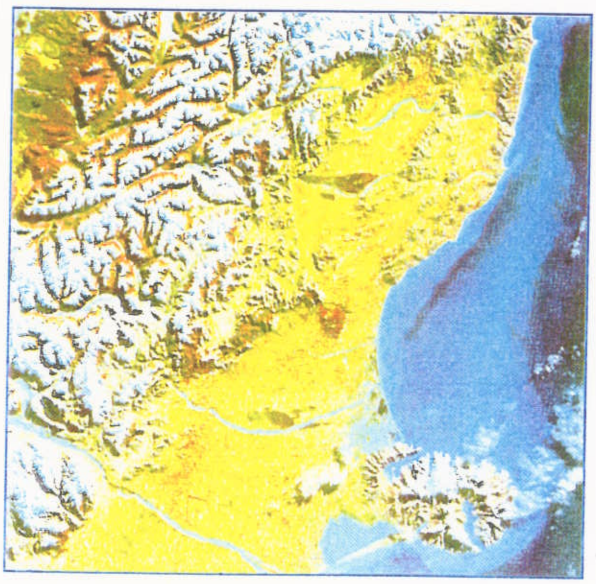
FINAL REPORT

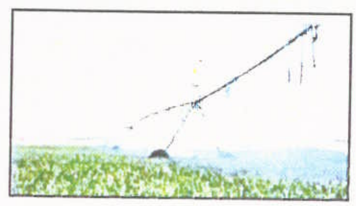
EMBARGOED UNTIL 7 FEBRUARY 2002

W Leathwaite

CENTRAL PLAINS WATER ENHANCEMENT

FEASIBILITY STUDY





Prepared for
Central Plains Water Enhancement Committee
Selwyn District Council and Christchurch City Council
c/- Private Bag 1
Leeston

31 January 2002

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FEASIBILITY STUDY

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Acknowledgements

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Introduction

In March 2000 the Central Plains Water Enhancement (CPWE) Steering Committee was established by the Selwyn District Council and the Christchurch City Council. The Councils' objective in setting up the Steering Committee is ***"to execute feasibility studies into the viability and practicality of water enhancement schemes in the Central Plains area, being that area approximately described as lying between the Rakaia and Waimakariri Rivers, the Main Divide to the west and the Coast to the east".***

The purpose of the feasibility study is to provide the Selwyn District Council and the Christchurch City Council information on whether such a scheme is feasible before proceeding with a commitment from potential financial participants, application/s for resource consents, detailed engineering, and securing of finance.

To achieve this objective, the Steering Committee has commissioned URS New Zealand Ltd (URS) investigate the need for, and feasibility of, a community based water enhancement scheme, situated on the 200,000 ha of flat land lying between the Waimakariri and Rakaia Rivers. For funding purposes, it is clear that significant water enhancement will depend on having a viable irrigation scheme.

This report is the Stage 2 Feasibility Study, and makes recommendations as to the preferred option, the technical, economic and environmental feasibility for consideration, prior to advancement into the resource consenting stage.

Base Scheme Concept

The base scheme has been referred to previously as the Wairiri Pumped Option. This refers to the use of the Wairiri Valley as the storage reservoir for water that is to be used during times water cannot be abstracted from the Waimakariri and Rakaia Rivers due to low flow restrictions. It also refers to the fact that pumping water from the headrace canal into the valley must fill the reservoir. Figure 2-5 outlines the main components of the scheme which include:

- A dam across the eastern mouth of the Wairiri Valley to provide a storage reservoir.
- An intake with fish screens and sediment control on the Rakaia River.
- An intake with fish screens and sediment control on the Waimakariri River.
- A pump station within the Rakaia River channel that would pump water from the stilling basin up onto the higher terraces above.
- A feeder canal from the pump station discharge into the head of the Wairiri Valley at Glenroy to fill the reservoir.
- A discharge canal from the reservoir adjacent to the Selwyn River, feeding into the main headrace.

- A level headrace canal with a nominal operating water surface level of 235m MAMSL (metres above mean sea level) connecting the stilling basins in each of the Rakaia and Waimakariri Rivers.
- An intake and pump station adjacent to the Kowai River to provide water to the Springfield/Sheffield area.
- An open race reticulation network to supply up to 84,000 ha of land for irrigation.

The operation would involve delivering water to the supply area from run of river water via the headrace system when water is available in the rivers with the shortfall being made up from storage. The order of priority of source shall be as follows:

1. Supply from available run of river water in the Rakaia River, subject to sharing with the Ashburton Community Water Trust (ACWT) as first priority.
2. Supply from available run of river water in the Waimakariri River as second priority.
3. Supply from storage during periods when run of river water is not available to meet the demand.

During periods when the supply exceeds the demand, surplus water will be delivered to the Wairiri Reservoir to replenish storage.

While the Wairiri Option has been referred to as the base case, it is evident that other options which are variations upon this may be viable. These may include alternative reservoir locations such as in the Waianiwaniwa Valley. Having alternatives such as this, add robustness to the feasibility of the scheme, as the feasibility does not therefore rely upon single locations for critical elements. This report therefore will assist in defining the ultimate scheme configuration.

Similarly the base case does not detail which of the enhancement opportunities will be included, as these need to be developed in consultation with the community. This will happen in the next stage of the scheme investigation.

Technical Feasibility

On the basis of the survey, geotechnical and design work undertaken as part of this project, it is concluded that the Base Scheme and its variants are technically feasible (able to be built). The costs presented are expected to be within an accuracy of ± 20%.

Base Scheme Cost

This scheme option has a total capital cost of $234M with annual operating and maintenance costs of $6.7M/yr. These costs assume that Springfield/Sheffield area are included within the total scheme area of 84,000 ha. If this area is separated from the main scheme area (and costed separately) the scheme costs will reduce to a total capital cost of $219M and operating and maintenance costs of $5.5M/yr. These costs are presented in Table E-1. It is important to note that in this table, the Annualised Cost per hectare is not the price of the water. The price depends upon many factors as explained later in this summary. However the annualised cost is useful to compare options in a way that capital and annual costs are included. This reflects the life time (20yr) cost of an option.

Table E-1: Base Scheme Costs

Item	Cost ($) Including Springfield/Sheffield	Cost ($) Excluding Springfield/Sheffield
Total Capital Cost	$235,031,000	$219,178,000
Total Annual Operating and Maintenance Cost	$2,295,000	$1,165,000
Total Annual Energy Cost for pumping	$4,425,000	$3,790,000
Annualised Cost per hectare [1]	$344	$311

Note 1. The annualised cost is the whole of life cost assuming a 20 year loan period and an interest rate of 8.0% expressed in terms of 2001 nominal dollars, equally shared over 84,000 ha. The 8% interest rate is used for economic analysis only and is not the finance rate (7%) used to establish the price of water.

There are many different possible arrangements for the final scheme that may ultimately be implemented, therefore it is important to understand how this base cost may vary depending on the assumptions made. The scheme area will depend upon the uptake and commitment from the farming community and funding bodies. Therefore a range of scheme areas, from 50% (42,000 ha) through to the full 100% (84,000 ha) has been costed. The range of total annualised costs/ha for different scheme areas is shown in Figure E-1.

The approximately 9000 ha in the Springfield/Sheffield area has unique requirements for irrigation and therefore has a marked impact on the scheme costs. In addition, the level of reliability provided by the scheme affects the cost. Each of these factors is shown in cost data in Table E-2. Table E-2 includes costs for different storage volumes, each of which provides a different level of service. The larger the reservoir volume, the greater the water available for dry periods and therefore the more reliable water supply to the irrigation area. The level of service to be provided will ultimately be decided by the stakeholders to any scheme implemented.

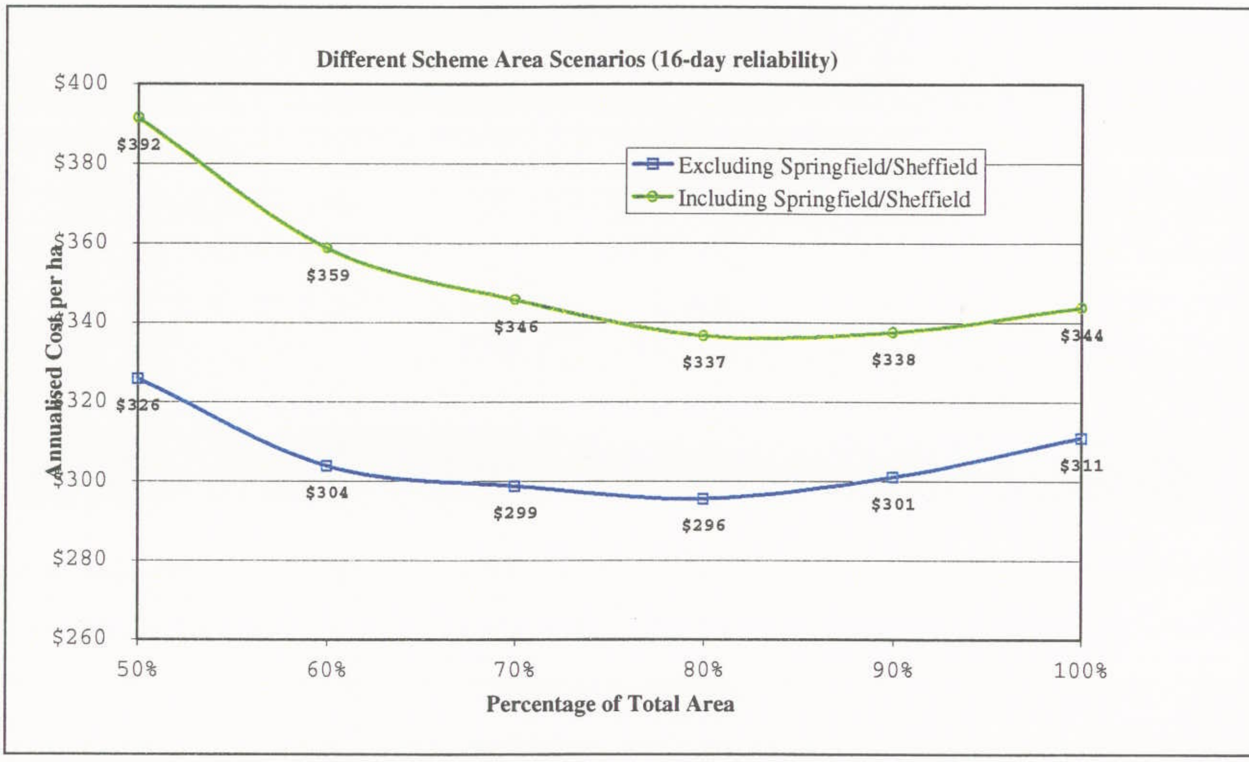

Figure E-1: Scheme Cost versus Scheme Area

Table E-2: Scheme Costs for Different Levels of Service

Item	Cost ($)	Cost ($)	Cost ($)	Cost ($)	Cost ($)	Cost ($)
	Including Springfield/Sheffield			Excluding Springfield/Sheffield		
Storage Volume MCM	290	250	220	290	250	220
Total Capital Cost	$235,031,000	221,770,000	191,412,000	$219,178,000	207,633,000	199,528,000
Total O&M Cost	$2,295,000	$2,295,000	$2,295,000	$1,165,000	1,665,000	1,665,000
Total Energy Cost	$4,425,000	$4,425,000	$4,425,000	$3,790,000	3,790,000	3,790,000
Annualised Cost/ha	$344	$331	$322	$311	$298	$289

Irrigation Schemes and Legal Structures

Irrigation schemes have specific characteristics that differentiate them from other types of business activities. Having consideration for these characteristics is essential for selecting the most appropriate legal and funding structures. Specific characteristics include:

- Irrigation schemes are essentially infrastructure assets similar to roads and utility power lines and poles. These assets typically have a monopoly of the supply to customers;
- Irrigation schemes typically require significant up-front capital investment;
- Constructing and operating an irrigation scheme is a long term activity with a long term payback period;
- Irrigation schemes are often a catalyst for a change in land use by customers of the irrigation systems in the medium term.

A range of possible legal/ business structures has been considered in detail within the study. The legal structures include:

- Partnerships (and unincorporated joint ventures)
- Co-operative companies
- Limited companies (and incorporated joint ventures)
- Trusts
- Unincorporated associations
- Incorporated societies

Each structure has advantages and disadvantages. Selecting the structure that is most appropriate for CPWE will depend upon what the scheme stakeholders consider to be the most critical outcomes from a legal structure. It is likely that a co-operative company structure will be utilised in some form. The stakeholder groups have not yet been defined, as these may involve more that the direct recipients of benefits from such a scheme. Councils may choose to have some form of ownership in relation to the control of the resource (water from the rivers and the storage systems), with the rural community focussing of the distribution systems and the operational aspects. Council participation has the potential to provide advantages for land acquisition.

Funding Structures

Irrigation schemes generally require a significant up-front capital investment. This can be funded from a mix of equity and debt. Various levels of debt and equity are considered in the study and their implications on the trade off between capital contributed up-front, and the level of operating cost per annum is presented. Generally the higher the debt funding, the higher the annual operating costs (including debt repayment and interest), and the lower the required initial capital contribution.

Price of Water

To establish a price for water, it was necessary to undertake a modelling exercise to provide a range of costs for the many different options available to CPWE. Three models were considered:

- Model 1 - Excluding Springfield/Sheffield
- Model 2 - Including Springfield/Sheffield – Water Charges Equalised
- Model 3 - Including Springfield/Sheffield – Separate Water Charges For Springfield/Sheffield Water Users

Using the three base case models, a series of scenarios have been run to assess the scheme's price sensitivity to movements in key variables. The following scenarios have been run:

- Debt/Equity – Funding options. The base case assumes 50% debt, 50% equity.
- Scheme Size. The base case assumes a scheme area of 84,000 hectares. Lower construction costs can be achieved by decreasing the area serviced by the scheme.
- Reliability. Water reliability is dependant on the volume of water that can be accessed from a storage facility during drought conditions. The base case assumes a storage volume of 290 million cubic meters of storage capacity.
- Finance Rate. The base case assumes a finance rate of 7.0%. With the assumption that 50% of the scheme will be funded through debt, a movement in the finance rate will have an impact on pricing.
- Finance Term. The base case assumes a finance term of 20 years.
- Equity Return. Return on equity for the base case is assumed to be 0%. If equity were to be sourced from other than land owners, there would need to be an adequate commercial return on the investment.
- Energy Costs. Energy costs for the base case have been assumed at 6.3 cents per kilowatt hour. Movements in energy costs are difficult to predict and it is therefore difficult to manage this risk over a longer period.

Results - Scenario analysis

Table E-3 provides a high level summary from the scenarios discussed above. All of the numbers are expressed in 2001 nominal dollars (i.e. the impact of inflation has not been considered).

Table E3: Summary of Cost of Water for Range of Scheme Options

	Excl. Spring/Sheff	Incl. Spring/Sheff (equal)	Incl. Spring/Sheff (separate)
Base case			
Up-front capital cost/ha	1,472	1,576	2,342
Operating cost/ha*	204	229	412
Capital Cost Range			
Lowest capital cost/ha	1,200	1,285	1,908
Highest capital cost/ha	1,732	1,854	2,757
Operating Cost Range			
Lowest operating cost/ha	168	191	356
Highest operating cost/ha	425	465	764

* Prior to repayment of debt – Details are presented in Appendix B.

Social Impacts

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

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

In addition to the social and economic effects of land use changes arising from accessing water from the proposed irrigation scheme, there are a number of other direct and indirect effects that are anticipated. The effects this assessment has identified have been organised into a number of themes: the local business sector, employment, the local economy, cost, community organisations, services and schools, disadvantaged groups, compensation, construction, recreational activities, risks to residents, site, visual and water. Under each theme there is a list of specific points that describes the nature of these anticipated effects.

A major irrigation project such as proposed for the Central Plains involves several strands of social change. The nature of these social changes will vary over the life cycle of the project, including the planning, construction and operational phases.

Monitoring the outcomes of the scheme from the point of view of farmers and their families, and other affected parties, will require the development of a detailed profile of farmers and families in the area. Additional information about water based recreation and effects may also be required once the water sources and scheme configuration to be put forward for consent applications have been confirmed. Further work is needed on mitigation strategies, and local input should be sought to develop them. It would be useful to establish a system to manage the social impacts of the scheme. One option to investigate in this regard is a community trust fund.

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

State Highway 77 runs through the Wairiri Valley and provides access to Windwhistle and the Rakaia Gorge through Glentunnel. If this road is relocated around the south side of the Harper Hills, then Glentunnel will not longer be on the State Highway. This potentially could have adverse impacts on the store and camping facilities in Glentunnel, but also may be seen as having a positive effect in relation to businesses in Coalgate and Hororata. The relocation of this road has been identified by the local residents at Glentunnel as a major issue.

Cultural Impacts

proposed options for a reservoir and canal network within the Malvern Hills area is currently located in an area that contains a generally high density of sites and areas of significance to Ngäi Tahu, Ngäti Mämoe and Waitaha.

Given the abundance of food resources, the suited climate for cultivation and the fact that this area was on-route to mountain passes, all contributed to the fact that historical occupation in, and use of, Waikirikiri/Selwyn River was generally of a larger scale than other foothill areas in the Canterbury region.

With this occupation, Ngäi Tahu applied their tikanga and kawa (cultural rites and customs) to the environment in order to protect and sustain the resources within the area that they harvested. These values remain today, having been passed down from generation to generation in the role of kaitiaki (guardianship).

With regard to the various options that this report has assessed, particular options have been assessed as having a have high impact on Ngäi Tahu cultural values and this gives an additional reason for recommending that the following options do not progress in their current form:

- Discharge from the Wairiri Reservoir to Headrace Canal via the Selwyn River
- Discharge from the Wairiri Reservoir to Headrace Canal via Buried Canal in the Selwyn River
- Waimakariri River to Springfield Canal Scheme
- Waimakariri River to Springfield Canal Scheme – Low Flow Replacement Option

At the point at which a final combination of options has been decided upon, it will be necessary to have further research and identification carried out on the area, in particular archaeological surveys. Once this level of detail has been established, it will be necessary to revisit this report and re-analyse the options against this new or more detailed information.

Environmental Concerns

The environmental effects resulting from the scheme relate primarily to the impacts of the taking of water from the Rakaia and Waimakariri River, the construction of the Wairiri Reservoir and the use of water for irrigation and the associated effects on groundwater and the effects of conversion to dairying.

During the initial years it is anticipated that water quality problems will be experienced in the Wairiri Reservoir with anoxic conditions developing in the lower levels of the reservoir. This is not an unusual condition in a new reservoir. The design of the outlet will be such that water can be drawn off at different levels so only the well oxygenated near surface water is discharged for irrigation. Clearing of the basin of vegetation prior to flooding can also help alleviate this potential problem.

As the take from the Rakaia river is within the National Water Conservation Order (NWCO), no more than minor impacts on the Rakaia River are anticipated and there is a low risk that this take will not be granted.

The taking of up to 40 m^3/s from the Waimakariri River is a relatively large take from the Waimakariri River. While this take is within the rules of the Proposed Waimakariri River Regional Plan (PWRRP) some detrimental environmental effects will be experienced in the river. These impacts primarily relate to the conditions deemed to be acceptable for salmon fishing, being reduced from 11 to 7 days per year on average and at times may reduce the stimulus for salmon to move upstream during prolonged periods of low flow. This is likely to attract opposition to the take and there is a risk that the full 40 m^3/s may not be granted. It is expected that there will be little impact on the fishery.

The irrigation of 84,000 ha of the Central Plains will result in increases in groundwater level under the scheme area of up to 18 m. This effect reduces towards the coast. Further inland the increased groundwater levels will have little impact. However at the edge of the confined zone increased groundwater levels of about 2m will have an impact on drainage of periodically wet land with land staying wet for longer periods more frequently. There may be future costs involved in mitigating these effects, but given the long time periods involved and the uncertainty of the effects, these can not be predicted at this time.

This assessment has assumed full development of the scheme area without a corresponding increase in abstraction by groundwater users below the scheme area. It is likely that abstraction of the groundwater resources will increase over this time period and the scale of the effects predicted will be reduced.

The increased groundwater levels will result in increased flow in the spring fed streams, which by some people will be seen as a beneficial effects.

Increased drainage from irrigated land will result in increased leaching of nitrate to groundwater. Based on the modelled drainage and groundwater flows it is estimated that groundwater nitrate-N levels could increase on average by between 3.5 and 4.5 g/m^3 to about 7.0 g/m^3. This is below the Drinking Water Standards for New Zealand 2000. However, other contributions to nitrate in groundwater exist and the increase could result in local or periodic increases of nitrate-N concentration to above the maximum drinking water concentration of 11.3 g/m^3.

The increased nitrate-N levels in groundwater will also result in increased Nitrate-N levels in the spring fed streams flowing into Lake Ellesmere. These stream already typically have elevated nitrate levels and phosphorus is the limiting nutrient in regard to phytoplankton growth. This is therefore unlikely to accelerate phytoplankton growth in the streams or in the lake.

Dairy farming and damage to waterways and contamination of groundwater has been a topical issue. Mitigation is likely to focus on improving farming practice and wastewater disposal in the CPWE area. The possibility of an environmental "warrant of fitness" for farms involved in the CPWE scheme has been suggested. This may include measures such as ensuring that stock are prevented from entering open water ways. The majority of the land to be developed under irrigation within the CPWE scheme is away from existing surface water ways, and this is thought to be a minor and controllable issue.

Not proceeding with the scheme will also have adverse environmental impacts, including increasing demand on groundwater resources and further depletion of low land streams.

Enhancement Opportunities

Increasing the supply of recharge water to the groundwater aquifers of the Central Plains will have the benefits of increasing pressure in the aquifers feeding the lowland streams such as the Avon and Heathcote, as well as the streams feeding Lake Ellesmere. These streams have been identified as becoming adversely affected by increasing abstraction of groundwater on the plains. This will benefit the environment and recreational users such as fishermen.

Increased groundwater pressures will also reduce the pumping cost to existing abstractors including irrigators and domestic supplies. The reliability of access to groundwater within the West Melton area will improve, as this area is already subject to restrictions at times of low groundwater levels.

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 this access 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. This will require a greater area of land but is indicative of the type of community projects that could be initiated with forethought.

The water conveyance system of canals, will not be able to have vegetated sides as this may compromise the flow of water and the water tightness of the embankments. There will be opportunities for areas adjacent to existing streams to be developed as wetlands where bypass flows from the scheme could be discharged. Any direct augmentation of stream flows will require passing through land based systems such as wetland areas. Such areas will prove habitat for a variety of bird species, including game birds and provide the opportunity to enhance native plant species. Existing irrigation canals in Mid-Canterbury are used for swimming, canoeing, kayaking and multi-sports events and wild fowl shooting. Non water based recreational activities include tramping along the canal banks, picnicking and photography. The canals are also an important water source for fire fighting purposes.

The scheme will result in increased population in rural areas with accompanying increases in school rolls, revitalised sports and community clubs and the provision of community services. Rural unemployment will become virtually non-existent with direct and indirect labour opportunities being created.

Feeding habitat within the Waimakariri and Rakaia Rivers for the Wrybilled plovers (which are an endangered species) will be enhanced.

The scheme will also provide an opportunity for environmental and community trusts to be established that could be the vehicle to promote development that benefits the wider community.

Affordability at Farm Gate

The results of the water affordability modelling for the main land uses are shown in Table E-4. It should be noted that these affordability calculations have been calculated based on the conversion of an existing dryland sheep farm to each of the irrigated land use options. This has been done because dryland sheep farming is by far the predominant land use in the scheme area. This table shows affordability over a range of farm productivity levels.

