Waianiwaniwa reservoir to provide storage for other irrigation schemes to the north of the Waimakariri River and to the south of the Rakaia River. Water could be stored and released into the rivers close to the intakes for these other schemes during times of full restriction, or alternately CPWE could use stored water, while providing others with access to CPWE run of river water instead. This would improve the reliability of the water supply for other schemes, which at present are reliant upon run of river supply. The economic advantages of increased reliability has not been estimated for any of these schemes as part of this evaluation.

For the purpose of this exercise, it has been assumed that an area of 20,000 ha with current run of river irrigation would want to join the CPWE scheme for storage of water. A simplified water balance model has been run to estimate the storage requirement assuming the same land use mix for CPWE, by simply increasing the demand area from 84,000ha to 104,000 ha. This would provide for full reliability for the extra 20,000ha. Full modelling of the requirement for storage needs to include the water currently allocated to the new schemes within the water availability for the combined scheme, so that the demand and supply for both schemes can be considered together. The maximum useful storage volume of the Waianiwaniwa reservoir is 450 MCM, at which point water will flow across saddles into other catchments. Figure 4-3 depicts the stage/storage relationship for the proposed reservoir. At this point in time, the value in adding saddle dams has not been evaluated, but this could increase the storage that could be provided to other schemes beyond that assumed in this simple assessment. On this basis, the pumping rate to fill the reservoir would have to be increased from 17 cumecs (CPWE alone) to 21 cumecs to provide a reliability of only 12 consecutive days with no water in the period of record for both CPWE and an additional 20,000ha.

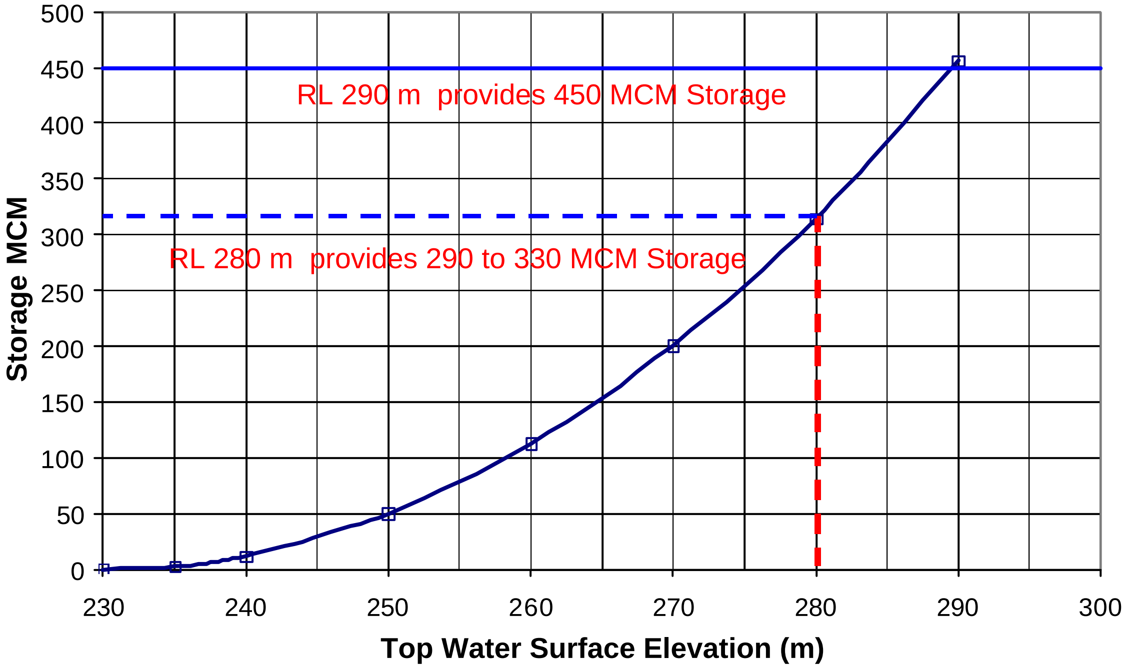


Figure 4-3: Stage/Storage relationship for Waianiwaniwa Reservoir

The cost to other schemes for the provision of this storage has been estimated on a proportionate basis, with 290/450 = 64.4% of the costs apportioned to CPWE and 35.6% of the costs apportioned to the other schemes.

It is interesting to note in Table 4-3, that the saving to CPWE by including other schemes is only $7M, even when the cost of the storage reservoir is shared approximately 2/3:1/3 between CPWE:Other. The reason that this occurs is that the cost of providing storage is increasing proportionately with storage volume, indicating a lack of economy of scale and decreasing marginal benefit.