In the table, the column to the left of each land use shows the range of levels of productivity. For dairy farming this is expressed as cows per hectare, arable farming is expressed as a multiple of average production and all other livestock land uses are expressed in stock units per hectare.

The grey shaded areas below the solid line in the table are those areas that do not provide sufficient surplus to be able to afford a water charge of $204 per hectare. The green shaded areas above the solid line, do provide sufficient surpluses. It should also be noted that the green shaded area exceeds $229 per hectare, which is the cost of the base scheme concept including the Springfield/Sheffield area.

Table E-4 : Water Affordability by Land-use Ranges

Cows /ha	DAIRY $/ha		ARABLE $/ha	S U / ha	SHEEP $/ha	S U / ha	BEEF $/ha	S U /ha	DEER $/ha	S U /ha	DAIRY SUP. $/ha
3.4	968	1.20	246	22	150	22	511	22	315	22	552
3.3	862	1.15	187	21	99	21	429	21	240	21	474
3.2	756	1.10	129	20	48	20	347	20	165	20	395
3.1	650	1.05	71	19	-4	19	265	19	90	19	316
3.0	543	1.00	13	18	-55	18	183	18	15	18	238
2.9	437	0.95	-45	17	-106	17	101	17	-60	17	159
2.8	331	0.90	-104	16	-158	16	19	16	-135	16	80
2.7	225	0.85	-162	15	-209	15	-63	15	-210	15	1
2.6	119	0.80	-220	14	-261	14	-145	14	-285	14	-77

* SU = Stock Unit

Points to note from this shading are:

- Dairy farming and its supporting land use of dairy support can afford the water charge at below average levels of performance.
- Arable farming can afford the water charge at productivity levels that are 20 percent above average. It should be noted that specialist arable land uses such as specialist small seed production and processed cropping would easily be able to afford the water charge because of their high levels of profitability.
- Sheep farming at 22 stock units per hectare does not produce sufficient surplus to afford the water charge. However sheep farming systems above 23 stock units per hectare would be able to pay the water charge.
- Both beef and deer farming systems at 19 and 21 stock units per hectare respectively can afford the water charge.

In summary, the above table indicates that in order to be able to afford an up-front capital.contribution of the $1,472 per hectare and an ongoing annual water charge of $204 per hectare (for the first 20 years of the scheme) that farmers are going to have to adopt a significant change in land use or achieve well above average levels of performance to be able to pay the additional costs of irrigation conversion and also make sufficient profits. The attractiveness of the proposed scheme to existing irrigators will depend on the depth of their existing groundwater source and its reliability and the ability to provide sufficient volume for their properties.

Other considerations that have not been incorporated into the model will also influence farmers decision-making including factors of reliability of production, increased specialist or niche land use options, and capital gains on increased asset value.

It appears that the proposed cost of the scheme is at the upper range of affordability as shown by the modelling and bears out the results of the focus group work. This will mean that existing dryland sheep farmers, who are the predominant land users in the command area, will need to address the water affordability issues on their property.

To achieve a satisfactory level of water uptake commitment the future Central Plains Water Enhancement entity will need to carry out an extensive education and farmer support program before seeking farmer's commitment to the scheme. Uptake by the farming community is critical to the success of this scheme.

The ability to trade water entitlements independent of land may also be an important element that should be considered in accelerating uptake or commitment to the scheme.

Regional Benefits

While the above analysis indicates the potential returns from individual activities, the community scheme will be able to supply water for a mix of land uses depending upon farmer preference and land suitability. A range of different mixes of land use are described in the economic report (Butcher 2000) to provide a range of economic benefits from the proposed scheme.

The Butcher Report details the wider benefits in terms of employment and total value added to the economy that will flow on from this development. For a likely development scenario on the 84,000 ha community irrigation scheme, the likely economic benefits are as follows:

- An increase in the annual net output at the farm gate of $153 million.
- An increase in the total annual regional output of Canterbury of $647 million.
- An increase in the total value added on-farm of $76 million.
- An increase in the total regional value added of $241 million.
- An increase in employment on farm of 477 full time equivalents.
- An increase in the total regional employment of 2630 full time equivalents.

Annual net output describes the value of increase output, expressed in dollars, at the farm gate, or increased farm gross revenue. The increase in total annual regional output describes the dollar value of the flow on effect of the increased output on the Canterbury regional economy. This incorporates the direct and indirect impacts of the extra economic activity created in Canterbury. Value added expresses the extra profit created which is available for reinvestment. This is typically described as the return to the investment in land, labour and capital.

Increased production for the Central Plains area will require additional processing and distribution, creating opportunities for producers and entities such as the Lyttelton Port and Christchurch Airport.

From a MAF study on the expenditure patterns of farmers within Canterbury, it was found that approximately 20% of farm expenditure was spent in Christchurch City. A sub-regional analysis of the data from this study showed that 39% of the farm expenditure from within the Central Plains region was spent in Christchurch City. This provides an indication that there will be a significant increase in direct expenditure from the rural community (between 20 – 40% of total farm expenditure) for goods and services in Christchurch City as a result of this scheme proceeding.

The impact of the scheme on spending in Christchurch is of a lift of between $48m and $66m in expenditure from farm working expenses and a lift of between $7.5m and $10m in personal expenditure. This gives a total increase in expenditure in Christchurch of between $55m and $76m. This is a significant increase on the current $58m

The creation of jobs would be across the whole spectrum of employment, including unskilled, skilled, trades and professional. It would be likely that this development would create a shortage of skilled workers within the rural communities.

Other benefits that have not been quantified include the protection of the agricultural sector in Canterbury which will face increasing international competition and increasing demand (and therefore a lower availability) of groundwater for irrigation development. The proposed scheme is viewed by some, to be essential to maintain a strong primary production base to the Canterbury Community.

Bankability

The assessment of affordability/bankability is not a fixed test, but rather a concept that encourages a wide consideration of the economic and financial issues to be considered. The final assessment of affordability/bankability must be made by considering all of the perspectives involved. These include:

- Affordability at the farm gate to the farmers;
- Strong regional economics to ensure down stream processing and marketing support;
- Sufficiently robust structures to provide confidence from the financiers; and
- Community value in terms of jobs and wealth creation.

The price of water has been estimated to be within the range of an up-front capital contribution of $1,450 - $1,600/ha, plus annual charges of between $189 - $229/ha/yr. At the farm gate, there are sufficient cash farm surpluses from a range of farming activities including dairy, high end arable, above average beef and deer, and dairy support, which are sufficient to pay for the cost of the community supplied water.

At the regional level, this scheme could boost the total annual regional output of Canterbury by $647 million and increase the total regional value added by $241 million.

The financial structures that must be put in place have yet to be determined, and will depend upon the collective stakeholders' priorities. It would be safe to assume at this stage of the study that there is a sufficient range of structural options available for all stakeholders needs to be met. It is premature at this stage to be specific on the guarantees that may be required by the funders of the scheme. These may include underwriting of debt by either local or national government.

It is anticipated that the scheme will increase the total regional employment by 2630 full time equivalent jobs. This will significantly distribute wealth throughout the community.

On the basis of the above assessments, a community irrigation scheme is financially viable and will be economically beneficial to the whole Central Plains area and is therefore both affordable and bankable. It should be noted that the affordability of the scheme is dependant upon change in land use, as some current land use practices are unlikely to generate sufficient returns to cover the cost of water.

Consentability

There is no certainty in relation to applying for resource consents. However a balanced judgement is required between the benefits and opportunity that this scheme would create, and the potential adverse effects that might arise.

There are three main issues in relation to obtaining resource consents. These are:

- The potential effects on individuals and communities, particularly in the Wairiri Glentunnel area, who are dislocated or otherwise disadvantaged as a result of the infrastructure development.
- The potential effects of the 40 m^3/s take on the Waimakariri River, even though this take would comply with the rules in the Proposed Waimakariri River Regional Plan (PWRRP).
- The potential impacts on groundwater from mounding effects and contamination by nitrate-nitrogen.

Impacts on host communities can be mitigated through measures such as appropriate compensation, and provision of new community assets such as recreational facilities associated with the development. It will be necessary to work closely with these communities to determine what solutions are the most appropriate for them. It could be beneficial to create Community Trusts to administer community mitigation measures.

The up to 40 m^3/s take from the Waimakariri River would be one of the largest such takes consented in Canterbury. However a take of up to this amount would not result in depletion of the river flows below the minima established in the plan. There may be some impacts on the fishability of the river. The low and stable flow conditions that may affect the migration of salmon are infrequent occurrences, which will have little effect on the overall sustainability of the salmon resource.

The 40 m^3/s take from the Waimakariri River includes a 6 m^3/s take from immediately above the Kowai River for the base case scenario with Springfield/Sheffield included in the scheme area. This will result in water being abstracted from the river at low flow conditions when the abstraction rules in the PWRRP would prevent this. In mitigation, the same volume of water would be released from the reservoir into the river to replenish the flow. The reach of river between the Kowai and the Waimakariri Gorge Bridge would be depleted of water however. This will be a difficult consenting issue.

Increased drainage from irrigated land will result in increased leaching of nitrate to groundwater. Based on the modelled drainage and groundwater flows it is estimated that groundwater nitrate-N levels could increase on average by between 3.5 and 4.5 g/m^3 to about 7.0 g/m^3. This is below the Drinking Water Standards for New Zealand 2000. However, other contributions to nitrate in groundwater exist and the increase could result in local or periodic increases of nitrate-N concentration to above the maximum drinking water concentration of 11.3 g/m^3.

While these issues are seen as the major issues to be faced in the consenting process, these all are surmountable, provided CPWE work closely with the potentially affected parties and find solutions that meet everybody's needs. The proposal is believed to be a sustainable use of the natural and physical resources of Canterbury as required by the Resource Management Act.

It is now a matter of public record that the Christchurch City Council and the Selwyn District Council, in conjunction with the Ashburton Community Water Trust (ACWT) have applied for resource consents to take water from the Waimakariri and Rakaia Rivers. These applications have included proposals for water sharing with the ACWT. It must be remembered that these consents are for the take of water only, and not for the use of that water. Other consents for the diversion, discharge and use of the water will be required, as well as all of the land use consents for the construction and use of the infrastructure before the water enhancement proposals can be implemented.

Scheme Feasibility

Considering the technical, economic, social, cultural and environmental factors raised through out this study has lead to the conclusion that a water enhancement scheme for the Central Plains:

- can be built
- is affordable
- will have effects that can be mitigated

It is therefore concluded that the scheme is feasible, remembering that this does require significant changes in land use practices.

1.1 Introduction

1.1.1 Background

In March 2000 the Central Plains Water Enhancement (CPWE) Steering Committee was established by the Selwyn District Council and the Christchurch City Council. The Councils' objective in setting up the Steering Committee is ***"to execute feasibility studies into the viability and practicality of water enhancement schemes in the Central Plains area, being that area approximately described as lying between the Rakaia and Waimakariri Rivers, the Main Divide to the west and the Coast to the east".***

The purpose of the feasibility study is to provide the Selwyn District Council and the Christchurch City Council information on whether such a scheme is feasible before proceeding with a commitment from potential financial participants, application/s for resource consents, detailed engineering, and securing of finance.

To achieve this objective, the Steering Committee has commissioned URS New Zealand Ltd (URS) investigate the need for, and feasibility of, a community based irrigation scheme, situated on the 200,000 ha area lying between the Waimakariri and Rakaia Rivers.

This report is the Stage 2 Feasibility Study, and makes recommendations as to the preferred option, the technical, economic and environmental feasibility for consideration, prior to advancement into the resource consenting stage.

1.1.2 Terms of reference

The Feasibility Study was split into three phases. This involved a Pre-feasibility phase where all those options selected from Stage 1 were further developed and evaluated in sufficient detail to enable one option to be selected for investigation at feasibility level.

Following selection of the preferred option the full feasibility study of that option investigated that option in more detail. The feasibility stage involved a technical and economic assessment of the selected option. This was to ensure that a "bankable" option is available, which can then proceed through the environmental assessment.

The assessment of the environmental assessment assesses the environmental implications of the selected option, to determine if the environmental effects are acceptable and whether consents required to proceed with the scheme are obtainable.

The full terms of reference for the Stage 2 Study are provided in "Terms of Reference for Stage 2 of the Feasibility Study" (URS June 2001).

1.1.3 Previous Studies

Many of the stages in the study involved stand alone reports. The following reports have been used in the compilation of this report

- Central Plains Water Enhancement Scoping Study (URS November 2000)
- Central Plains Water Enhancement, Interim Report (URS May 2001)
- Central Plains Water Enhancement, Scheme Concept for Consultation, Interim Report2 (URS May 2001)
- Geological Investigations for the Proposed Central Plains Water Enhancement Scheme Technical Memorandum, (URS September 2001)
- Options for Water Supply to Christchurch City Council, (URS September 2001).
- Financial Structures for Community Owned Irrigation Schemes, (Deloitte Touche Tohmatsu October 2001)
- Economic and Social Impact of Proposed Irrigation Schemes in Canterbury (Butcher Partners and Agriculture New Zealand 2000)
- Cultural Impact Report for Central Plaines Water Enhancement Phase II (David O'Connell)
- Central Plains Irrigation Scheme, Preliminary Social Assessment (Taylor Baines and Associates October 2001)
- Central Plains Water Enhancement: an assessment of potential environmental effects (NIWA October 2001)

1.1.4 Outline of report

This report starts by describing the base case scheme under consideration in Section 2 to provide the reader with an understanding of the scheme at the start.

The report then describes the process undertaken by CPWE to arrive at the base case scheme and technical investigations undertaken in Sections 3 and 4.

The report then proceeds to consider the Financial and Economic implications in Section 5. This includes aspects such as optimisation of components of the scheme, and sensitivity to scheme area and reliability.

In Sections 6,7 and 8 the Environmental, Social and Cultural impacts of the scheme are considered.

The scheme feasibility is then considered in Section 9 by identifying the risks to the success of the scheme, identifying mitigation measures for the risks and assessing the implications of those risks that cannot be mitigated. Recommendations for the way forward are then outlined in Section 10.

2.1 Introduction

This section presents what should be considered as the "Base Case Scheme" against which variations can be considered. Many of these variations cannot be resolved at this time and do not affect the overall feasibility of the scheme. For example the base case scheme area has been selected as 84,300 ha, although it is highly unlikely that any scheme ultimately implemented will be exactly this area. Therefore it is necessary to not only describe the base case, but also how this may be varied by future decisions, such as a reduction in area, so the impacts on the main components of the scheme can be determined as well as impacts on the cost and level of service. The impacts of varying factors such as area, methods of conveying water, particular areas being included or excluded, and the level of service are discussed in detail in Section 5, where their implications in terms of scheme costs are fully explained.

2.2 Scheme Area

The design area for the community scheme is 84,000 ha. This area was determined as part of the Scoping Study (URS 2000), after consideration of factors such as rainfall in different areas of the Central Plains, soil type, potential land use, topography, aquifer recharge and future groundwater abstraction and costs of groundwater abstraction.

The basic premise was that the area within the community supply zone would be able to be serviced with water at a cost similar to the cost of abstracting groundwater at the lower boundary of the scheme zone. In the scoping study, this was determined as the line which delineated the area based on a cost of $250/ha/yr to abstract water from the ground. This cost has been updated to allow for the known increases in power charges and line charges over the next two years. It is now approximately $295 - $300/ha/yr.

From the total zone defined in the Scoping Study, it has become evident that some areas close to the foothills can not economically be included within the community supply zone. These include areas along the Kowai River to the north-west of Springfield, and the areas around Windwhistle which do not have access to any of the canals proposed as part of this scheme concept.

Figure 2-1 outlines the community supply zone within which up to 84,000 ha can be potentially irrigated.

2.3 Water Demand

2.3.1 Irrigated Area and Land Use

Based on work undertaken in the Scoping Study the design irrigated area and land use for the Central Plains community supply zone has been assumed to be as listed in Table 2-1.

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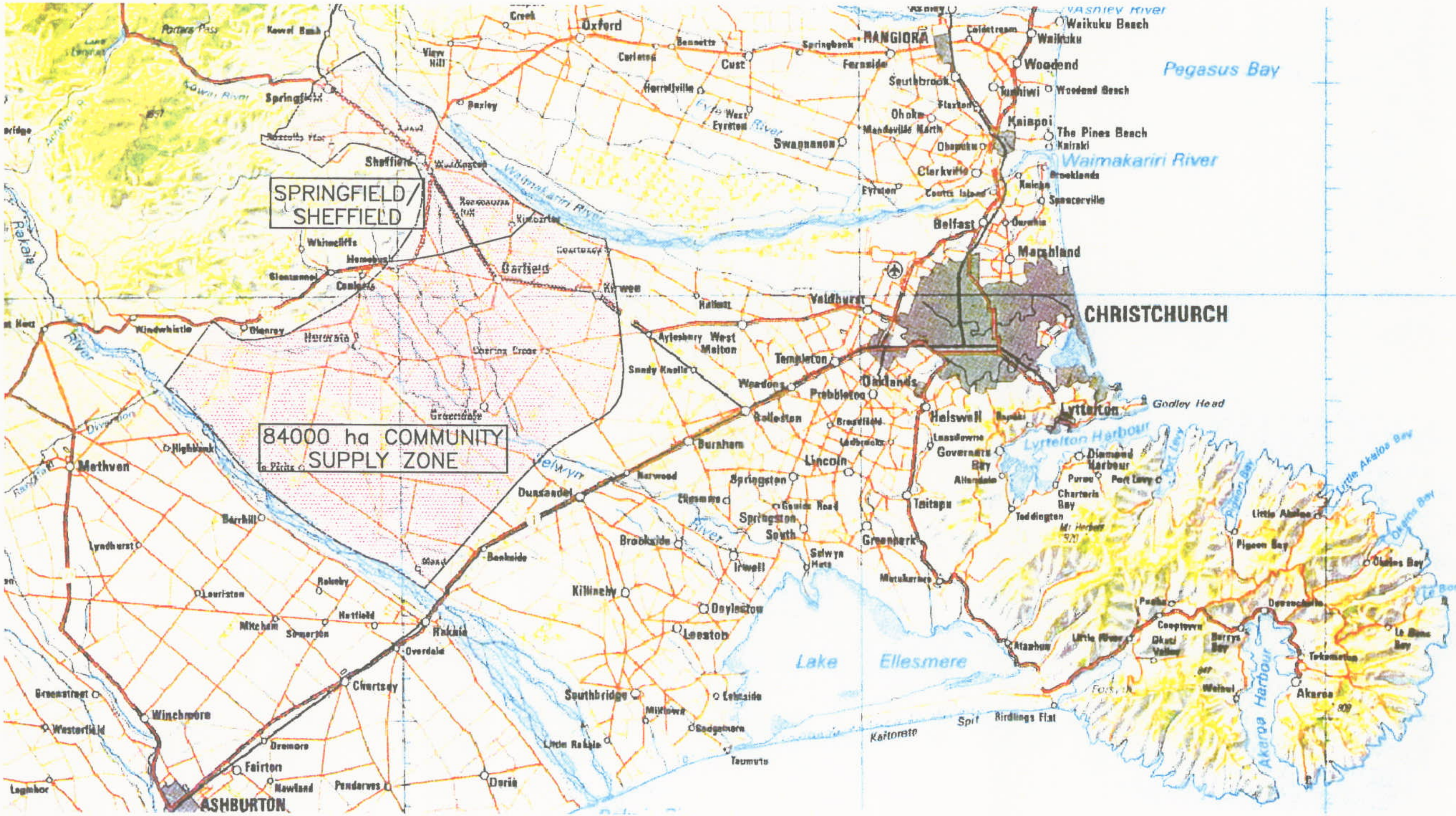

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Dames & Moore

Title
COMMUNITY SUPPLY ZONE

Figure No. FIGURE 2-1

Table 2-1: Irrigated land area by land use for each supply zone

	Intensive Pasture	Arable Cropping	TOTAL (hectares)
Springfield Sheffield Zone	3,381	6,489	9,870
Central Plains Zone	68,500	5,900	74,400
TOTAL	71,881	12,389	84,270

These areas are shown in Figure 2-1 with the likely land use shown in Figure 2-2.

2.3.2 Modelling of Water Demand

Design On-farm Flow Rates

Peak flow rates were determined from daily climate data. The irrigation demand depends on evapotranspiration and rainfall. Together these determine the flow rate required if irrigation is to keep up with crop water demand. The water demand varies continuously during a season, and from season to season. It is usually uneconomic to design irrigation systems to provide a flow rate that meets irrigation demand 100% of the time. The extra investment required to increase the design flow rate from the 90% level to the 100% level is rarely matched by increased economic benefits. Peak rates were set to satisfy demand 90% of the time for intensive pastoral farming and 80% of the time for intensive cropping.

The peak on-farm capacities used were: 0.6 l/s/ha for pasture, 0.45 l/s/ha for cropping in the Lincoln and Te Pirita/Mead rainfall zones and 0.4 l/s/ha for cropping in the Darfield and Homebush rainfall. Rainfall zones are shown in Figure 2-3. These values are similar to those used on irrigation systems installed in the last few years, and provide farmers with the ability to maximise crop production in all but extremely dry years.

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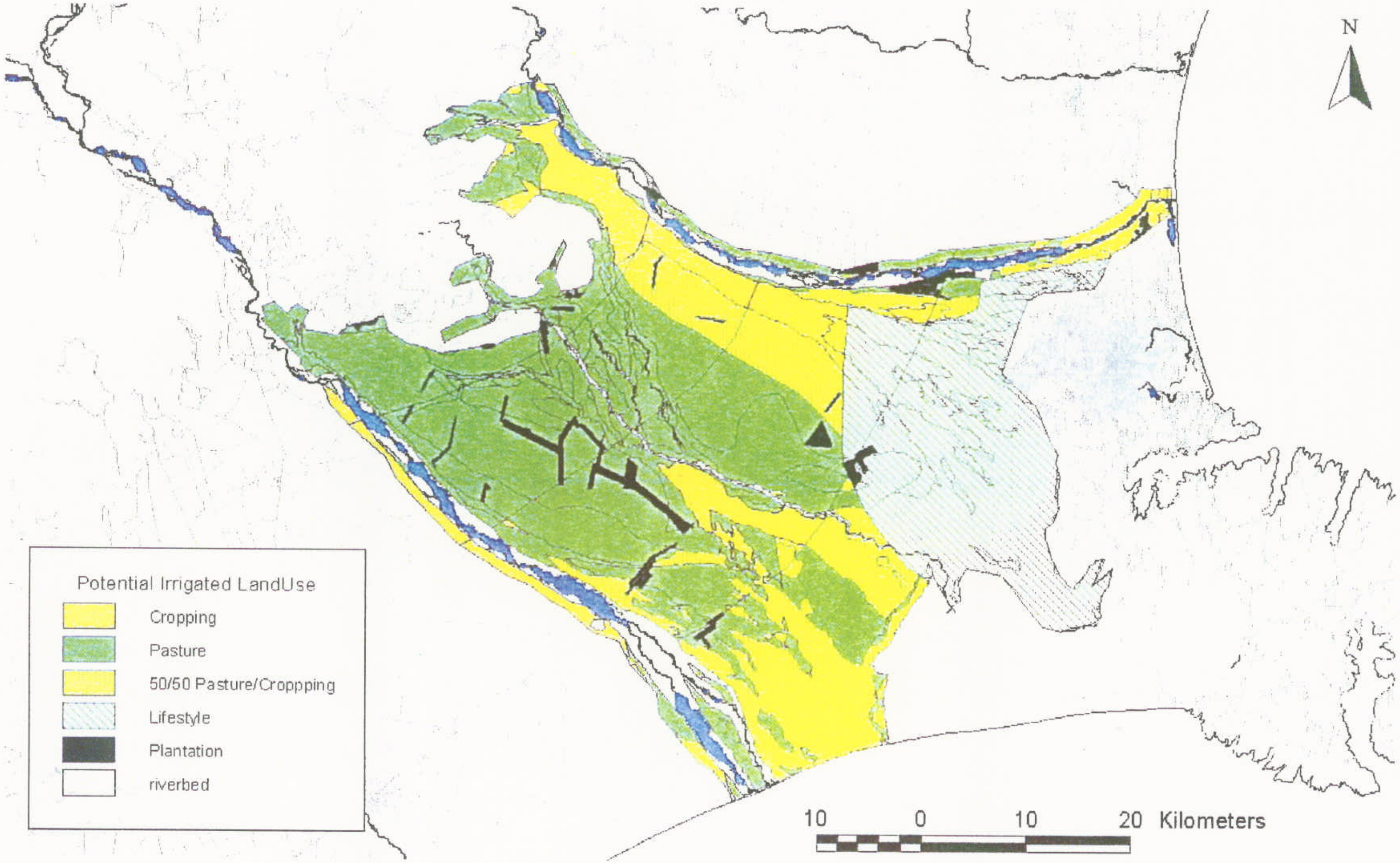

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LIKELY LAND USE SCENARIO

Figure No. **FIGURE 2-2**

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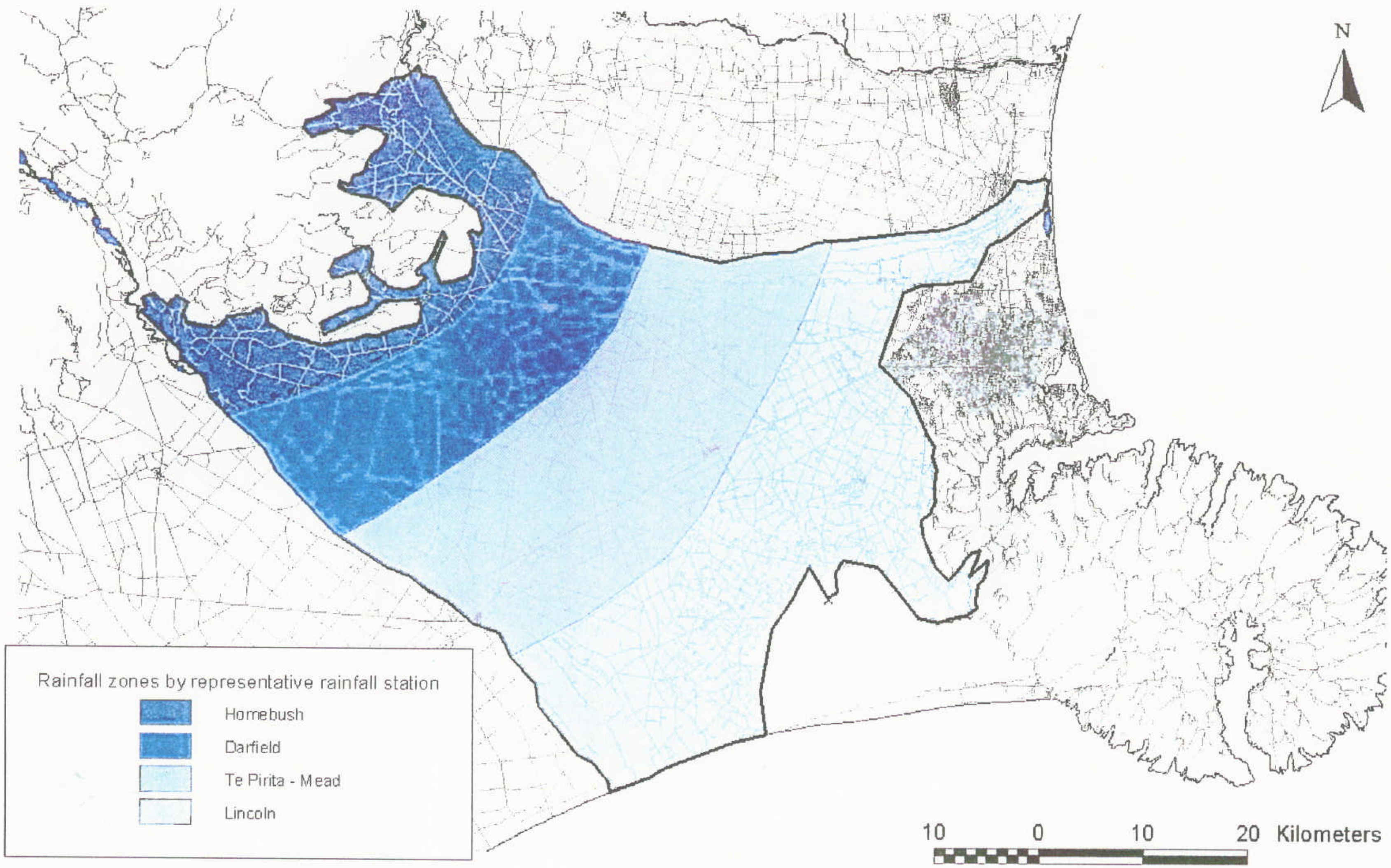

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Title
RAINFALL ZONES

Figure No. **FIGURE 2-3**

Irrigation Practices and Management

On-farm irrigation decisions, such as whether to irrigate, how much water to apply and the frequency of irrigation, all influence the overall demand for irrigation. Demand is simulated by representing all existing and potential irrigation, using irrigation depths, frequencies and efficiencies that represent reasonable irrigation management using currently available technologies. The irrigation return period and depth differed with soil class as shown in the Table 2-2.

Table 2-2: Assumed Irrigation Practices by Soil Type and Land Use

SOIL TYPE	IRRIGATION PRACTICE
Shallow Soils (Average water holding capacity 60 mm)	Irrigation return period: 7 days Pasture irrigation: 45 mm fixed application depth Crop irrigation: Variable application depth
Medium Soils (Average water holding capacity 90 mm)	Irrigation return period: 10 days Pasture irrigation: 55 mm fixed application depth Crop irrigation: Variable application depth
Deep Soils (Average water holding capacity 120 mm)	Irrigation return period: 14 days Pasture irrigation: 65 mm fixed application depth Crop irrigation: Variable application depth

The efficiency of distribution and irrigation was assumed to be 80% for fixed depth irrigation, and the 85% for variable depth irrigation.

Simulation of Irrigation Demand

Daily irrigation demand estimates were based on existing soil and climate data, representative irrigation practices and the assumed land-use scenario of Figure 2-2. The estimates were made using Lincoln Environmental's Irrigation Scheduling and Demand Model. A 33 year record of daily climate data from June 1967 to June 2001 was used to indicate the variation in demand throughout a season and from periods of drought through to very wet seasons.

Predicted Irrigation Demand

The total amount of water required for irrigation per season varies from year to year, and is more sensitive to soil and rainfall parameters than the peak rate of take. For example, average seasonal water demands for the medium (90mm water holding capacity) soils in the Te Pirita/Mead rainfall zone ranged from 400mm for arable cropping, to 480mm for pasture, while maximum demands ranged from 610mm to 730mm respectively.

The peak flow requirements are as calculated in Table 2-3. It should be noted that for this study, the peak demand has been rounded to 60 m^3/s to remain conservative.

Table 2-3: Peak water requirements by water supply zone

	Area ha	Peak Demand l/s/ha	Demand m^3/s
Springfield/Sheffield Zone			
Pasture	3,381	0.6	2.0
Arable	6,489	0.4	2.6
Plains Zone			
Pasture	68,500	0.6	41.1
Arable	5,900	0.45	2.7
System Losses			
Canal Leakage Efficiency		90%	4.8
Operational Efficiency		90%	4.8
Total Peak Demand			58[1]

Note 1. Peak demand rounded to 60 m^3/s for this study.

The seasonal water requirements are listed in Table 2-4.

Table 2-4: Seasonal water requirements by water supply zone

	Average Seasonal requirement (MCM)[1]	Average seasonal requirement converted to continuous flow rate over 8 months (m^3/s)[2]	Peak seasonal requirement (MCM)
Springfield/Sheffield Zone	40	1.9	68
Plains Zone	400	19.1	613
Total Scheme Zone	440	21.0	681

Note:

1. (MCM) – million cubic metres
2. Average requirement includes all system losses

2.4 Water Balance Summary

Over the long term, the average water demand from the Rakaia and Waimakariri Rivers combined is 13.85 m^3/s. Of this some is lost in leakage and evaporation from the headrace canal and the distribution system, and some is lost through operational losses (bywash). The balance between these components is as listed in Table 2-5. Data from Table 2-5 has been used in the drainage modelling to assess the impacts on groundwater – Section 6.

For the CPWE study, it has been assumed that the total losses will be in the order of 20%. In the RDR schemes of Mayfield-Hinds, Valetta and Ashburton-Lyndhurst, the water delivered to the farm is between 92.3% - 93.2% of the water taken. The total distribution losses from the Lower Waitaki Irrigation Scheme were limited at the design stage to less than 20% and this was confirmed during operation (Hamilton 1994). These examples indicate that the assumptions used for the CPWE scheme are appropriate and if anything conservative.

Table 2-5: Average Annual Water Balance

	Average Annual Water Demand m^3/s
Headrace Canal Leakage	1.0
Distribution Canal Leakage	1.7
Operational Losses	0.7
Irrigation Usage	10.45
Total Average Annual Demand (12mths)	13.85

2.5 Water Availability

The availability of surface water for abstraction is determined by:

- the natural flow in the rivers,
- environmental flow requirements,
- existing users, and:
- the water allocation regime (priority system).

Environmental flow requirements have two components – the flow regime required to maintain the river or stream's life-supporting capacity and its inherent characteristics, and the regime desired to support instream uses such as recreational, cultural, amenity and other uses. Environmental flow requirements and allocation regimes on the Rakaia River and Waimakariri Rivers have historically been established through public processes and are formalised in the National Water Conservation (Rakaia River) Order (1988) (NWCO) and the Proposed Waimakariri River Regional Plan (PWRRP) (Environment Canterbury, 2000).

All existing stockwater and community takes have been taken into account and are assumed to have higher priority than irrigation water to the Central Plains area.

The availability of water from the Rakaia River and Waimakariri Rivers has been based on daily flow records since 1967.

The Selwyn River has not been included as a source of water for the plains. The Selwyn River has a mean annual flow of 3.4 m^3/s measured at Whitecliffs. It is known to have no surface flow in some reaches during dry summers. It is therefore unlikely to provide a reliable source of irrigation water, and because the mean flow is less than 3% of the peak flow rate required for irrigation, it is unlikely to provide enough water even if all the water could be stored and used on an annual basis.

2.6 Sharing of Rakaia and Waimakariri River Water

Water in the Rakaia and Waimakariri Rivers should be considered as a scarce resource. It has been a desire of CPWE to ensure that the use of these resources maximises the potential benefits for all users and that as part of this study the needs for water by the neighbouring communities should be considered. To this end, CPWE have taken into account the existing and stated requirements of other abstractors from both the Rakaia and Waimakariri Rivers.

The storage assessments in the Scoping Study assumed that the scheme would have access to all water that was not consented to other users as at June 2000. In addition, the Barrhill Chertsey consent to take $17m^3/s$ from the Rakaia River was assumed to have been granted. Since then, the Barrhill Chertsey consent has been granted, Waimakariri Irrigation Limited (WIL) have been granted consent to use an additional 1.5 m^3/s from the Waimakariri River, and have applied for consent to use a further 2 m^3/s.

In addition, the Ashburton Community Water Trust (ACWT) have developed proposals for irrigating the Mid-Canterbury area that rely on the Rakaia River to fill storage and as a run-of-river take. There is therefore considerable competing demand on the water required for the Central Plains proposals. This sections outlines a joint solution to the water sharing in the rivers that fully complies with the Rakaia NWCO and the PWRRP.

2.6.1 The Waimakariri River

When the increased allocation to WIL is taken into account, the existing consented takes from the Waimakariri River are:

- WIL 10.5 m^3/s
- Other Irrigators 2.5 m^3/s
- Stockwater 4 m^3/s

The PWRRP 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 17 m^3/s is permitted to other abstractors. This therefore provides 5 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 PWRRP 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 Kaianga must be used. This is the measured flow, plus the removals for irrigation and stockwater.

2.6.2 The Rakaia River

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 (Ashburton), and 9 m^3/s to the north of the river (Central Plains). In addition there is 1.9 m^3/s allocated for stockwater. Of this 29.5 m^3/s, the Barrhill-Chertsey water has the lowest priority. Barrhill-Chertsey's consent is for irrigation and power generation. All other consents are for irrigation only, but under the existing allocation regime are assumed to occur year round.

The 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 8 m^3/s and the ACWT proposes to take 32 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 2-6. For each month Table 2-4 details the NWCO minimum Rakaia River flows, 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, that 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 instream values/uses. Table 2-6 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.

Table 2-6: 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 full 70 m3/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

2.6.3 Joint Rakaia Water Sharing Study with ACWT

A report was commissioned to assess the interaction between the Ashburton Community Water Trust's proposals and the Central Plains proposals (Lincoln Environmental, 2001). The models used in the separate studies were combined to assess the effects of the current proposals on each other and to assess options for shared use of the Rakaia River. Assumptions used in the report and the findings are summarised below.

For both Ashburton and Central Plains, the models were set up to represent the option that is most sensitive to the availability of Rakaia River water.

Ashburton infrastructure

- Stour Reservoir (390 MCM) fed from Potts, South Ashburton, and Cameron intakes.
- Channel capacities – 30 m^3/s run-of-river intake from Rangitata, and 40 m^3/s intake from Rakaia.
- RDR schemes modelled as per existing.
- Irrigation demand was first met from the Rangitata River, then the Rakaia River and finally from storage.

Central Plains infrastructure

- Wairiri Valley storage (250 MCM) fed by pumping (max 19 m^3/s) from the Rakaia River water via the run-of-river canal - Note: both the Ashburton and Central Plains scoping studies include the Rakaia riparian area (a one kilometre strip along both sides of the river). When this overlap is removed, the reliability criteria for Central Plains can be met with a 19m^3/s pump capacity.
- Channel capacities – 40 m^3/s run-of-river intake from Waimakariri River, and 40 m^3/s intake from the Rakaia River.
- Irrigation demand was first met from the Waimakariri River, then the Rakaia River and finally from storage.

Assumptions on Sharing between the Two Scheme Proposals

There were two decision steps applied in the combined model to allocate water to the two schemes. First was the initial allocation rule that calculated how much of the available water each scheme received.

The second decision was whether or not the two schemes will be managed co-operatively. All takes to the proposed schemes will be metered and able to be adjusted in real time. There is therefore considerable potential to operate the two schemes co-operatively so that when one side does not need their allocation, the other side has access to it. With this arrangement, the peak rates of take into each scheme could be 40 m^3/s but at all times the combined take would comply with the NWCO.

A number of different assumptions were made over the sharing. These were:

- The sharing of the water was such that both schemes obtained comparable reliability.
- Existing abstractors maintained their priority rights to water.
- CPWE and ACWT would maintain equal priority access to the available water.
- Water not used by one scheme would be available to the other on a real time basis.

- Water presently allocated to the "North Irrigators" would be available to CPWE for winter abstraction to replenish the reservoir.

There were a number of different scenarios considered, however the above formed the basis for equitable sharing of the resource and agreement between ACWT and CPWE.

2.6.4 Results of the Joint Study

"Existing-Consents-As-Is" with 9m^3/s available to CPWE in the winter

When the existing consents were operated "as is" with existing priorities, the water allocation and sharing rules can be visualised using Figure 2-4. The presently unallocated water was divided to give an 80:20 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 2-4. 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 Figure 2-4. The in between flows require the take to be reduced proportionately.

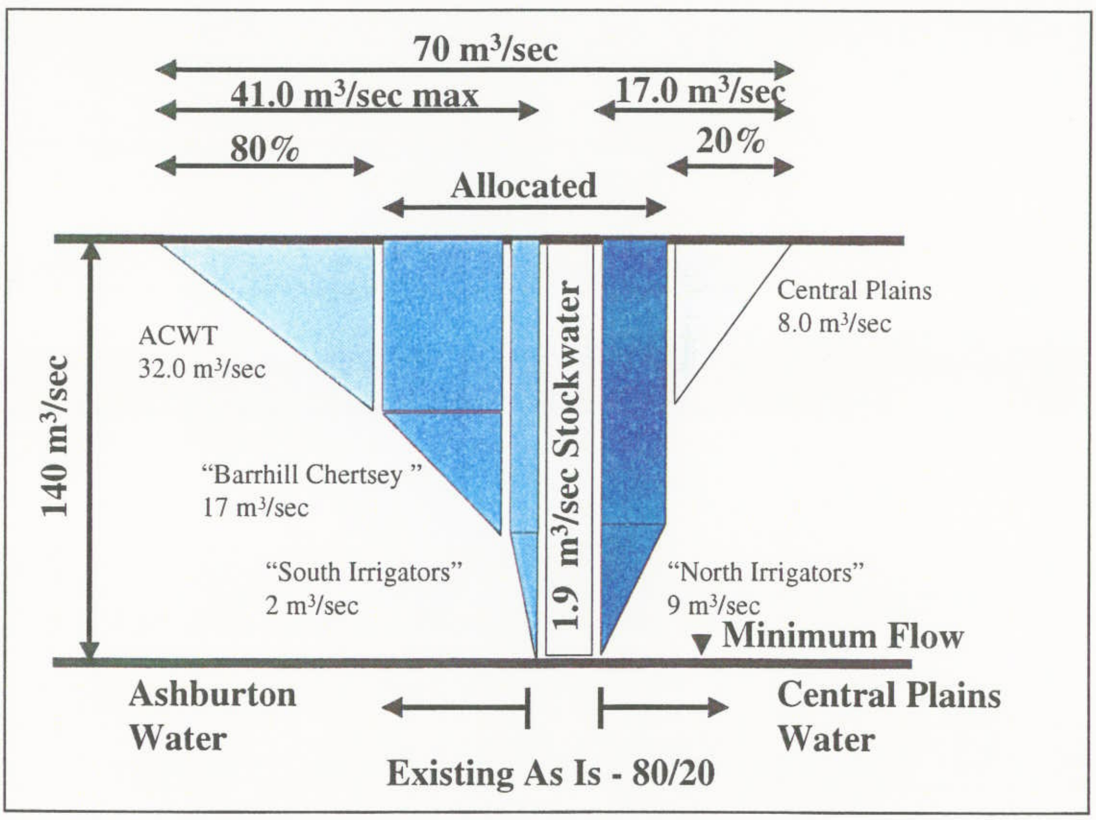

Figure 2-4: Existing As Is Sharing Scenario

2.6.5 Key Conclusions for Central Plains for Sharing the Rakaia River

- The Ashburton proposal is more sensitive to the availability of water from the Rakaia River than Central Plains. However, the Central Plains water proposal is sensitive to the sharing rules on the Rakaia River, and the exercise of existing consents.
- The loss of water due to sharing with Ashburton can be compensated for by increased access to water over the winter to fill the storage volume.

2.7 Access to High Priority Rakaia Water

The ability to acquire higher priority water from the Rakaia River was evaluated. High priority water is water that would be available for longer times during the dry periods of the year. This would reduce the size of the reservoir needed to meet the demands of the scheme. This water would have to be "purchased" from the northern irrigators on the Rakaia River.

The analysis was conducted for the period from June 1972- May 2000 for the 84,000 ha scheme. The smaller range was used because of the limited ability to modify selected portions of the Rakaia River data. The evaluation of the impacts was conducted by limiting the size of the storage until there were no days where demand exceeded the supply. Table 2-7 shows the resultant reservoir volume for the various high priority flows from the Rakaia.

Table 2-7: Modified storage requirements based on access to high priority Rakaia Water

High Priority Rakaia Water (cumecs)	Reservoir Volume (MCM)
4	250
6	230
8	220

The access to this water can only be obtained through negotiation with the existing irrigators from the lower Rakaia River. Discussions at a very preliminary level have indicated a willingness to discuss options. This will need to be advanced in the subsequent stages of this project.

2.8 Scheme Requirements

The reliability of run-of-river supply for this zone was assessed by comparing the time series of daily demand over the 33 year simulation with the daily time series of flows available from the Rakaia and

Waimakariri Rivers combined. The available water in the two rivers combined is capable of meeting the full demand only 79% of the time with 50 % of the demand being met 88% of the time.

There is therefore insufficient flow available from the rivers to provide a sufficiently reliable run-of-river water supply to irrigate the whole of the surface water supplied zone.

Storage via a reservoir system is an obvious option to improve the reliability of supply to the Community Scheme Zone. However, storage requires that there is enough water available on an annual basis to meet demand. In all 33 years, there was an average flow rate of $62m^3/s$ available for allocation from the Rakaia and Waimakariri Rivers. These flow figures indicate that the river flows could, with sufficient storage, provide a constant flow of $62m^3/s$ throughout each year. Given that irrigation water is only required for at most 8 months, there is more than sufficient water available to meet the irrigation demand. The issue is more a mismatch of supply and demand than a water availability problem.

Determination of Storage requirements

Computer modelling using daily times series of supply and demand for water, including the operation of storage facilities, was used to determine storage options. Water supply was a daily time series of water availability from the Rakaia and Waimakariri Rivers (added together), allowing for existing takes. Irrigation requirements for the riparian zones were given priority over water to the scheme. Simulations were run over 33 years from the 1967/70 season to the 2000/2001 season. Any surplus water was routed to the storage if it was needed to restore the storage to full capacity. When the supply from the rivers was insufficient to meet demand the shortfall was met by drawing water from storage.

A 290 MCM (million cubic metres) storage enabled full irrigation requirements to be met on all but four occasions in the 33 years simulated. With the maximum continuous period without water being 16 days.

2.9 Scheme Description

The base scheme has been referred to previously as the Wairiri Pumped Option. This refers to the use of the Wairiri Valley as the storage reservoir for water that is to be used during times water cannot be abstracted from the Waimakariri and Rakaia Rivers due to low flow restrictions. It also refers to the fact that the reservoir must be filled by pumping water from the headrace canal into the valley. Figure 2-5 outlines the main components of the scheme which include:

- A dam across the eastern mouth of the Wairiri Valley to provide a storage reservoir.
- An intake with fish screens and sediment control on the Rakaia River.
- An intake with fish screens and sediment control on the Waimakariri River.
- A pump station within the Rakaia River channel which would pump water from the stilling basin up onto the higher terraces above.

- A feeder canal from the pump station discharge into the head of the Wairiri Valley at Glenroy to fill the reservoir.
- A discharge canal from the reservoir adjacent to the Selwyn River, feeding into the main headrace.
- A level headrace canal with a nominal operating water surface level of 235m MAMSL (metres above mean sea level) connecting the stilling basins in each of the Rakaia and Waimakariri Rivers.
- An intake and pump station adjacent to the Kowai River to provide water to the Springfield/Sheffield area.

The operation would involve delivering water to the supply area from run of river water via the headrace system when water is available in the rivers with the shortfall being made up from storage. The order of priority of source shall be as follows.

1. Supply from available run of river water in the Rakaia River (subject to sharing with ACWT).
2. Supply from available run of river water in the Waimakariri River.
3. Supply from storage during periods when run of river water is not available to meet the demand.

During periods when the supply exceeds the demand, surplus water will be delivered to the Wairiri Reservoir to replenish storage.

The scheme operates by taking water from each of the two rivers when it is available. Rules governing these takes have been developed that provide for the priority use of existing irrigators on the Rakaia River while at the same time not contravening the total abstraction limits specified by the Rakaia River National Water Conservation Order. In addition the take from the Waimakariri River will work within the abstraction limits and low flow criteria established under the Proposed Waimakariri River Regional Plan.