Table 4-3: Cost of providing storage to other irrigation schemes

Item	CPWE only ($M)	CPWE + Other ($M)	CPWE Cost Share ($M)	Other Cost Share ($M)
Pump station below Dam	16.5	19.8	12.8	7.0
Outlet Canal	0.2	0.2	.1	.1
Dam Embankments	82.5	126	81.1	44.9
Land Purchase	Not included	Not included	Not included	Not included
Roading and other costs	1.3	1.3	.84	.46
Spillway	0.01	0.01	.01	0
Outlet Structure	4.5	4.5	2.9	1.6
Total Storage Cost	**105.0**	**151.8**	**97.8**	**54.0**

This assessment has assumed that the other schemes would require 160 MCM of storage. It is possible that these other schemes would accept a lower level of reliability and therefore purchase a smaller storage volume from CPWE. The difficulty with an assessment such as outlined above is that the relationship between storage and reliability is dependant upon many factors, including the time of year that the restrictions occur, the irrigation demand over that period, the pumping rate to fill the reservoir and the availability of water in the source rivers to fill the reservoir. Over the period modelled (1967 – 2000) the period that determined the storage requirement of 450 MCM for the total area of 104,000 ha was 4 – 15th February 1974. If the storage was reduced to 360 MCM the reliability over this same period would not have changed, however the period 4 – 27th March 1971 (24 days) would have had no water unless rationing of the stored water was brought in. A 25% rationing of supply starting when the reservoir was 50% full would reduce the number of days with no water to 12 days – the target reliability. A 29% rationing of supply starting when the reservoir was 50% full would reduce the number of days with no water to zero, as would starting the rationing at 64% full.

Thus it can be seen that reducing the storage has resulted in a switching of critical periods. Ultimately the choice of storage required would be a “purchaser’s” choice and for the example provided, there may be little benefit of providing the additional 90 MCM of storage (450-360=90MCM).

The unit cost of $0.34/m^3 would be a realistic rate to estimate the costs of storage to any new scheme for these lesser options, up to a combined storage volume of 450 MCM within the valley.

5.1 Introduction

The preceding sections demonstrate that construction of a reservoir within the Waianiwaniwa Valley is feasible. This therefore provides two options to CPWE for the storage component of the scheme. Information in this section has been compiled to identify the differences between each site. This is tabulated in Table 5-1. In this table, an indication of the site with the more favourable attributes in relation to the feature discussed has been included. This table must not be used as a simple score card, with the site with the greatest number of favourable features, assumed to be the better site. No attempt has been made to rank the relative importance of each feature, therefore the selection of a preferred site lies outside the scope of this report.

Table 5-1: Comparative Features of Wairiri Valley and Waianiwaniwa Valley

Feature	Wairiri Valley Site	Waianiwaniwa Valley Site	Site Favoured
Ability to meet storage requirements of CPWE scheme	290 MCM	290 MCM	Neutral
Ability to provided storage for other schemes	No easily assessable additional storage	Up to 450 MCM storage attainable	Waianiwaniwa
Pumping head to fill reservoir	105m	55m	Waianiwaniwa
Capital Cost	$118.2M	$116.4M	Waianiwaniwa
Operating Costs	$1.41M/yr	$1.04M/yr	Waianiwaniwa
Annual Cost in $(2002)	$17.0M/yr	$14.6M/yr	Waianiwaniwa
Hydro Electricity Potential	Low, uneconomic.	Medium, most likely uneconomic.	Waianiwaniwa
Flooded Residences	13 completely flooded with NZDF buildings on ridge to be relocated	12 completely flooded with a further 2 unacceptably close.	Neutral
Roading	State Highway 77 must be relocated	Secondary roads only affected	Waianiwaniwa
Other Structures	High Tension Power Lines to be raised	N/A	Waianiwaniwa
Other Issues	Potential increase in public activity around NZDF facility, within blast protection zone.	N/A	Waianiwaniwa
Other activities within valley	Farming	Farming, coal mining and forestry	Wairiri