When water is available for abstraction under these rules, and there is a demand for water on the Central Plains, water is taken for irrigation as a first priority. At any time when the supply of water exceeds the demand for irrigation or enhancement opportunities, and the Wairiri Reservoir is not full, water is pumped into the high level feeder canal to replenish the reservoir.

At times when the demand for irrigation water exceeds that available from the rivers, then additional water is discharged from the reservoir into the headrace canal for distribution across the plains.

Below the headrace canal will be a number of distribution canals distributing the water throughout the community supply zone. Each farm will be provided with an abstraction point from which they will have access to pump water into their on farm irrigation system. The distribution in the race system will be operated as a demand driven system with the amount of water released into the system matching the water requirements with an allowance for losses and bywash. The operation of the distribution system will be automated to enable management of the system from a central location.

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CENTRAL PLAINS
IRRIGATION SCHEME COMPONENTS
FIGURE 2-5

The community scheme does not include any on-farm irrigation works. It will supply water to the farm gate, and from that point onwards, it becomes the responsibility of the farmer to provide the infrastructure to utilise the water.

The main components of the scheme are discussed in detail in the following sections.

2.10 River Intakes

2.10.1 Waimakariri River Intake

The proposed intake site is at the Waimakariri Gorge bridge. Siting it on the upstream side of the gorge, on the outside of a stable river bend, is expected to minimise the chances of significant bed degradation occurring, and reduce the risk of sediment build up in front of the intake. This has been a major problem for Waimakariri Irrigation Ltd. The additional cost of a tunnel intake compared to a canal intake will need to be resolved in the design stage depending upon the operational cost savings from cleaning.

A stock water race intake slightly downstream of the recommended intake is founded in rock, and is understood to have operated satisfactorily for many years.

The intake system as depicted in Figure 2-7 would comprise:

- an automatically controlled gate at the diversion point;
- a low diversion weir in the river (~ 1.2 metres);
- approximately 500 metres of tunnel that conveys the flow into a 750 metre long coarse sediment trap /sediment flushing race;
- sluice gate, by-wash weir and sluice channel leading back to a natural river braid;
- fish screens and a fish pass leading back to an active natural river braid;
- a fine sediment settling pond;
- control gates for regulating flow into the terrace channel.

The intake systems characteristics are largely determined by the need for sediment management and fish exclusion. The by-wash weir set in parallel with the sluice gate is intended to function as an emergency by-wash only, have a nominal operating capacity of 50 m^3/s, and discharge into the same channel as the sluice gate.

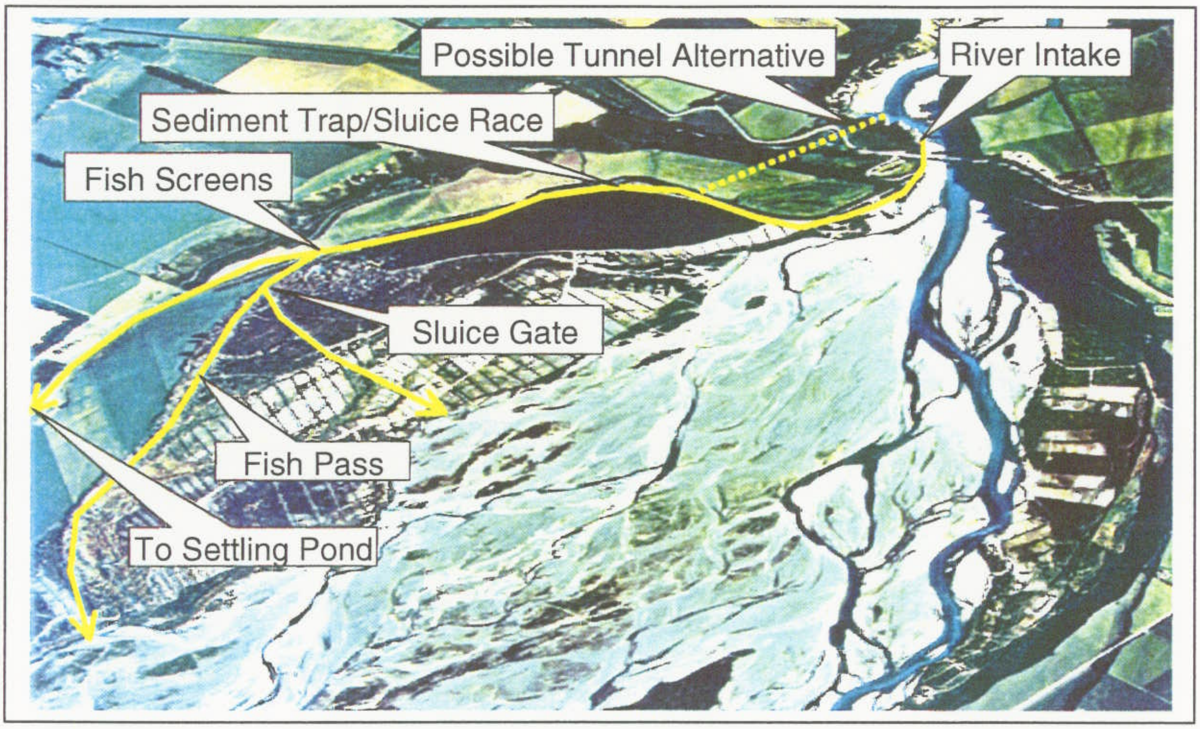


Figure 2-7: Waimakariri Intake – General Layout

Sediment Management

A large number of sediment trapping and removal options were investigated in 1985 as part of the Lower Rakaia Irrigation Scheme engineering feasibility study (MWD, 1985). This study concluded that the combination of a short sluice race, which firstly traps and then periodically sluices out coarse sediments, and a settling pond for trapping the fine sediments was the best option for managing sediment from a braided river such as the Rakaia. This approach, and the associated design criteria, have been adopted for this investigation.

Preliminary design of the intake has assumed a maximum diversion rate of 50 m^3/s. Sediment flushing has been designed to occur under a sustained flow of 50 m^3/s. The initial flushing flow is approximately double this flow rate, but drops rapidly.

The proposed dimensions of the intake section and sluice race section are shown in Figure 2-8. The tunnel section is designed to convey sediment from the intake gate into the sluice race with minimum deposition.

With the sluice gate closed, the flow velocity in the sluice race varies between 0.5 m/s and 1 m/s. The sluicing velocity, at a flow of 50 m^3/s, is approximately 2.4 m/s.

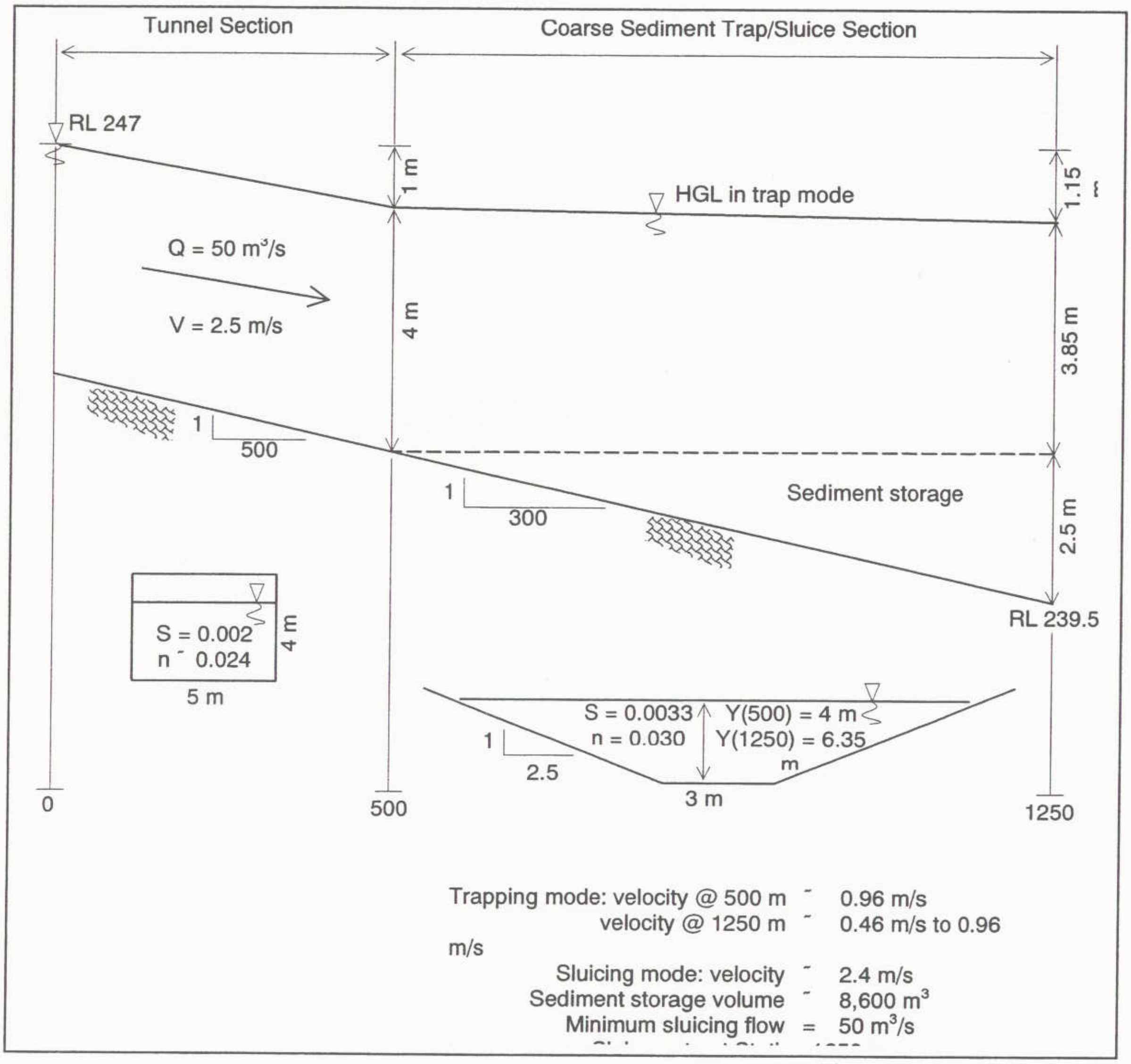


Figure 2-8: Waimakariri Intake – Sediment Trap/Sluice System

The operation of the sediment sluice race was modelled using mean daily river flow data, a sediment rating developed by Griffiths (1979), and an operating strategy that sluices sediment every night, provided the mean daily river flow is greater than or equal to 300 m^3/s. The period of analysis was 1972 to 2000. It was assumed that all of the flow available to the scheme, under the prevailing water allocation rules, would be abstracted. The mean annual actual take would be less than this, but takes are likely to be at their maximum allowable at times when both the river flow and sediment concentration are high.

Sediment sluicing would occur for up to 2.25 hours, depending on how much sediment is to be removed. This is based on the assumption that the outlet sediment concentration would be 3%, which is at the bottom end of the range used by MWD (1985).

The proportion of time a specific mass of sediment is settled in the sluice race is shown in Figure 2-9, together with the cumulative distribution function for the mass of settled sediment. The capacity of the sluice race is sufficient to meet sediment storage requirements for better than 95% of the time.

The days when the storage capacity is insufficient are associated with days of river flow in excess of 1000 m^3/s. This establishes a constraint on the operation of the intake that results in the intake being closed for 18 days over the period of analysis (based on excess sediment accumulation). This constraint is identical to that which is necessary on the Rakaia River takes to avoid sediment over-load.

To increase the removal of fine sediments it will be necessary to pass the flow through a settling pond. A pond that reduces flow velocity to 0.05 m/s and provides a detention time of about 3 hours was estimated by MWD (1985) to increase the sediment trapping efficiency of the intake system to 78%. A pond with a depth of 3.5 metres, of which up to 0.5 would accumulate sediment, 350 metres width and 550 metre long would meet the velocity and detention time requirements. This pond would require mechanical cleaning every five or six years. Potential locations for this pond have not been identified.

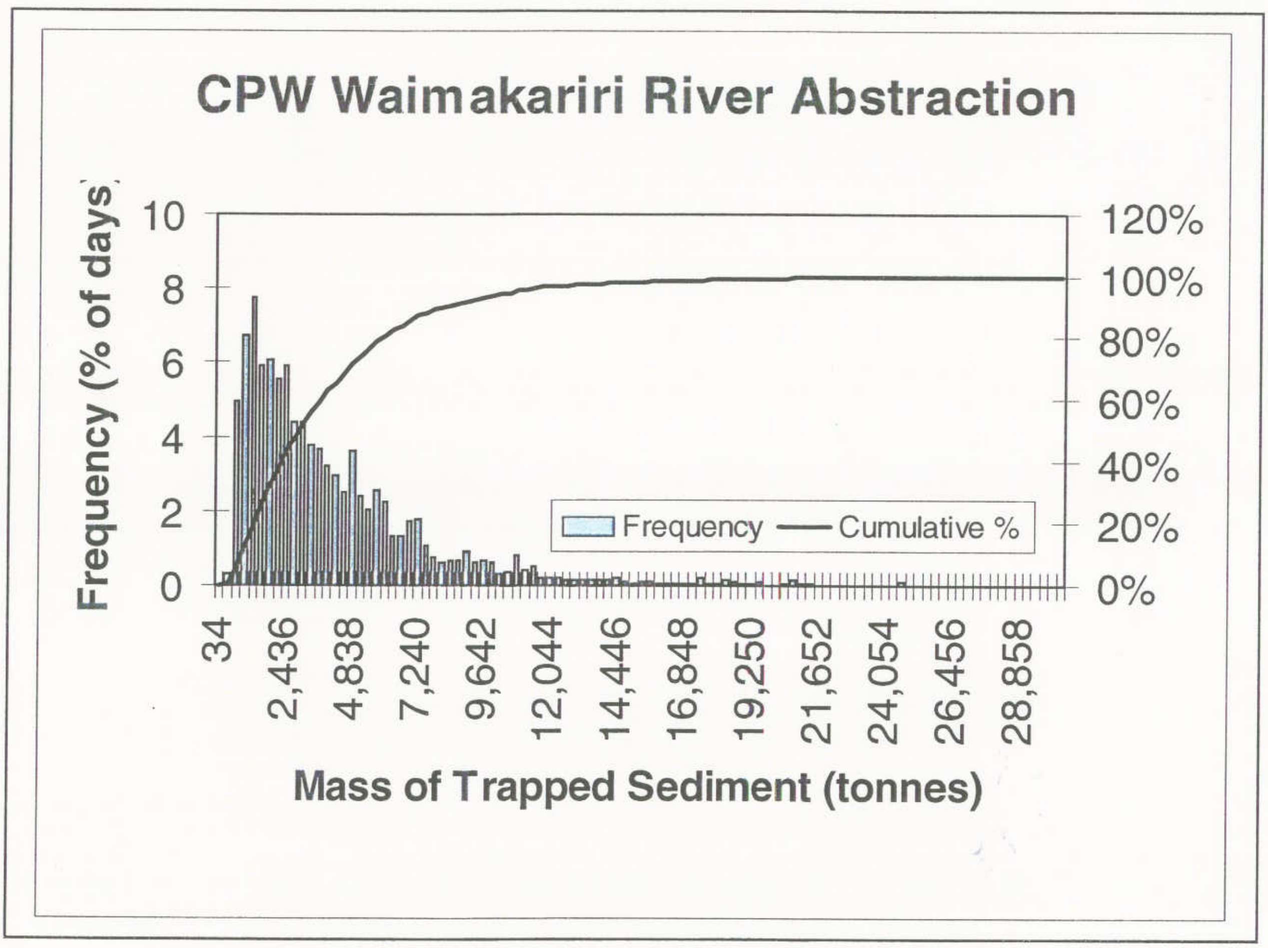


Figure 2-9:Waimakariri Intake – Sediment in Storage

Fish Exclusion

All flow to the terrace race would pass through a bank of flat stationary screens set into the race in the same plane as the race batters (2.5:1). The submerged height of the screens is designed to be 8 metres, and a width of 4 metres. The screens are arranged in two banks of 8 screens each, set on opposite sides of the channel. This screen area is sufficient to provide an average water velocity through the screen of less than 0.12 m/s. A screen aperture size of 5 mm is required to exclude salmon smolt.

Fish travelling down stream past the screens would be conveyed back to the river via an open, smooth chute. The outlet of the chute would drop approximately 1.2 metres into a pool in an active river braid, and thus function as a "velocity trap" to prevent upward migration of fish.

The location of the fish screens within the sediment trap/sluice system is shown in Figure 2-10.

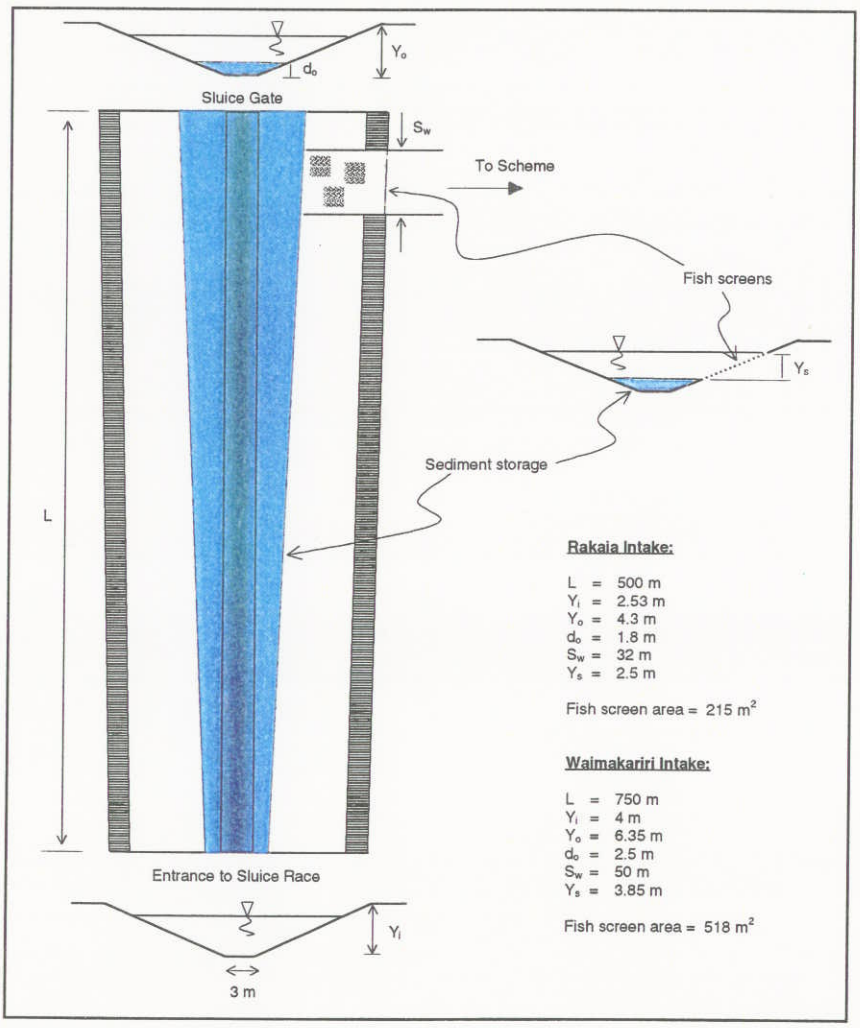


Figure 2-10: Intakes – Location of Fish Screens within the Intake System

By-wash

The general arrangement of sluice gate, fish pass and by wash is shown in Figure 2-11.

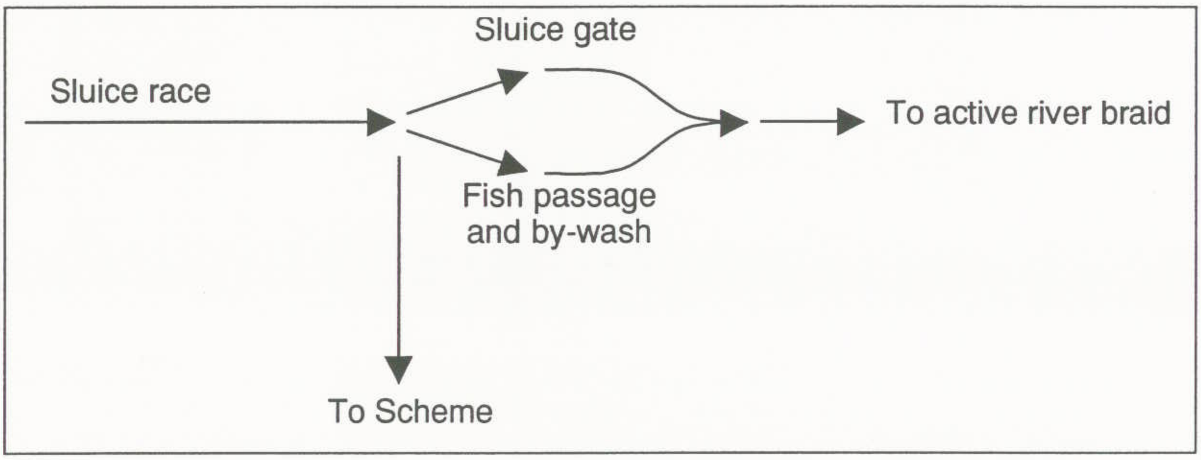


Figure 2-11: General Sluice Gate and Fish pass arrangement

Capacity to by-wash 15% of the design take will be provided for. It is necessary to provide safe passage for any mismatch between the take and fish pass flow and the flow rate diverted from the river. As the diversion is automated, the mismatch should normally be only that due to measurement and control tolerances. To handle a failure, such as diversion gate stuck open and zero take, it will be necessary to open the sluice gate.

Fish pass

The fish pass flow required is that which is necessary to maintain a flow depth of ≥300 mm, particularly in the channel that leads back to an active river braid. At both CPWE intakes, there should be sufficient head to enable use of a velocity trap. This means the intake and fish pass only has to accommodate fish moving downstream.

It is proposed that a compound weir would be used in parallel with the sluice gate. The inner section of weir will be sized for a continuous flow of 1 m^3/s (which should be sufficient to maintain flow depth in the channel leading back to an active river braid). The outer section will be sized to convey a flow of 15% of the design take.

The flow over the weir would be conveyed via open chute to the channel the sluice gate discharges to. By doing so, a flow of at least 1 m^3/s is maintained in this channel. The velocity trap (weir 1.2 m high) will be located at the end of the chute, where it joins the sluice channel.

The fish pass would not serve species that prefer to remain near the channel bottom. Daily operation of the sluice gate will provide passage for these species.

2.10.2 Rakaia River Intake

The Rakaia River intake concept is identical to that for the Waimakariri river intake, except the diversion from the river would be via box culverts through river protection works, rather than through a short tunnel. The layout for the Rakaia intake is shown in Figures 2-12 and 2-13.

Preliminary design of the intake has assumed a maximum diversion rate of 40 m^3/s. Sediment flushing has been designed to occur under a sustained flow of 40 m^3/s. The initial flushing flow is approximately 80 m^3/s, but drops rapidly.

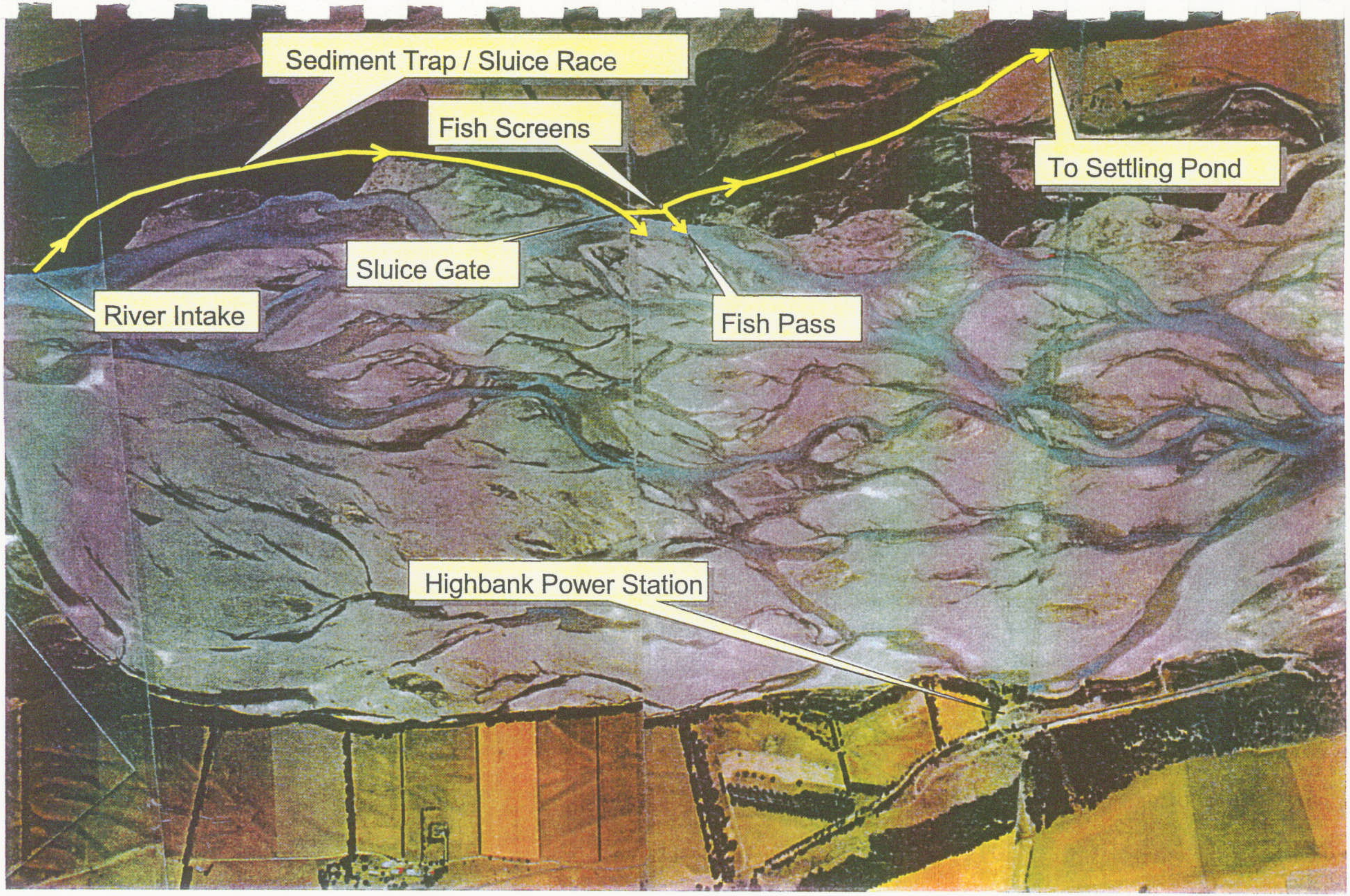
The proposed dimensions of the intake section and sluice race section are shown in Figure 2-13. The intake section is designed to convey sediment from the intake gate into the sluice race with minimum deposition.

With the sluice gate closed, the flow velocity in the sluice race varies between 0.5 m/s and 1 m/s. The sluicing velocity, at a flow of 40 m^3/s, is approximately 2.4 m/s.

Sediment sluicing would occur for up to 1 hours, depending on how much sediment is to be removed. This is based on the assumption that the outlet sediment concentration would be 3%, which is at the bottom end of the range used by MWD (1985).

The proportion of time a specific mass of sediment is settled in the sluice race is shown in Figure 2-14, together with the cumulative distribution function for the mass of settled sediment. The capacity of the sluice race is sufficient to meet sediment storage requirements for better than 95% of the time.

The days when the storage capacity is insufficient are associated with days of river flow in excess of 1000 m^3/s. The scheme intake would be shut down during these periods.



DRN: JCB CKD: DNB DATE: 2 Nov 2001 © LINCOLN VENTURES LTD	CPW Water Supply Enhancement Scheme: Rakaia River Intake	CPW Rakaia River Intake **Figure 12-2**	LINCOLN ENVIRONMENTAL A division of Lincoln Ventures Ltd

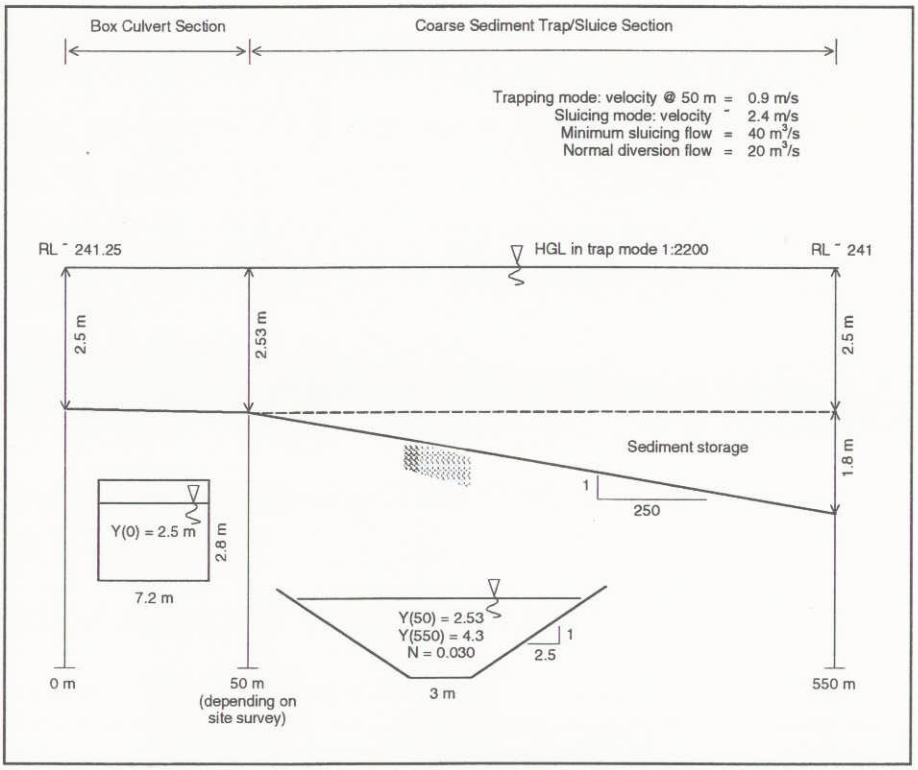


Figure 2-13: CPW Rakaia Intake Profile

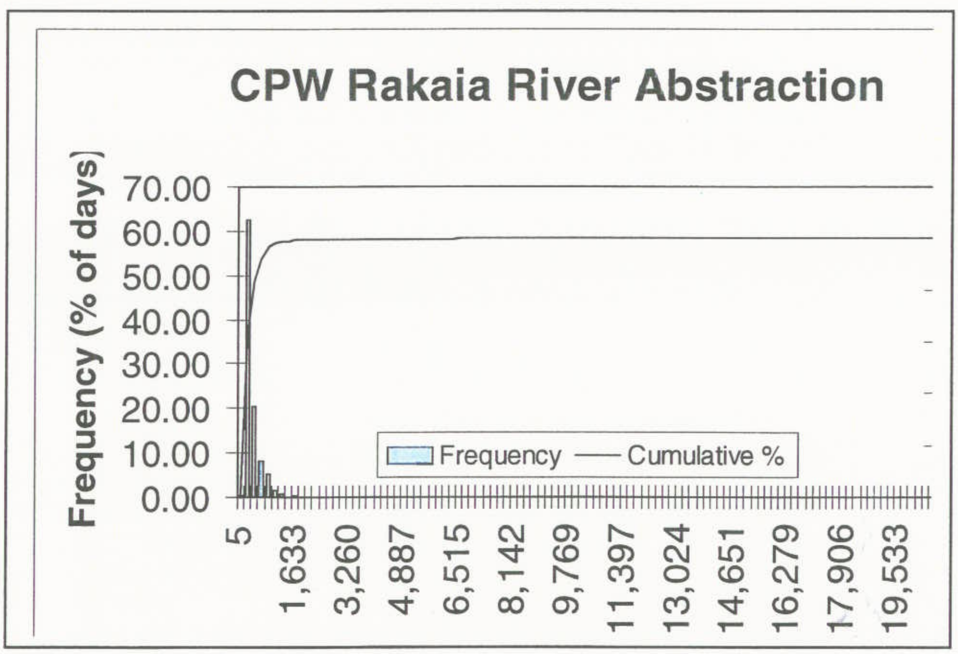


Figure 2-14: Rakaia River Intake Sediment in Storage

2.11 Pump Stations

Preliminary pump station design for feasibility provides flexibility to pump the required flow in 1 m^3/s increments, to allow for restrictions in the allowable abstraction rate at times of low river flows. Standby pumping capacity has not been provided on the basis that maintenance and repairs can be carried out during the wetter seasons and the cost of standby units would not be warranted. Having multiple pumps also means that standby is not necessary, as it is relatively infrequently that all pumps are required to operate all at the same time.

The pump station layouts consist of a concrete dry well housing the pumps located adjacent to the stilling pond, which receives water from the river off take. The proposed pumps are conventional dry-mounted, vertical shaft, split-casing, double suction pumps, installed in parallel. These pumps are designed for pumping large flows at high heads. Vertical mounting allows the motors to be located above probable water levels and reduces the horizontal distance between pump centrelines, resulting in a smaller overall pump station size. Large capacity air release valves would be installed at each pump station to allow any air to be exhausted from the pipelines.

The pump station building would consist of a steel frame, with standard steel cladding, incorporating an overhead travelling crane capable of lifting the heaviest separate item of equipment in the station (eg. a motor). To allow for the height of the pumps (6 to 8m) and crane, an overall building height (floor to ceiling) of 13 to 15 m would be required. The building would be force ventilated with fans to provide cooling for the motors, It has been assumed that there would be no specific requirement for sound insulation as the pump stations are located away from populated areas.

A preliminary surge analysis has indicated that pump stations will require the use of surge tanks or feed tanks to protect the pipeline and pumps against water hammer in the normal function of starting and stopping and in the case where all pumps stop suddenly in due to a power supply failure. It should be emphasised that the surge analysis was only a preliminary assessment involving many assumptions. Detailed designs may vary these assumptions requiring greater or lesser levels or alternative methods of protection.

The pump station would have a power requirement of approximately 22 MW. Discussions with Orion has indicated that a special power supply would be brought to the site most probably from the Hororata Substation.

A general arrangement for this pump station is contained in Figure 2-15.

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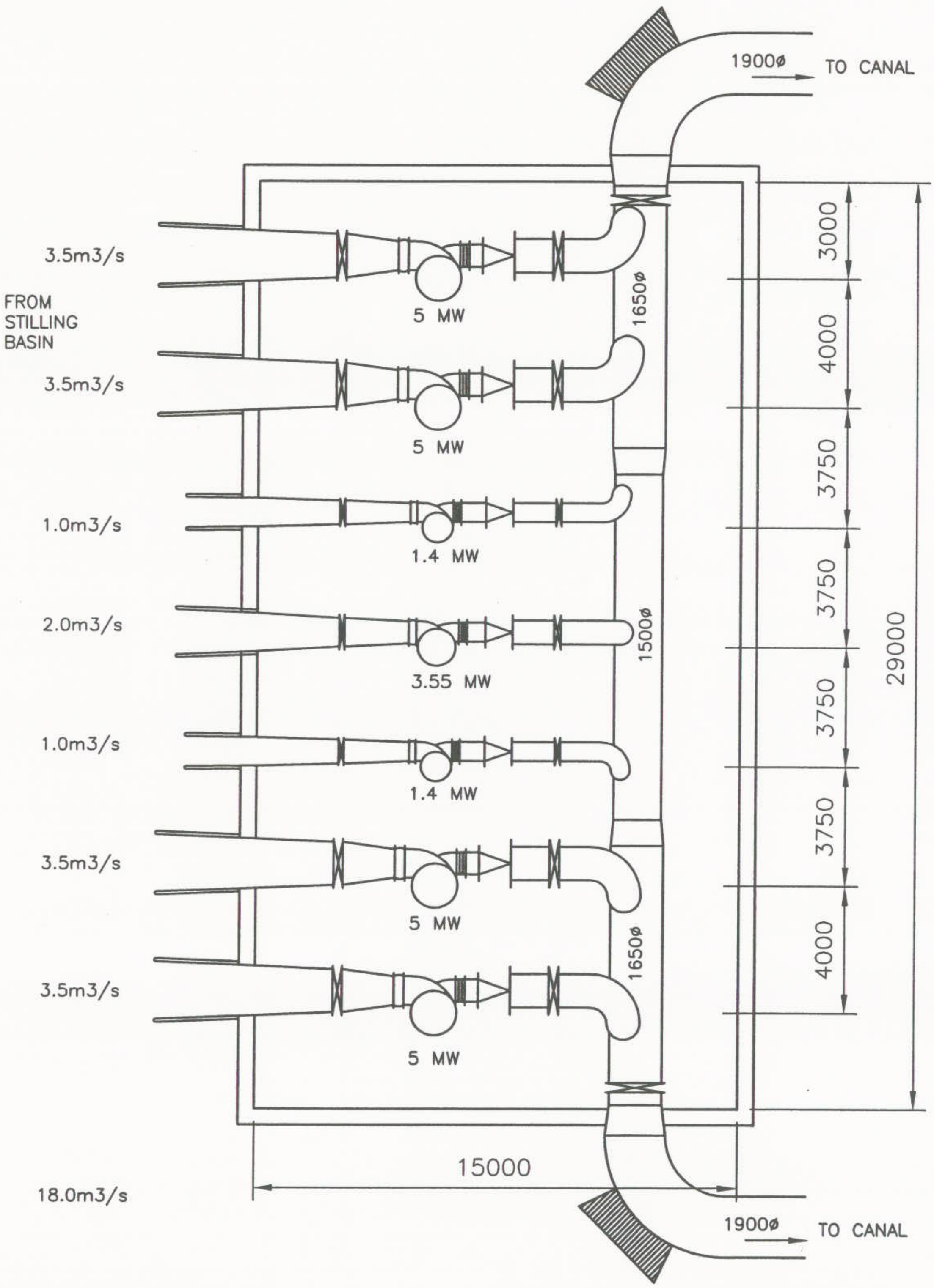

DIMENSIONS AND LAYOUT ON THIS
DRAWING ARE INDICATIVE ONLY.
SUBJECT TO FINAL DESIGN.

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Title
RAKAIA PUMPSTATION

Figure No. **2-15**

2.12 Storage Reservoir

The water storage reservoir is to be located in the Wairiri valley. The lake will be approximately 6.5km long and 1-2km wide with an average depth of around 30 metres. The extent of the lake is shown on Figure 4-2. The water surface is required to reach an elevation of approximately 318 m to contain the required 290 million cubic metres of water.

The lake will be contained by a large embankment dam located at the downstream end of the valley, some 2.5 kilometres from Glentunnel. The main embankment dam has a crest length of 640 metres between the two abutments. As the left abutment has an elevation of only 306 m the embankment is required to extend along the crest of the ridge on the north-western side of the reservoir for an additional 1700 metres. A low point in the ridge (RL 307 m) adjacent to the New Zealand Defence Force (NZDF) site will also require an additional 1100 metre-long embankment. There are three other low points at the head of the valley. Two of these will require minor embankments (<5m high) and the third (RL 318m, at Glenroy) will form the inlet from the Windwhistle canal that delivers water from the Rakaia pumping station.

While the reservoir water level will lower during times of high water demand, the lake will be available for recreation for significant parts of the year. Access for recreation will be provided both at the Glenroy and the Glentunnel ends of the Lake.

2.12.1 Main embankment design

The main embankment will be a zoned earthfill structure with a low-permeability core and free-draining shoulders. A typical cross section through the dam is shown in Figure 2-16. The total height of the dam is 72 metres, with the crest being 52 metres above the existing valley floor. Shoulder slopes of 2.5 (horizontal) to 1 (vertical) will be required to achieve the necessary seismic stability. A reinforced concrete outlet tower will allow water to flow into the outlet canal towards the head race.

The core will be constructed from weathered silty gravels sourced from within the reservoir. Suitable construction materials for the embankment shoulders include sandy greywacke gravels from large deposits downstream of the dam site and weathered sandy gravels from within the reservoir. It is likely that a combination of these will be used to achieve the necessary free-draining and high-strength characteristics of the shoulders. The embankment will be designed to meet stringent requirements for stability under high seismic loading and appropriate water-level drawdown rates for irrigation supply.

The main embankment site is underlain by approximately 20 metres of generally soft saturated sediments above weak tertiary sandstones. The most practical foundation option for the embankment is to excavate the underlying soft sandy silts from beneath the dam footprint to the tertiary rock contact. The excavated sediments will be spread across the valley floor upstream of the dam. Provision for dewatering will be necessary to maintain this excavation during construction. A low-permeability cut-off trench constructed through the stiff sand and into the basement rock will limit seepage.

It is expected that most of the upstream face of the dam will require riprap protection from wave and current erosion as the reservoir water levels will vary significantly. Suitable riprap should be available from the strong blocky volcanic rocks that outcrop around the reservoir.

The dam concept design has assumed full excavation of the marine sediments below the dam foot print. This is a conservative assumption and has been adopted at this to provide realistically high costs for the dam. The marine sediments may be subject to liquefaction during earthquakes, therefore their removal as proposed fully mitigates this risk. The sediments are also weak, and may not be able to support the weight of the dam embankments. Removal also mitigates this risk fully. It may be possible to found the dam on these sediments, reducing excavation and fill volumes significantly, by pre-loading the sediments to increase their strength. This option could only be considered at the design investigation stage, when more geotechnical data would be obtained.

A Roller Compacted Concrete (RCC) dam concept was considered, however this was more expensive and at this stage technically a higher construction risk. With suitable shoulder and core fill material available within the Wairiri Valley, earthworks costs are low. Therefore the cost advantages of reducing fill material by adding cement are diminished in this situation. In addition, a RCC dam has a smaller footprint which would place higher loads on the foundation material, which is this case is a weak sandstone. Therefore without further geotechnical information and specific design, an RCC dam construction option is not recommended.

2.12.2 Ridge embankment design

The ridge embankments are generally underlain by tertiary siltstone/sandstone covered by no more than a few metres of residual soil or loess. In some places weathered gravels corresponding to the Hororata Formation may be up to 10 m deep. The likely design option for the ridge embankment will again be zoned earthfill with a low permeability core and cut-off trench to limit seepage. Where the ridge dam is smaller a homogeneous earthfill embankment constructed from relatively impermeable compacted silty gravels will be more appropriate.

The choice of a smaller volume reservoir will have a significant effect on the size and length of the ridge dams:

- For a storage capacity of 290 million m^3 (RL ~318 m), the total length of ridge embankments is 2800 metres with an average total height of 17 metres and an average base width of 92 metres.
- For a storage capacity of 250 million m^3 (RL ~314 m), the total length of ridge embankments is 2500 metres with an average total height of 13 metres and an average base width of 70 metres.
- For a storage capacity of 220 million m^3 (RL ~310 m), the total length of ridge embankments is 2200 metres with an average total height of 10 metres and an average base width of 52 metres.

2.12.3 Safety features

Since the reservoir site has only minor inflows and a very small catchment area there is little risk of overtopping the embankment during rainstorm or flood events. The freeboard height of at least 2 m between the maximum water level and the embankment crest will be designed to allow for seiching and rainstorm events. A small spillway will provide additional protection against erosion and overtopping the embankment crest, while a dam break analysis will be carried out as part of the consenting process.

2.13 Source of Stored Water

The water stored in the reservoir originates from the Waimakariri and Rakaia Rivers. The amount from each source can vary depending on the year and the operational decisions of the scheme. If maximum available water was taken from the Rakaia then the Rakaia water on average will constitute 22 percent of the water pumped to storage. If minimum available water was taken from the Rakaia then the Rakaia water on average will constitute 4 percent of the water pumped to storage. For the worst year, the values were 41 and 19 percent respectively.

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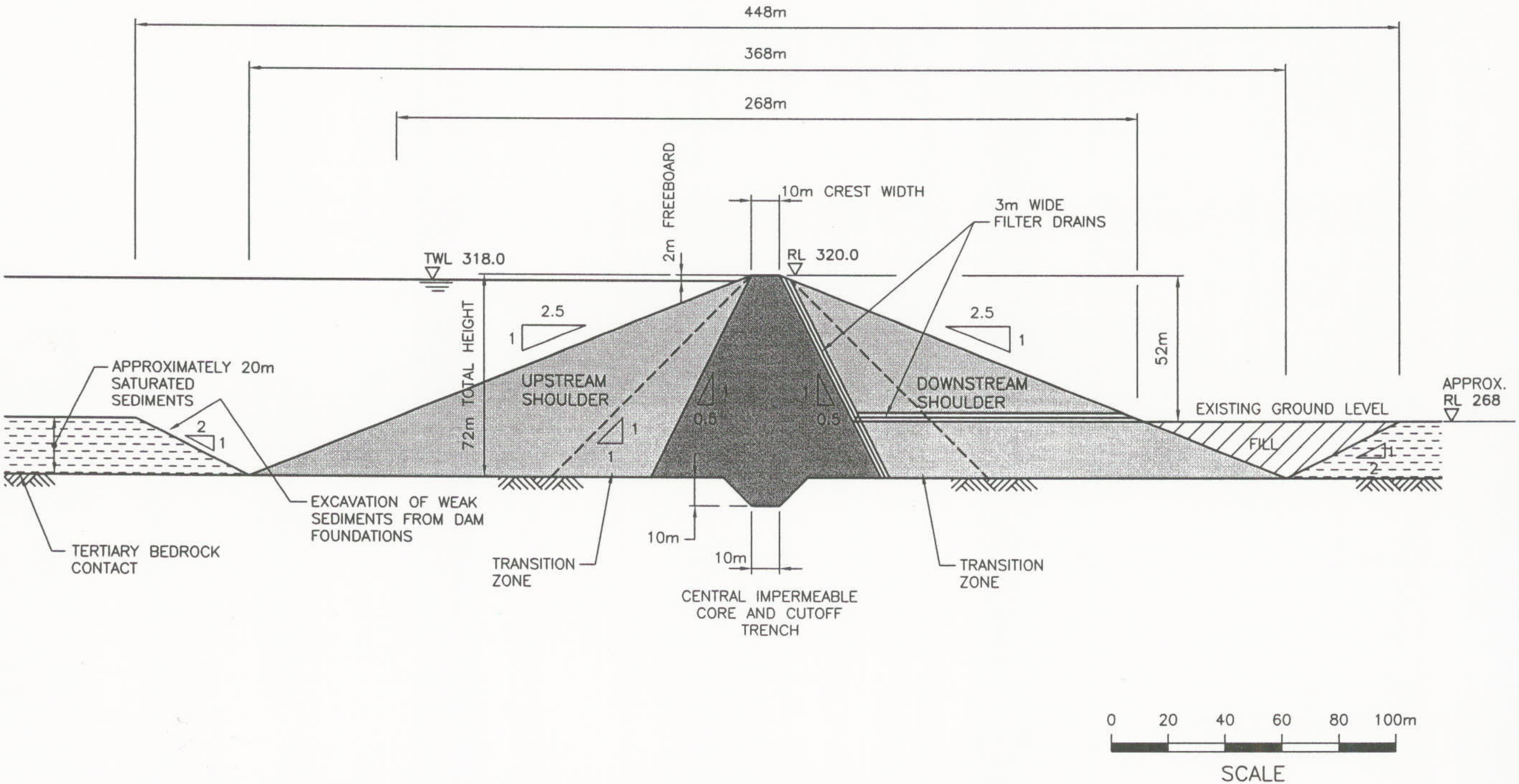

TYPICAL CROSS SECTION – WAIRIRI EMBANKMENT DAM
(FOR 290Mm³ STORAGE)

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Figure No. **FIGURE 2-16**

2.14 Exposed Reservoir Area

As the reservoir is drawn down during the irrigation season, the proportion of the reservoir bottom exposed will increase. The change in area in the upper portion of the reservoir is small when compared to the lower portion of the reservoir. The lower portion of the reservoir is only exposed during extreme events. Figure 2-17 shows the area of the reservoir (290 MCM) exposed as a percentage of time during the period of record and the associated reservoir volume. The water surface area of the reservoir at 290 MCM is approximately 945 ha. For example, 130 ha of the reservoir bottom will be exposed approximately 20% of the time with a corresponding reservoir volume of approximately 155 MCM.