Feature	Wairiri Valley Site	Waianiwaniwa Valley Site	Site Favoured
Heritage and other sites	One heritage site – Tara Ghur homestead. One designation – NZDF. Two QE II covenants	One heritage site, six heritage trees, one cultural site, one designation.	Waianiwaniwa
Loss of Productive land	1000ha	1300 ha	Wairiri
Immediately downstream residences.	Glentunnel	Coalgate	Waianiwaniwa
Land stability	Minor slumping can be expected	Minor slumping can be expected	Neutral
Availability of construction material	Available within valley	Available within valley	Neutral
Seismic Risk	No immediate faults through dam footprint	No immediate faults through dam footprint	Neutral
Canterbury Mudfish	Limited populations could be relocated in constructed reserves	Significant populations, mitigation measures to be further examined	Wairiri
Water Quality	Mean depth >25m	Mean depth ~ 24m	Wairiri
Drying out and dust potential	Inlet at upper end provides opportunity to keep valley floor wet.	Inlet at dam makes it more difficult to keep upper valley reaches wet.	Wairiri
Recreation	Single large open expanse of water, access at dam and head of valley only	Many inlets and embayments, access at dam plus three other points.	Waianiwaniwa

Davies-Colley, R.J. 1989. Optical properties of New Zealand Lakes.

Glova, G.J.; Hulley, G. 1998. Tutaepatu Lagoon devastated by drought. NIWA Water & Atmosphere 6(1): 5.

Glova, G.; Duncan, M.; Henderson, R.; Kelly, D.; Walsh, J. 2001. Central Plains water enhancement: an assessment of potential environmental effects. NIWA Client Report: CHC01/85.

Godshalk, G.L.; Barko,J.W. 1985. Vegetative succession and decomposition in reservoirs. pp. 59-78. *In:* Microbial Processes in Reservoirs. Gunnison, D. (Ed.). Dr. W. Junk Publishers. Dordrecht, Netherlands..

Green, J.D.; Viner, A.B.; Lowe, D.J. 1987. The effects of climate on lake mixing patterns and temperatures. pp 65-96. *In:* Inland Waters of New Zealand. Viner, A.B. (Ed.). DSIL Bulletin 241. Department of Science and Industrial Research, Wellington, New Zealand.

Gunnison, D.; Engler, R.M. ; Patrick, W.H. Jr. 1985. Chemistry and microbiology of newly flooded soils: Relationship to reservoir-water quality. pp. 39-58. *In* Microbial Processes in Reservoirs. D. Gunnison (ed.). Dr. W. Junk Publishers. Dordrecht, Netherlands.

Henriques, P.R. (Ed.). 1987. Aquatic Biology and Hydroelectric Power Development in New Zealand. Oxford University Press, Aukland. 277 p.

Hill, C.F. 1975. Impounded lakes of the Waikato River. pp 140-150. *In:* New Zealand Lakes. Jolly, V.H.; Brown, J.M. (Eds.). Aukland University Press, Aukland.

Hoare, R.A;, Pridmore, R.D.; Vant, W.N. 1987. Prediction of phytoplankton abundance and its effect on water quality. pp 180-191. *In:* Aquatic Biology and Hydroelectric Power Development in New Zealand. Henriqes, P.R. (Ed.). Oxford University Press, Auckland.

Jellyman, D.J. 1989. Diet of two species of freshwater eel (*Anguilla* spp.) in Lake Pounui, New Zealand. New Zealand Journal of Marine and Freshwater Research 23: 1-10.

Jolly, V.H.;. Irwin, J. 1975. Physical characteristics: Thermal conditions. pp 190-105.. *In:* New Zealand Lakes. Jolly, V.H.; Brown, J.M. (Eds.). Aukland University Press, Aukland.

Kirk, R.M. 1989. Dust storms (loess genesis) at Lake Tekapo, October 1989. A report to South Island Hydro Group, Production Division, Electricorp, Dunedin.

McDowall, R.M. 1990. New Zealand freshwater fishes: a natural history and guide. Auckland, Heinemann-Reed.

Meredith, A.S. 1999. Water Quality of Lake Opuha: Limnological issues in a newly formed lake. Environment Canterbury Unpublished Report. June 1999.

Morris G.L.; Fan J. 1997, Reservoir Sedimentation Handbook: Design and Management of Dams, Reservoirs and Watersheds for Sustainable Use.

Smith, J.M. 1991. Wind-wave generation on restricted fetches. Miscellaneous Paper CERC-91-2, Coastal Engineering Research Center, Vicksburg.

URS 2002. Central Plains Water Enhancement Feasibility Study, Report R001A-03 for Central Plains Water Enhancement Committee, 31 January 2002.

URS 2002. Geotechnical Investigations for the Proposed Waianiwaniwa Water Storage Dam, Report R1099 for Central Plains Water Enhancement Committee, 11 October 2002.

Viner, A.B.; White, E. 1987. Lake Plankton Processes: Phytoplankton Growth. pp 191-224. *In:* Inland Waters of New Zealand. Viner, A.B. (Ed.). DSIL Bulletin 241. Department of Science and Industrial Research, Wellington, New Zealand.