The drying of the reservoir could 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). Figure 2-17 provides the data on how often different areas of the lake bed will be exposed.

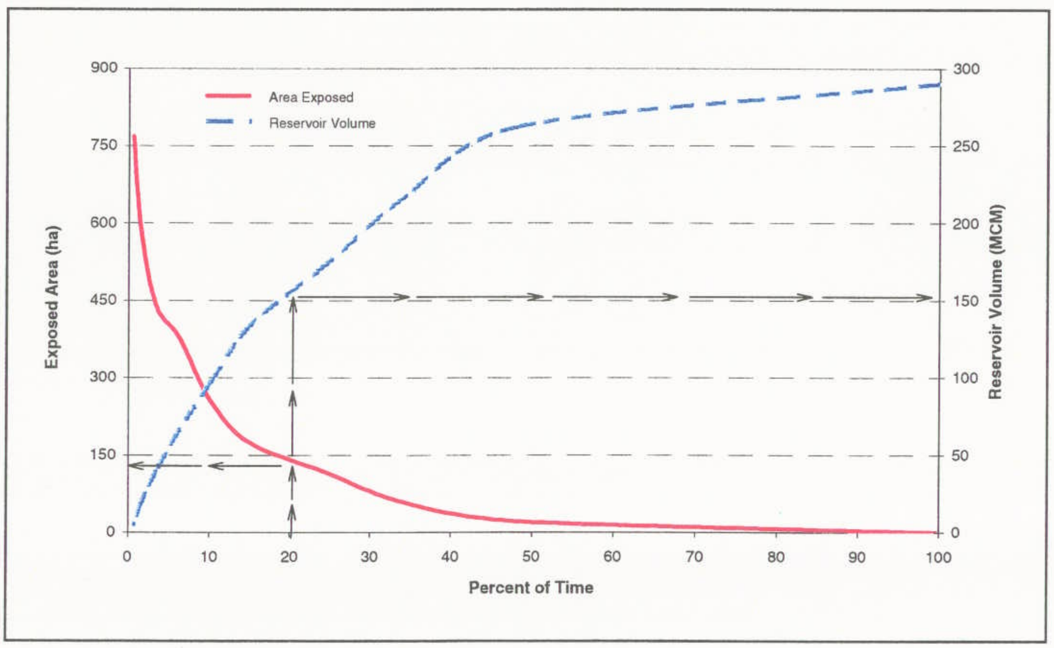

Figure 2-17: Reservoir Bottom Area Exposure and Volume

Mitigation is proposed for dust control within the reservoir by creating a series of low dykes along lines of constant level that will form ponds behind them that will not fully drain. This concept would be much like that of a rice paddy, with the incoming water from the Windwhistle canal running down into the areas behind the dykes, filling them and then cascading over into the next area. These dykes would be confined to the flat bottom areas of the valley, where the maximum benefit could be obtained from them. The cost of constructing such dykes on the sloping sides to the valley would make their construction unfeasible.

2.15 Headrace Canal

The headrace is a 56 km-long open canal designed to deliver the allocated flows of water across the width of the plains to distribution canals. Water is supplied to the headrace from intakes on both the Rakaia and Waimakariri rivers, and from the Wairiri storage reservoir via a 5.5 km-long outlet canal. Water may flow both directions in the headrace depending on different supply and demand scenarios. The canal is level across the entire width of the plains and water is induced to flow in either direction by raising the water level at the inflow locations and drawing outflows into the distribution canal system. Flow velocities are kept below 1m/s to minimise potential for scour or erosion of embankments.

2.15.1 Alignment

The headrace alignment is shown on Figure 2-5. The optimum location for the headrace follows approximately the 235m contour between the Waimakariri and Rakaia rivers. At this elevation the canal traverses gently sloping to slightly undulating topography yet maintains enough height to pass reasonably close to the storage reservoir. Any higher and the canal would require significantly larger cuts and fills around the around the base of the Harper hills near Coalgate and the Homebush foothills. The plains drop toward the coast at approximately one vertical metre for every 50-100 horizontal metres over the majority of the headrace route. As a result the exact alignment of the canal can often be shifted up to a few hundred metres from the proposed 235 m contour by altering the cut to fill ratio. This provides the flexibility to avoid important features and structures.

2.15.2 Earthworks

The headrace has a trapezoidal cross-section as shown in Figure 2-18. A bottom width of 3m and side slopes of 2.5 (horizontal) to 1 (vertical) remain constant along the entire length. The embankment height and corresponding top width are varied along the length according to the required flow capacity in each reach. Typically the canal will be designed to carry a flow depth of up to 4.0-4.5 m with a width at the design water level of 20-25 m and a total structure width (including embankments) of 40-50 m. Embankments will be designed to maintain stability and integrity under anticipated maximum seismic loads and fault movements. Cuts and fills are to be balanced to achieve the most efficient use of on-site materials.

The majority of the headrace will be constructed within in-situ alluvial outwash deposits consisting of sandy and silty gravels of various ages and degrees of weathering. A 2 km traverse around the base of the foothills behind Homebush may cut into Tertiary sandstones. Major cuts and fills in alluvial gravels, each up to 15 m high are required as the canal sidles around steep river terrace banks while climbing out of the down-cut Rakaia and Waimakariri river channels. Here the canal crosses loose colluvium covered gravel slopes. Such earthworks will require specific design for seismic loading.

Canal construction with older and siltier gravels found especially around the base of the Harper hills and Homebush ridge will provide a relatively impermeable canal lining. In some places the canals cross much more recent gravel deposits containing less fine material and exhibiting a higher permeability. This includes the lengths of headrace where it climbs terraces out of both the Waimakariri and Rakaia rivers and where the canal crosses modern river floodplains, especially the Selwyn. Over time these canals will develop a natural lining as fine silts and clays carried within the water fill open pore spaces between the larger size particles. Sections of the headrace may still require lining.

Leakage losses from the canals is a major issue that requires further investigation, as the potential loss of water from the distribution system could be very large. Leakage from the headrace can be limited at the time of construction through adequate provision of a liner along the base and sides of the canal. The liner is usually constructed by placing and compacting suitable material at a depth of approximately 300mm.

Experience from the Ministry of Works in the 1970's (Lewthwaite 2001) indicated that sealing was effective if the base material had 10% fine material, being silts and clays. Compaction of this material provided permeabilities (a measure of the leakage potential) of $1x10^{-7}$ m/s. This lead to leakage losses of about 1 % by seepage from the whole network in the Amuri Scheme.

On the basis that it will be possible to locate suitable materials along the canal route for compaction to achieve a permeability better than $1x10^{-7}$ m/s, and a lining thickness of 0.3m is provided, then the leakage from the headrace canal would be approximately 1 m^3/s. The average annual water demand for the scheme is 13.85 m^3/s, therefore a leakage loss of 1 m^3/s is approximately 7.2%.

The Lower Waitaki Power investigations (MacFarlane 1988) demonstrated that the Georgetown Gravel and Smillie Gravel, each with fines content of 8% were capable of compaction to permeabilities of 0.03 – 262 $x10^{-8}$ and 1.5 – 63.0 x 10^{-8} m/s respectively, while the Morven Gravel with only 3% silt could achieve 0.22 – 0.53 $x10^{-8}$ m/s. These gravels would be similar to most of the gravels in the scheme area.

Assessment of the leakage from the Lower Waitaki Irrigation Scheme showed that losses in the smaller distribution races exceeded the 20% total losses assumed in the scheme design (Hamilton 1994). This was determined to be from areas of race constructed using graders forming the embankments with no special compactive effort, over free draining gravels. These areas were later remedied by applying approximately 150mm of silty gravel and compacting with the wheels of the spreading graders. Conveyance losses from leakage, evaporation, bypass and other minor takes (i.e. stockwater) were then within the design parameters. This was deemed to be a more cost effective method of controlling leakage losses than lining all of the canals from the outset.

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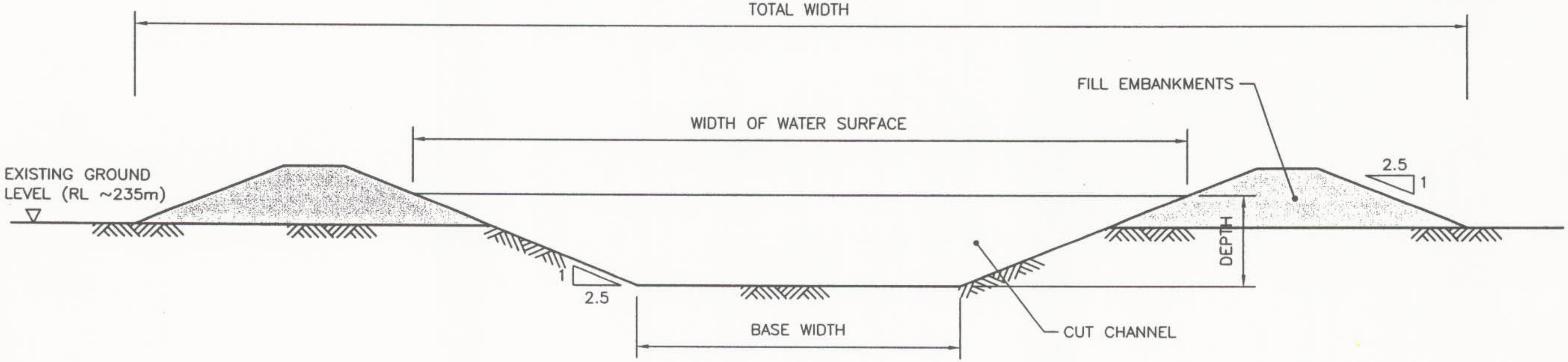

FLOW m^3/s	DEPTH (m)	BASE WIDTH (m)	WATER SURFACE WIDTH (m)	FREEBOARD (m)	EMBANKMENT SLOPE (H:V)	TOTAL WIDTH (m)
12 – 40	3.5 – 4.5	3.0	20.5 – 25.5	1.0	2.5:1	40 – 50

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Title
TYPICAL HEAD RACE CROSS SECTION

Figure No. **FIGURE 2-18**

The RDR management company undertook an assessment of the leakage losses from their approximately 67 km of main race and determined that the leakage loss was approximately 20.4 l/s/km, which was equivalent to a total scheme water loss of 4.4% (Ollett 1997). This study showed that there was a short reach (approximately 0.6 km) of canal in which the leakage losses were major and the company was proposing remedial action. This would reduce the losses mentioned above.

The RDR canals were not specifically lined, and have relied upon sealing from the silt and clay material transported in the water over the many decades that the scheme has been operating. For the Central Plains scheme, it is proposed not to rely solely on the sealing of the canals over time, as the losses in the early years could be significant in terms of the impacts on groundwater. Nevertheless it can be expected that what ever leakage rates are obtained during the commencement years, this will decrease over time.

On the basis of this local experience, it is apparent that leakage losses can be controlled to be in the order of 1 m^3/s from the headrace. In addition to this, it has been assumed that a further 1.7 m^3/s will be lost in the distribution system and further drainage from the irrigated pasture will also add to groundwater recharge.

Lining of the canal will come at a cost, and from the experience in the Amuri scheme, this added approximately 15% to the cost of the earthworks.

It will also be important during construction to pay attention to the interface between structures and the canal earthworks, as these locations have a greater potential to leak. Construction supervision will be extremely important to maintain the integrity of the scheme.

Outlet Canal

The outlet canal between the Wairiri reservoir and the headrace is designed to pass a peak flow volume of 60 m^3/s. The canal will have a water depth of 4.5 m and a width at the water level of 27 m. Embankments will require design for seismic stability with side slopes of 2.5 (H) to 1 (V), and a corresponding total width of the structure up to 50 m. An allowance has been made for half of this canal to be fully lined with weather gravels imported from off site.

The alignment follows the right bank of the Selwyn river before running beneath the river through a concrete siphon and running the final kilometre to the headrace along the left bank. In two locations where the Selwyn river runs close to it right bank the canal will be fed into concrete culverts partially buried in the side of the hill. The remainder of the canal would be constructed as a balanced cut and fill. The foundation materials are likely to be recent outwash gravels over approximately half its length, with the remainder on weak Eyre Group fine sandstones mantled by a few metres of colluvium along the right bank of the Selwyn at the base of the northern Harper hills.

The canal drops approximately 34 m in elevation between the base of the dam and the headrace. As the canal must maintain a relatively flat slope (0.015%) it is necessary to lose the majority of this head with the use of large concrete or gabion drop structures along its length. At its junction with the headrace, the outlet canal will be fed into a stilling pond to reduce flow velocity.

Outlet, Bridge and Siphon Structures

Outlet structures are to consist of a double-gate system, which allows water flows within the headrace and distribution canals to be fully controlled. Gates will be actuator operated vertical lift steel assemblies within a reinforced concrete structure.

Approximately 40 single-lane and 13 double-lane bridges will be required along the length of the canal to allow for farm access and road crossings. farm access bridges will be single lane width and constructed using precast concrete bridge units mounted on concrete abutments and fabricated on site. The standard of construction for road bridges will be conducive with the class of road. Small gravel roads will cross the canal on a single-lane width bridge, while higher volume roads will have double-lane bridges with vehicle load ratings.

The Hororata, Selwyn and Hawkins rivers will be bypassed with concrete culvert siphons running beneath the river bed. Siphons will be constructed from precast concrete box-culvert units installed at least three metres below bed level to allow for erosion and scour. The length of the siphons may be up to 400 metres long.

2.16 Distribution System

Distribution of irrigation water will be via a network of surface water canals which follow existing road alignments. The canals will be constructed by excavation with spoil being spread to waste. This will reduce the distance of encroachment on to adjacent properties and avoid potential problems with construction of embankments providing the required level of permeability and minimise the visual impact.

The design capacities for the distribution canals vary from between 7.2 m^3/s down to 0.1m^3/s, these flow rates include an allowance of 20 % for losses as the anticipated geology is sandy gravels. It has been assumed that canals will self-seal with fine suspended sediment over time and that there is no requirement for the lining of the channel.

The canals will have side slopes of 2 horizontal to 1 vertical with a bottom width of 1.2–3 m depending on the design capacity. The channel gradient has been designed to maintain maximum flow velocities of approximately 0.8 m/s which will minimise the potential for scour of the channel. At these peak flows any sediments will remain in suspension however periodic maintenance with an excavator will be required to remove sediment that settles out when flows are reduced or there is no flow within the channel.

Drop structures will be required at regular intervals along the canals, as design gradients are flatter than the slope of the plains. These will be constructed using gabions baskets and have a drop of approximately 0.5 m with scour protection provided in the area immediately upstream and downstream of the drop. The design freeboard of the channel varies between 1.0 m immediately downstream of drop structures to 0.3 m immediately upstream of the drop structure.

Control structures provided at junctions will control flow down the individual canals. These will be concrete structures with actuator operated vertical lift steel gates. Overflow canals will be provided at the end of each branch channel to transport excess water to adjacent watercourses.

Abstraction of the water from the channel will be via permanently mounted suction pipes extending down into the channel at the various abstraction locations. Depending on the type of pump and its elevation above the water level, suction pipes may require footer valves to prevent the need to prime the pump each time it is operated.

It has been assumed that crossings of the canal will be required at approximately 450 m intervals for access to farmland and domestic properties. The crossings will be single lane width constructed using culvert pipes for canals with flows up to approximately 1 m^3/s and precast concrete bridges for the larger canals. Road crossings will also be constructed using culverts and bridges depending on the size of the channel and the class of the road.

It may be preferable to construct the distribution canals along the alignment of the extensive existing water race canals that cross the plains. There will be advantages in terms of land acquisition, easements and land use. However if the stock water race system is made inoperative by such use, then an alternate supply would become a cost to the scheme. If the irrigation distribution system were to be used for stockwater reticulation, there are likely to be higher losses to groundwater than from the existing system as a consequence of the larger canals (more leakage from a greater area). This matter can be resolved during the design stage to find the optimum solution.

2.17 Roading and Power Supply

2.17.1 Infrastructure Roading Affected

There are a number of roads within the Wairiri Valley that would be flooded and access to the land beyond would be cut off. These include:

- State Highway 77 for 7 km length from Glenroy to just south of the Wairiri River Bridge.
- Turnbulls Road for a 1.6 km length which provides farm access and access to a Defence establishment.
- Davies Road for 2.4 km length which provides farm and forestry access.

Figure 2-19 depicts the roading options for the scheme.

2.17.2 Roading Options for State Highway 77

There are two main options for the SH 77 relocation:

Raise SH 77 adjacent to the Lake Wairiri

This option involves 7 km of reconstruction of the SH raising it to approximately RL 320.0m? some 2.0 m above the lake level. The scope of the roading work would be large with approximately 2,000,000m^3 of earthworks with major cuts (to 40m high) and fills (to 35m high). The fill in some locations extends into the lake so considerable erosion protection would be necessary. There is likely to be some significant geotechnical issues to overcome as there is some evidence of instability along some of the high faces on the north face of the Harper Hills. The roadway would cross a saddle opposite the SH 77/ Hardys Road intersection and joins Downs Road north of Glenroy. The estimated cost for this option is $36.75M.

Relocate SH 77 to Downs Road and Upgrade

This option involves seal widening of Downs Road for 12.8 km, curve improvements, and traffic service upgrade to State Highway standard. Although the length of route is some 1.8 km longer than the existing State Highway, it can be upgraded relatively cheaply, compared to the above option, to provide a better overall standard of road than the existing route. The existing route has a single lane bridge and a section of highway with 70 km/hr speed restriction at Glentunnel. This option would pass through Coalgate rather than Glentunnel, and would not be elevated as for the option above, so would be less affected by snow in marginal weather conditions. If this option is to be considered further then a traffic survey should be carried out to establish whether traffic dis-benefits are significant or not and the resultant Present Value of user costs. It is most unlikely the difference in user costs between the two options would justify the extra capital cost being spent on the new road within the Wairiri Valley. The estimated cost of improvements for the Downs Road option is $7.2M.

With the significant difference in costs between a new road within the Wairiri Valley and the upgraded Downs Road option, the only feasible option to be considered is the Downs Road upgrade.

2.17.3 Turnbulls Road Relocation

This relocation would involve approximately 2.8 km of new road, which would primarily provide access to the NZDF establishment. It would need to connect to the northern end of the NZDF internal roading, where a new administration block would need to be sited. It is important to the NZDF that the access road to their facilities be a single point access that is able to be controlled by them. The conceptual road alignment is along the top of the western embankment at the edge of the lake, sidling down across the downstream face of the dam and connecting to the Wairiri Bridge (assuming the SH 77 relocation to Downs Road is adopted). The cost of the Turnbulls Road relocation is in the range of $1.0M to $1.7M

2.17.4 Davies Road Relocation

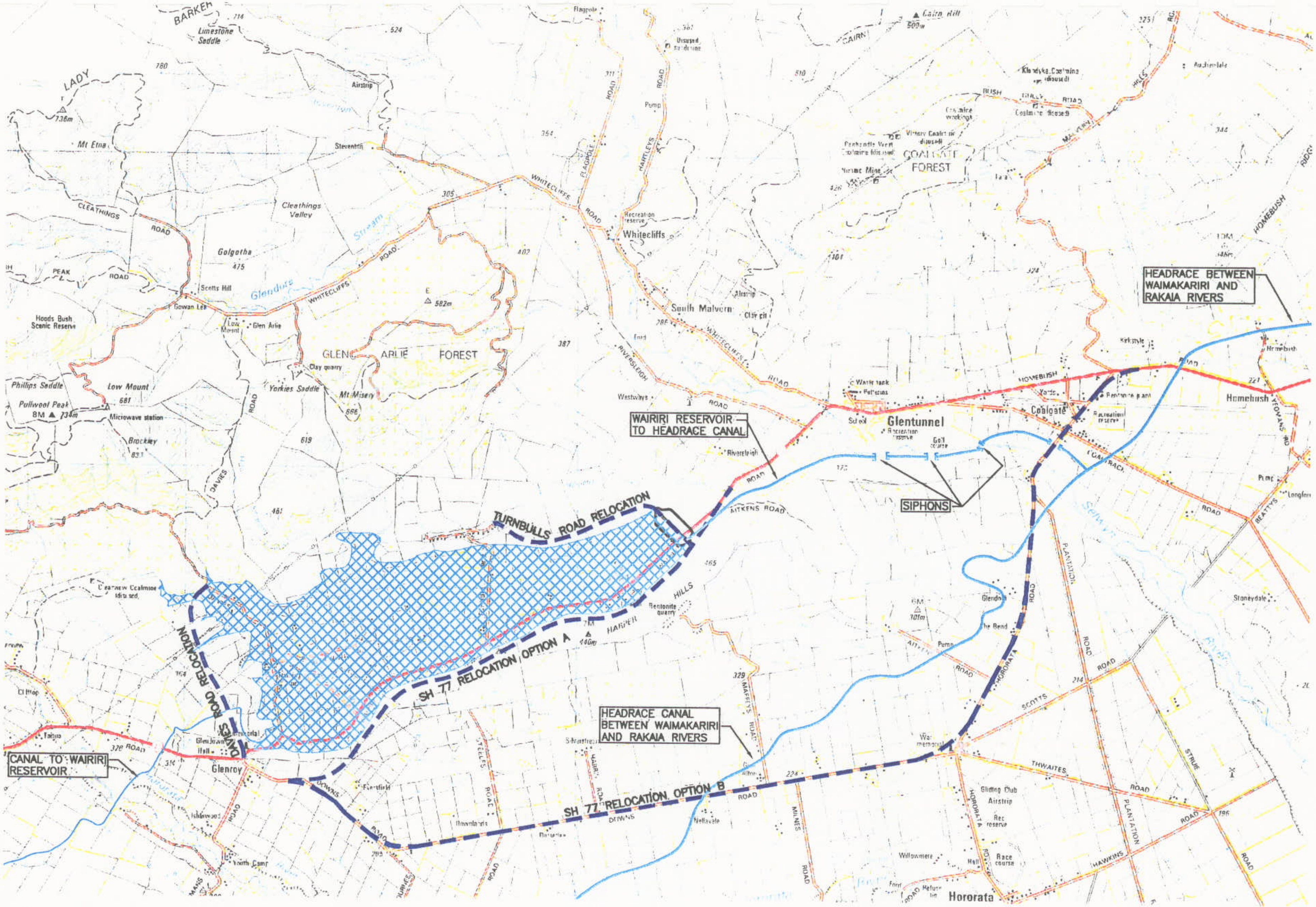
This relocation involves shifting the road to the southern side of the hills at the top end of the reservoir and involves 2.4 km of reconstruction. The road would depart from the existing State Highway by the memorial at Glenroy and follow the flatter contours on the southern side of the ridge, to join up with the road where the forest area commences. As this road would largely be for forestry access it is not proposed that it be sealed. The cost of this work is estimated at $1.1m.

2.17.5 Powerline Relocation

Transpower have the main power lines from Benmore to the North Island located through the Wairiri Valley. At least one of the towers within the valley would be inundated by the water. This tower would require reconstruction either onto dry land or to a height that keeps it well clear of the water surface.

Transpower have special clearance requirement between their transmission lines and water, primarily to protect from yacht masts. These clearances are greater than for open land. There is also a short region of the transmission line that crosses what will be an arm to the lake on the northern side of the valley. This length will require elevating, most probably involving reconstruction of the towers at each side of the valley.

There are no other significant power lines within the valley requiring protection, apart from the power supply to the NZDF facilities.



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Title
WAIRIRI ROADING OPTION

Figure No. **FIGURE 2-19**

2.18 Scheme Reliability

2.18.1 Background

To economically size a scheme, a realistic level of reliability must be defined that meets farmers expectations and allows risks to be carried at the most appropriate level. The methodology used describe reliability for "run of river" and "groundwater" systems are not applicable to a "run of river with storage" scheme. The concept of scheme reliability for the project was discussed with a focus group of farmers to provide direction and comments for presenting information.

The important aspects in relation to reliability and level of service from this focus group can be summarised as:

- The CPWE scheme needs higher levels of reliability than those currently obtainable from "run of river" schemes in the Canterbury region.
- The 16-days without water under the base scenario would not be as amenable as a scenario that involved partial restrictions to prevent the outage completely.
- The ability to forecast potential shortages in water supply would significantly alter the level of risk and management strategies an individual would implement.
- A single, set level of reliability may not be applicable to all farmers and a range of reliability should be considered. Farmers will tend to vary their risk management strategy depending on their specific situations.
- There was a general consensus from the group that indicated the project should have a high level of reliability and individual operators would manage their own level of risk.
- The current design capacity of 0.6 l/s/ha has a level of increased reliability because it exceeds the expected capacity of most farming operations.
- Farmers would like the opportunity to trade water, either to use someone else's allocation if not needed or to purchase more water shares to off set the partial restrictions in the dry years.
- Farmers would like variable entry points into the scheme, so that a level of service and risk could be individually decided upon by them.
- To encourage existing groundwater users to join the scheme, a high level of reliability would be required.
- Cropping farmers tended to be less affected by the potential water restrictions.
- Annual allocations of water would tend to encourage wise use of water early in the season. Efficient farmers should not be penalised by restrictions later if water is wasted by others.

The work required to present all the information requested by the focus group was beyond the scope and time frame of this phase of the project. However, these comments should be considered in future work and in future presentations with the landowners.

The reliability discussed later in this report discusses the methodology and alternatives to provide a scheme where water is supplied for all years. The reservoir storage and level of supply was varied to evaluate the potential impacts on the cost of the project.

2.18.2 Analysis

The base case scenario (290 MCM, 17.2 m^3/s) indicates that if full demand is met at all times, there will be a period of 16 days in the driest year where there is no water available for irrigation. This was chosen as the basis to size the scheme components so that:

- It would not be oversized and therefore too expensive,
- Was comparable to the level of service to be provided to irrigators to the south of the Rakaia, and
- Was sufficiently reliable to obtain support from the farming community.

This level of service was generally thought to be acceptable to the focus group provided it was managed so that the 16 consecutive days with no water was avoided. A period of 16 days with no water would cause the pasture to die and then not respond to water once it was available again. The operational characteristics of the reservoir were evaluated to produce scenarios where the days without water were reduced to zero by restricting the supply when the reservoir was nearing empty.

Most irrigation schemes in the world with storage have an operational procedure that implements restrictions during poor water years. The level of restrictions and the methodology for implementation can vary significantly. This report evaluates the total amount of water delivered. This report does not evaluate the day to day or farm to farm strategies that could be implemented.

The first step to determine the potential impacts to the operational restrictions was to develop an estimate for the demand of water from storage. The base case was analysed, for the period of record, to determine the amount of stored water needed at various times of the year to meet demand. This analysis accounted for the pumping that occurs throughout the year as well as the variability in the end of the irrigation season. These values were compiled to generate Figure 2-20. Figure 2-20 shows the demand from storage for various times during the irrigation season. The individual curves represent the probability of reaching the end of the irrigation season without running out of water.

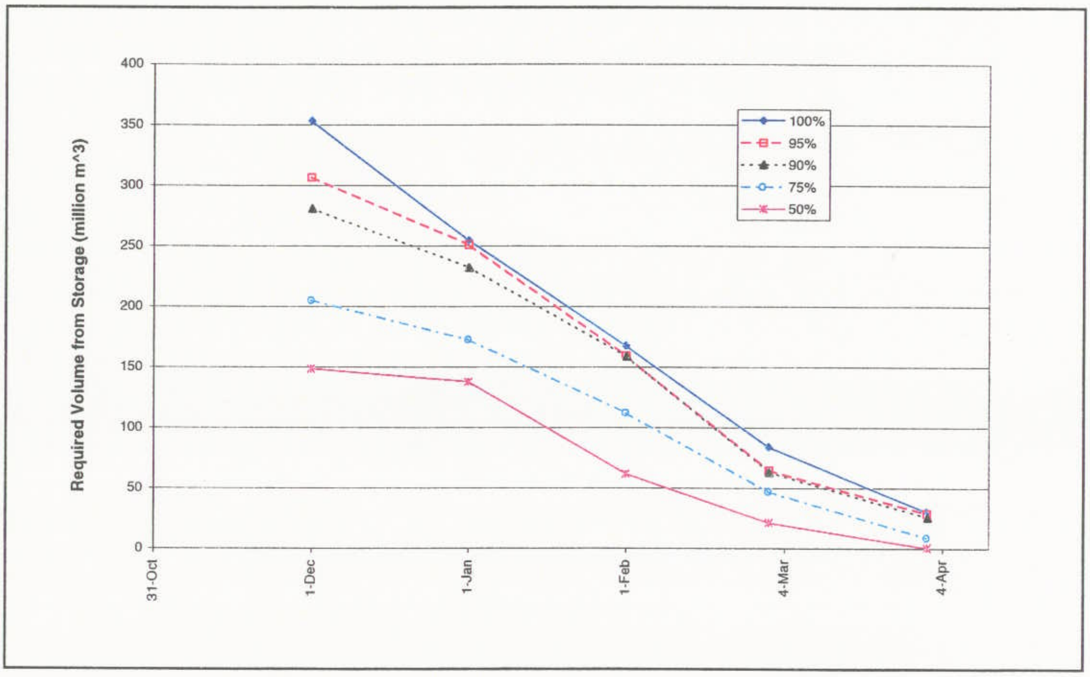


Figure 2-20: Demand from Storage by Month

The information shown in Figure 2-20 was used to conceptualise an operational scheme for the reservoir. The conceptual plan was to restrict the amount of water supplied from the reservoir for periods when the reservoir appeared to have insufficient water. The implementation of restrictions to early can produce more frequent occasions when less water is delivered than is required. This can have an adverse effect on the profitability of the scheme. Therefore, the level for implementing restrictions early in the season was set at a very low level. The restrictions become more important at the end of the irrigation season when there is little chance to refill the reservoir.

The zone for the implementation of the restrictions is shown in Figure 2-21. The line used to establish the restrictions, after the first of February was the 95% line. The 95 and 90% lines are very close in this portion of the graph. These represent the chance you would have of making through the irrigation season without running out of water.

The maximum storage volume in the reservoir was decreased in a effort to reduce the cost of the project. The smaller reservoir will require more severe restrictions to maintain the performance of no days without water. A restriction of 22%(78% of demand is met) is required to achieve no days without water for the base case. Table 2-8 shows the restrictions required for various reservoir sizes and the impacts on the quantity of water delivered each year.

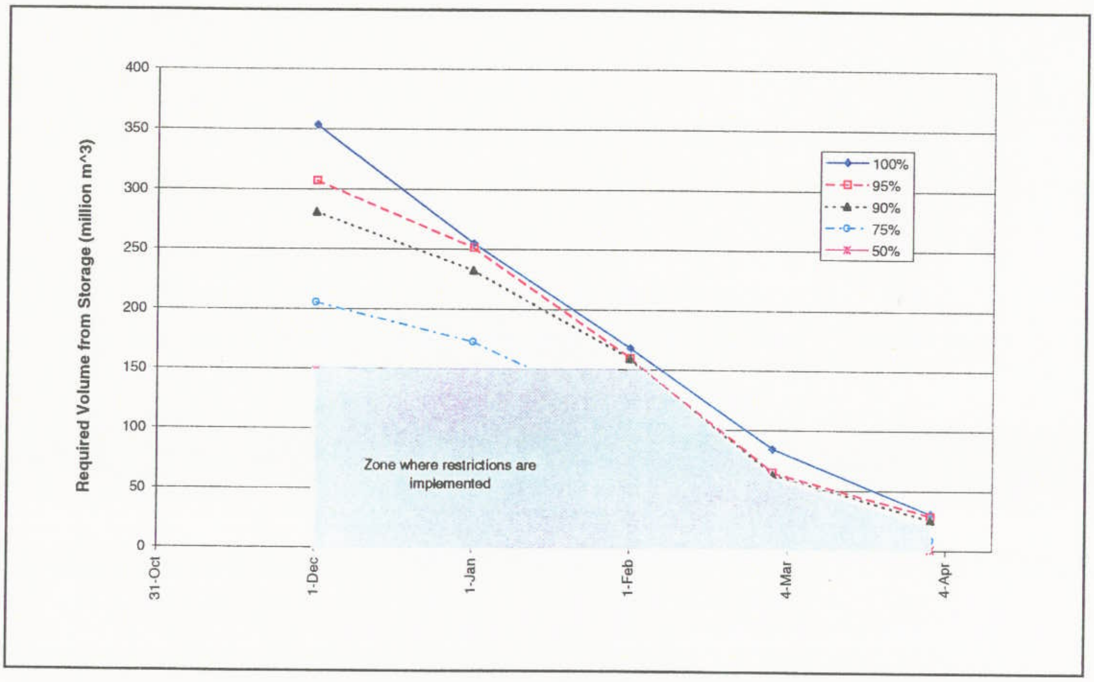


Figure 2-21 – Zone for implementing restrictions

Table 2-8: Effects of restrictions on reservoir size and water delivery (40 m³/s)

Restriction (%)	22	28	32	38
Reservoir volume required for no days without water (MCM)	290	270	250	220
Percent of yearly demand supplied	98	96	95	91
Percent of yearly demand supplied during worst year on record	89	84	81	76
Percent of time when yearly supplies are greater than 95% of demand	82	71	53	41
Number of years where supplied values were greater than 99% of demand for the 34 years on record	21	15	15	9

For the base scenario (290 MCM), a restriction of 22% is required to maintain water availability for all days. This level of restriction would result in 98% of the yearly demand being met on average. During the worst year of record, 89% of the annual demand would be met. Full demand was met on 21 of the 34 years.

Figure 2-22 shows how a restriction might have been implemented during the drought of 1971. This restriction provides water throughout the entire event.

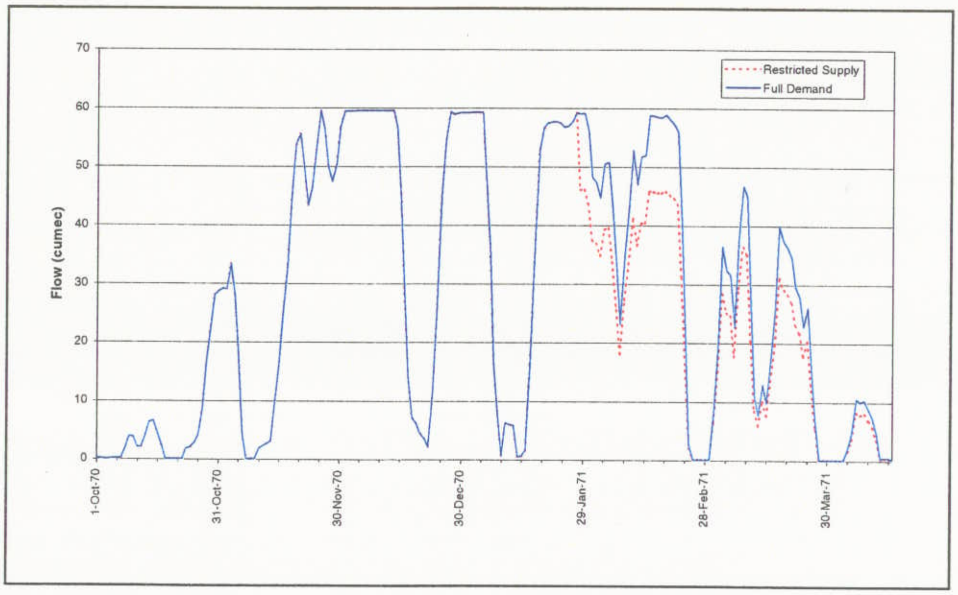


Figure 2-22 – Sample of restricted supply for the 1971 drought

The availability of water from the Waimakariri can have an impact operations of the scheme. Less water would require larger restrictions to maintain the ability to deliver water for all days. A decrease in the water available from the Waimakariri would also increases the annual pumping costs. Table 2-9 summarises the results for different takes from the Waimakariri using a reservoir volume of 290 MCM.

Table 2-10 shows the impacts on the restrictions when the take on the Waimakariri is reduced to 30 m^3/s and the reservoir volume is varied. The analysis is similar to the one for the Table 2-9 except that the Waimakariri take was reduced from 40 m^3/s to 30 m^3/s.

The level of restrictions can mean something different to the farmer in the area depending on their location. Farmers located higher in elevation are apt to receive more rainfall and have lower potential evaporation. This could mean restrictions would have a lesser impact on their activities when compared to farmers lower in the plains. The specific cropping practices of the individual farms will contribute to the impacts of the restrictions. The timing of the restrictions could also cause more difficulties for individual farmers.

Table 2-9: Impacts of water delivery for various Waimakariri takes

Waimakariri Take (m3/s)	40	35	30	25	20
Restriction (%)	22	24	27	31	34
Percent of yearly demand supplied	98	97	96	94	92
Percent of yearly demand supplied during worst year on record	89	86	83	78	73
Percent of time when yearly supplies are greater than 95% of demand	82	74	65	53	41
Number of years where supplied values were greater than 99% of demand for the 34 years on record	21	17	16	12	10
Average Annual Pumping Costs ($ Million)	3.4	3.6	3.8	4.1	4.3

Table 2-10: Effects of restrictions on reservoir size and water delivery (30 m^3/s)

Reservoir volume required for no days without water (MCM)	290	270	250	220
Restriction (%)	27	32	34	41
Percent of yearly demand supplied	96	94	92	88
Percent of yearly demand supplied during worst year on record	83	79	78	73
Percent of time when yearly supplies are greater than 95% of demand	65	53	41	29
Number of years where supplied values were greater than 99% of demand for the 34 years on record	16	12	11	5

2.19 Hydraulic Analysis of Headrace Canal

A hydraulic analysis of the main headrace was conducted using HECRAS. HECRAS is a one dimensional steady state analysis tool developed by the U.S. Army Corps of Engineers. Two operational scenarios were used to show the expected bounds of the system. The two scenarios were:

- Transferring 40 m^3/s from the Waimakariri (22.8 m^3/s is used for irrigation and the remaining 17.2 m^3/s are pumped to storage from the Rakaia Stilling Basin)
- Meeting the maximum demand from storage (including 6 m3/s to the Waimakariri Stilling Basin to be pumped to the Springfield/Sheffield area)

The hydraulic analysis assumed a trapezoidal channel with a 3 meter bottom width and side slopes of 2.5 H to 1 V. A manning's "n" value of 0.035 was assumed. The upstream boundary conditions assumed normal depth with a small slope. The downstream boundary condition was varied because of the potential variations in the design of the pumps and gates structures. All velocities were maintained below 1.0 m/s. Figure 2-23 shows the water surface profiles for a channel with a flat bottom. The Rakaia River is at the zero Distance where the Waimakariri and dam outlet are at 56.3 and 31.5 km respectively.

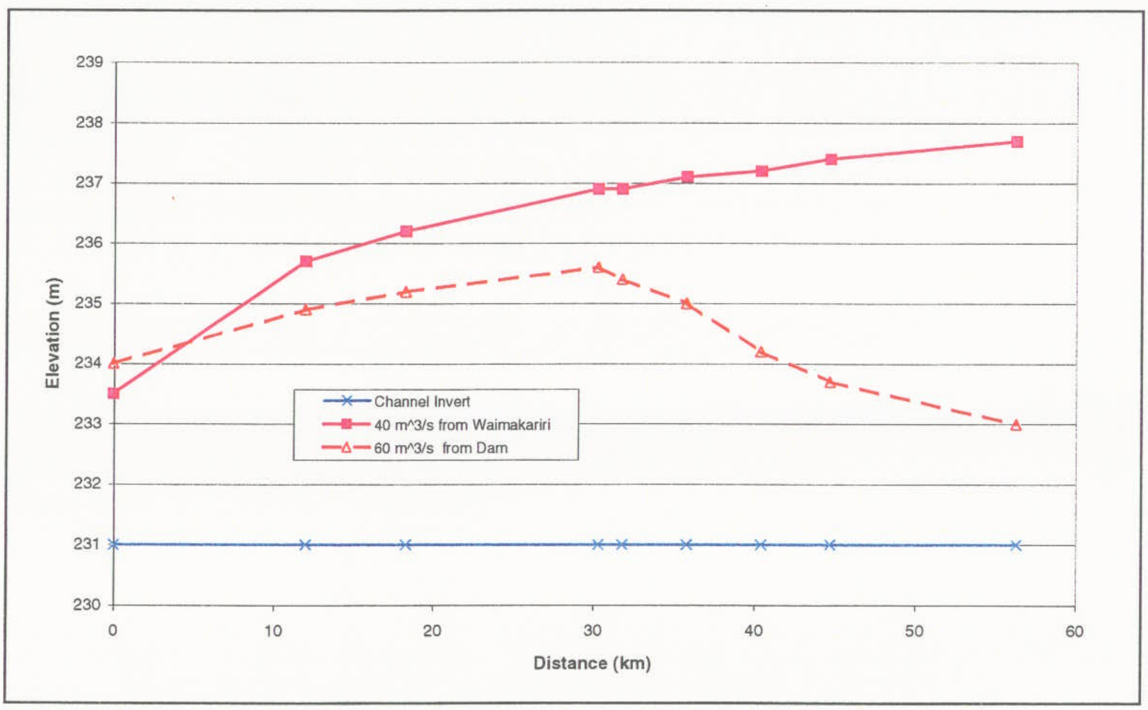


Figure 2-23: Water surface elevations for the main race (flat bottom)

The flat bottom channel yields some large depths towards the Waimakariri. These large depths are a result of drawing more water from the Waimakariri than would normally be delivered for irrigation. The normal operating capacity of the head race is close to 30 m^3/s. This is a result of the 60 m^3/s supply form the dam being delivered to a central location and being split evenly between the north and south portions of the irrigation scheme. Therefore, a channel with a sloping bottom was analysed. The channel invert at the Waimakariri was elevated 2 meters and sloped uniformly to station 31.8 km (near Coalgate). Figure 2-24 shows the water surface profiles for the sloped channel.

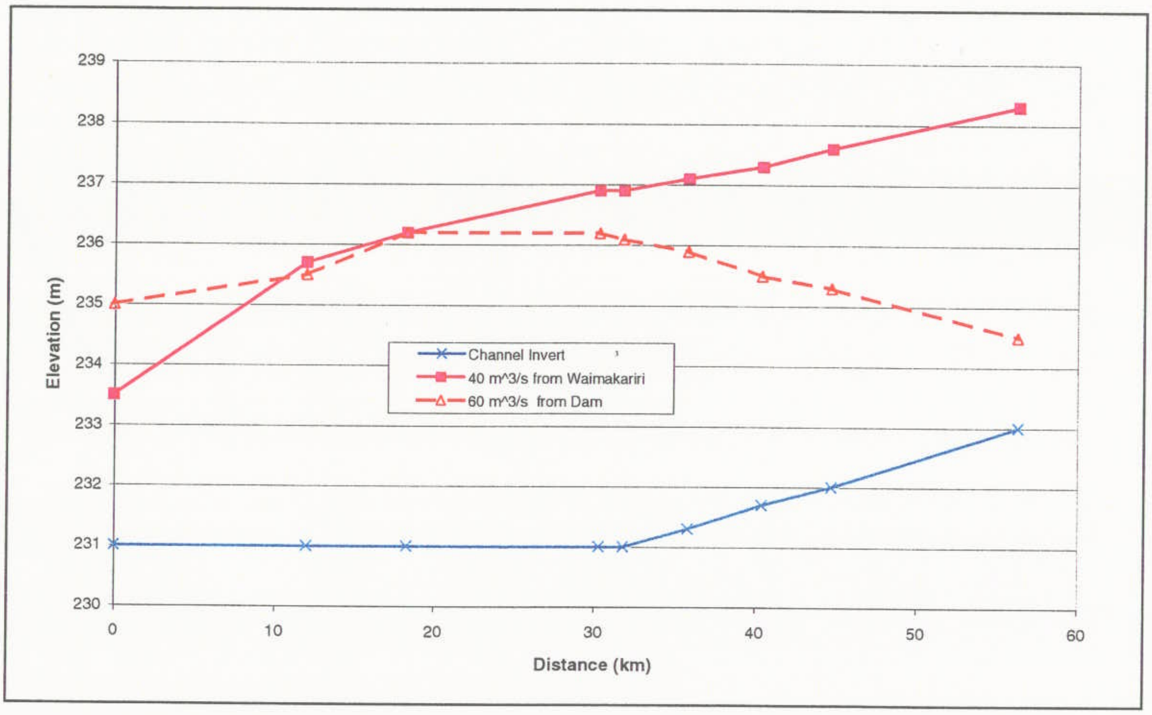


Figure 2-24: Water surface elevations for the main race (sloped bottom)

The sloped channel raises the water surface profile during the 60 m^3/s scenario. Figure 2-25 shows a comparison of the flow depth between the flat bottom channel and the sloped channel. The flow depth plus freeboard can be considered the required depth of construction. The shallower depths provided by the sloped bottom could reduce the cost of the main head race. A more detailed analysis of the canal hydraulics may yield additional cost savings.

Never the less the concept of having a canal design that allows water to flow from the Rakaia to the Waimakariri River and vice versa is preserved with a range of designs.

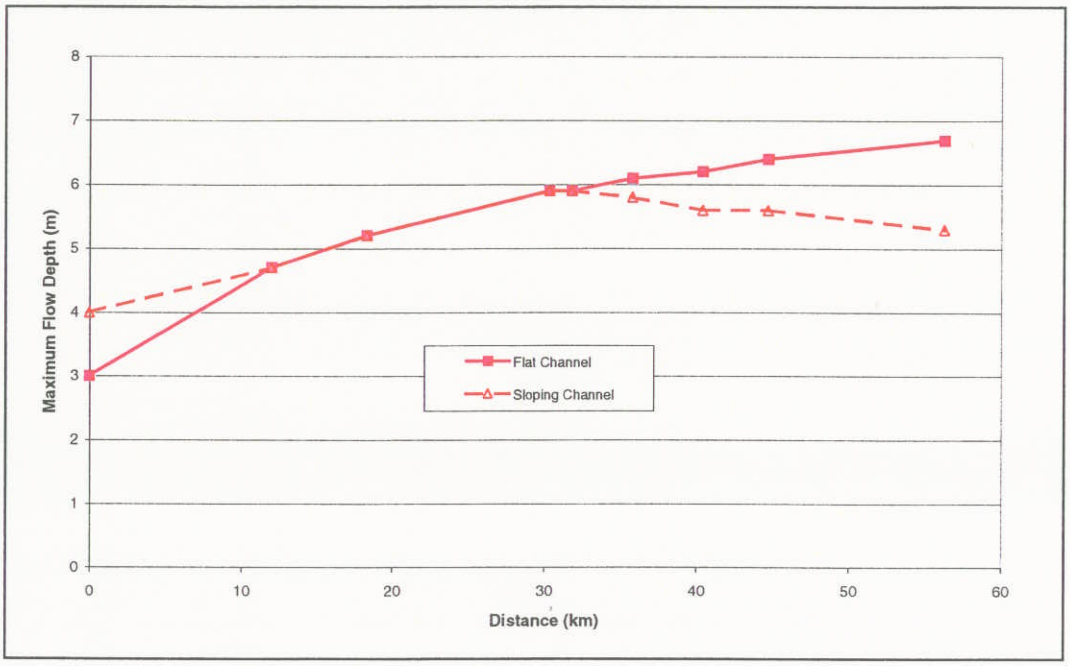


Figure 2-25: Comparison of maximum flow depths for the flat and sloped bottom canals

3.1 Introduction

The process of identifying the preferred option for the feasibility study has been a multi-stage process involving the URS team, CPWE Steering Committee and the Working Party. This process has been described in the Scoping Study and interim reports. A summary of the process is outlined in this section.

3.2 Scoping Study Options

In the Scoping Study all possible methods of providing water to satisfy the demand were identified. This was undertaken in the format of a Brain Storming Workshop where participants were instructed not to be constrained by technical, economic or environmental considerations. From these option scheme options capable of supplying the whole supply area at the appropriate reliability were developed.

In summary the Water Supply Options identified in the Scoping Study were as follows:

1. Coleridge
2. Coleridge Wairiri
3. Coleridge Flagpole Hill Selwyn
4. Coleridge Whitecliffs Selwyn
5. Coleridge Selwyn Wairiri
6. Pumped Wairiri
7. Pumped Waimakariri Waianiwaniwa
8. Waimakariri Tributary (Broken River)
9. Waimakariri Tributary (Poulter River)
10. Waimakariri Tributary (Esk River)

Based on the findings of the investigations undertaken by the Project Team and the recommendations of the Working Party, a number of these options of supplying water for the Central Plains Water Enhancement, were considered to be feasible from a technical, economic and environmental perspective. It therefore recommended that the following options be carried through for investigation in the Stage 2 Feasibility Study.

- Those options involving storage in the Wairiri Valley. (Coleridge Wairiri, Coleridge Selwyn Wairiri and Pumped Wairiri options),
- The Coleridge Option, and

- The Options involving storage in the Selwyn River Valley (Coleridge Flagpole Hill Selwyn and Coleridge Whitecliffs Selwyn).

3.3 Short Listed Options

The options identified in the Scoping Study involved four main storage locations. These options are described fully in the Scoping Study and briefly summarised below.

Lake Coleridge

This option would involve using Lake Coleridge for storage. Water from Lake Coleridge would be discharged to the main run of river races near Glenroy.

Highpeak Reservoir on the Upper Selwyn River

This option would involve construction of a storage reservoir on the Selwyn River on High Peak Station at Flagpole Hill. The storage reservoir would be supplied from Lake Coleridge via a water race to the head of the Selwyn River and then down the river. Water from the reservoir would be discharged from the storage via the Selwyn River with an off take to the main run of river races at the downstream end of the gorge.

Whitecliffs Reservoir on the Selwyn River

This option would involve construction of a storage reservoir on the Selwyn River at Whitecliffs. The storage reservoir would be supplied from Lake Coleridge via a water race to the head of the Selwyn River and then down the river. Water from the reservoir would be discharged from the storage to the main run of river races near Glentunnel via a race.

Wairiri Reservoir

This option would involve construction of a storage reservoir in the Wairiri Stream valley. The storage reservoir would be supplied by pumping from the main Rakaia race or from Lake Coleridge via a water race via the Selwyn River or directly via Windwhistle. Water from the reservoir would be discharged from the storage via a race to the main run of river races near Glentunnel.

There are two potential dam sites in the Wairiri Valley. The upper site will require a shorter higher dam while the downstream site will require a longer lower dam.

In May 2001 an assessment process that compared the potential storage locations against technical, financial and environmental criteria was undertaken (URS May 2001).

3.3.1 Selection Process

The selection process involved the Working Party undertaking a ranking exercise similar to that used in the Scoping Study. This involved each of the options being scored against criteria identified by the Working Party as important in the decision making process. These scores were weighted according to the importance each criteria was to the individual, thus providing a weighted total score for each option. These weighted scores then provided the ranking for each option. The average weighted score for each option is presented in Figure 3-1.

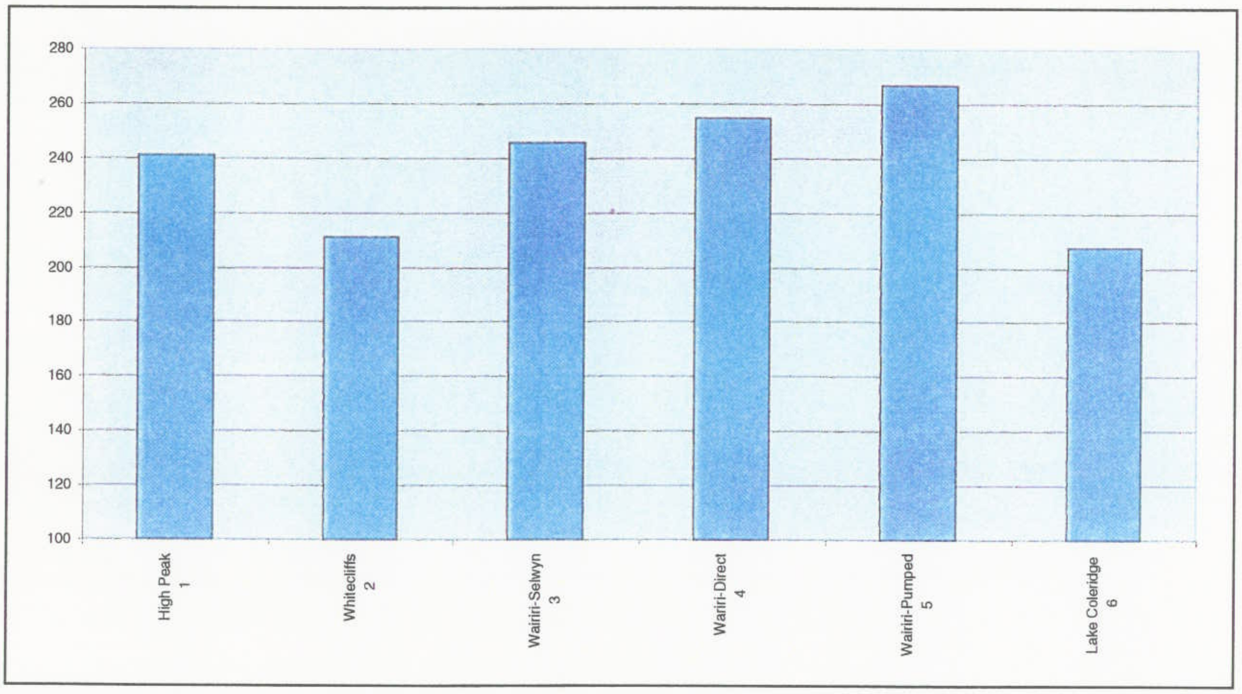


Figure 3-1: Scoring for Storage Options

The second part of the selection process involved a "show of hands" voting at the working party meeting. Both of these methods indicated a clear preference for the Wairiri Valley.

This preference from the Working Party coincided with the recommendation from the URS that supported the selection of those options involving the Wairiri Reservoir for further investigations. These include Coleridge Wairiri, Coleridge Selwyn Wairiri and Pumped Wairiri options.

3.4 Selection of Preferred Scheme

There are five technically viable scheme options that can be compiled from the short-listed options and a pumped Waianiwaniwa Reservoir option. The pumped Waianiwaniwa Option was included as it was an option that had not previously been considered. The supply system components e.g. headrace canal and Wairiri Reservoir which are combined to define each discrete option. These options are discussed more fully in "Preferred Scheme Concept, Interim Report No. 2 (URS July 2001) and summarised below.

To aid description of each option, they have been grouped according to whether they store their water in a reservoir in either the Wairiri or Waianiwaniwa valleys. There are four options which pump water into storage from the headrace canal and one gravity option taking water from Lake Coleridge by gravity into the Wairiri Reservoir.

3.4.1 Options A and B - (Wairiri Pumped)

The basis of Options A (Figure 3-2) and B (Figure 3-3) would be as follows:

- A central headrace canal would bring water from both the Waimakariri and Rakaia Rivers to a pumping station, which would pump the water into the Wairiri storage reservoir.
- Alternatively the central headrace canal would transport water from the rivers directly to the distribution races serving water enhancement projects and farms on the Plains.
- During periods of high irrigation demand, stored water would be released back into the central headrace canal from the Wairiri Reservoir via either a canal alongside the Selwyn River past Glentunnel and Colgate (Option A) or through a tunnel into a stilling basin near Aitkens Road (Option B).
- A separate scheme supporting irrigation in the Springfield/Sheffield area would pump water from the Waimakariri River up onto the plains into a small headrace canal running across the Plains at the RL 380 m contour from near Springfield to Wyndale Road. When Waimakariri River restrictions are in place, water will still be taken from the pumping station adjacent to the Kowai River mouth, and compensation flows would be released from the Wairiri Reservoir along the central headrace canal into the Waimakariri river to replace water abstracted for the Springfield/Sheffield area.

3.4.2 Options C - (Wairiri Pumped)

Option C (Figure 3-4) is almost identical to Options A and B described above. The only difference is that water would be pumped directly from the Rakaia River up the terrace into a canal at the RL 320 m contour that would flow directly into the head of the Wairiri Reservoir.

3.4.3 Option D – (Coleridge - Wairiri)

Option D (Figure 3-5) is almost identical to Option A except that the Wairiri Reservoir would be filled by gravity from Lake Coleridge rather than pumping from the main rivers.

3.4.4 Option E – (Waianiwaniwa Pumped)

Option E (Figure 3-6) differs from Options A to D by using the Waianiwaniwa reservoir to store water. Water would be pumped into the reservoir from the central headrace canal using a pumping station located near Homebush Road. A short length of canal would transmit the water back into the canal for distribution.

Similarly the option of discharging through a tunnel to Dalethorpe will involve increased costs for the tunnel and the discharge canal to the central head race canal, and these need to be considered against the savings in cost for the dam at High Peak.

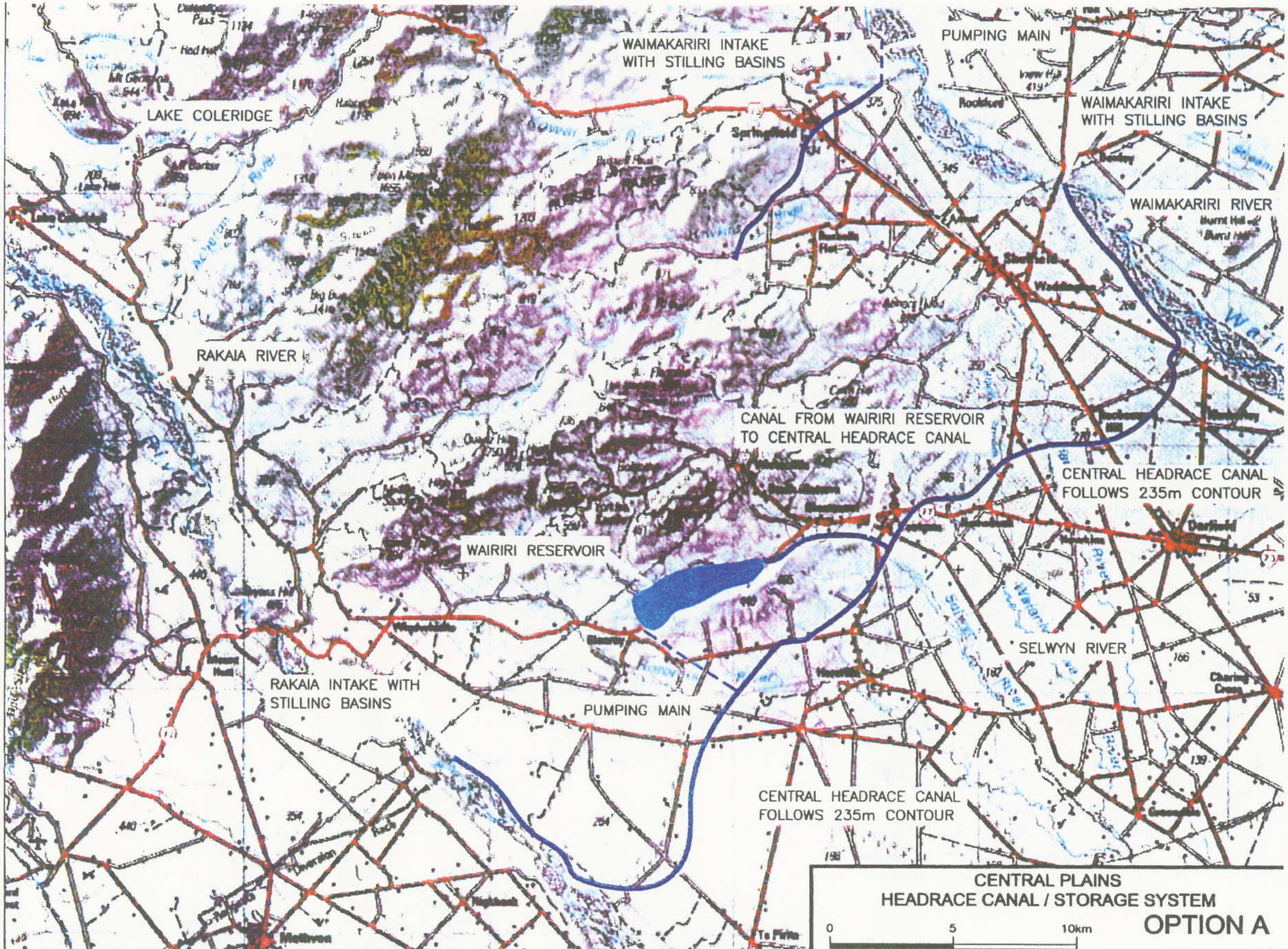
3.5 Recommended Option

These options were considered from a technical feasibility and cost perspective and Option A Wairiri Pumped was the recommended base option. This is option involves a level headrace canal with a pump station located close to the Wairiri Valley to transfer water from the Rakaia River to storage. The discharge canal from the reservoir would be fitted in between the Malvern Hills and the Selwyn River allowing the Selwyn River to maintain its existing course. The operating level of the headrace will be RL 235 m. This will provide the facility to run water from storage back to the Waimakariri River.

The Springfield/Sheffield area has been incorporated within this scheme option. This area would be irrigated by pumped water from the Waimakariri River and a compensating flow would be returned to the river during times of restrictions.

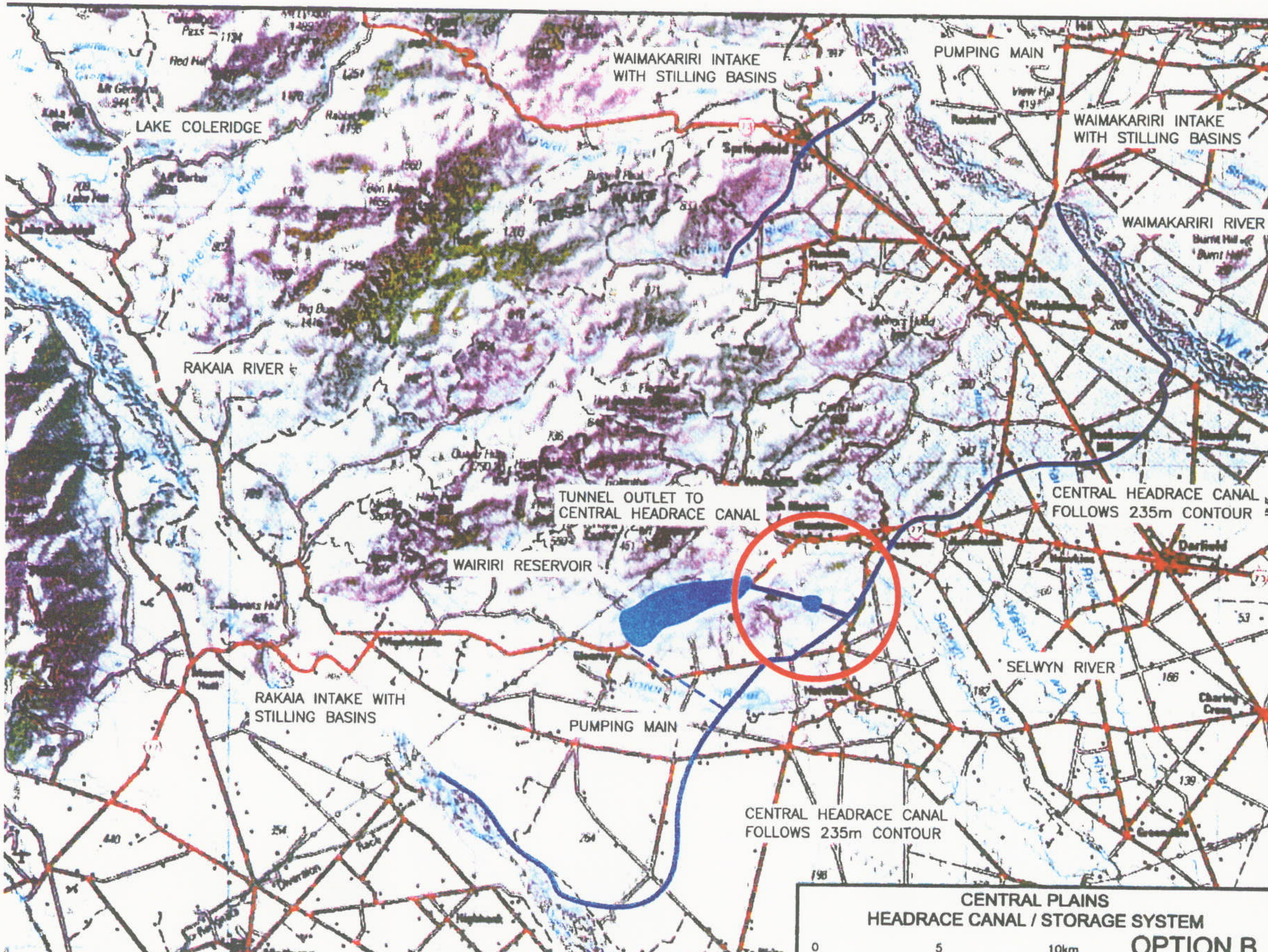
The base case storage requirement of 290 MCM should be planned for, until such time as suitable access to water from the Rakaia River is secured. At the time that this recommendation was made the base case storage requirement was assessed as 250 MCM, however the extending of the period of record from 1972 to 1967 has resulted in an increase in the storage volume due to the 1971 year being the worst on record.

This option maintains the maximum flexibility of all options considered. The level headrace also would enable water from the Waimakariri to be used to fill storage during the winter. The Wairiri Valley is also able to accept water from Lake Coleridge, however this is not the preferred option at this point in time due to the cost of conveyance to the reservoir, the cost to purchase access to the water from Trustpower, and the potential conflict with the NWCO.



CENTRAL PLAINS
HEADRACE CANAL / STORAGE SYSTEM
OPTION A

Figure 3-2



CENTRAL PLAINS
HEADRACE CANAL / STORAGE SYSTEM
OPTION B

Figure 3-3

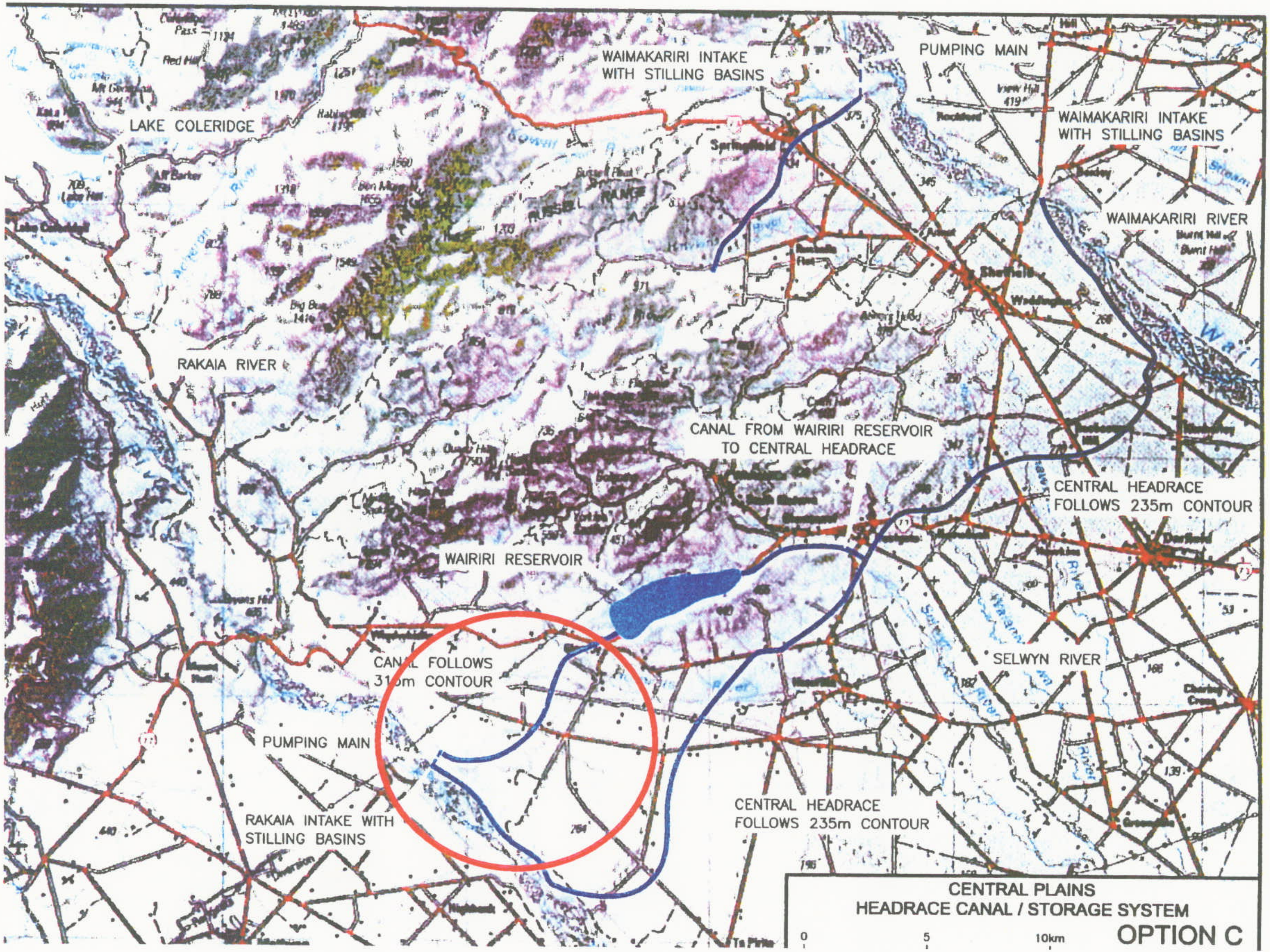
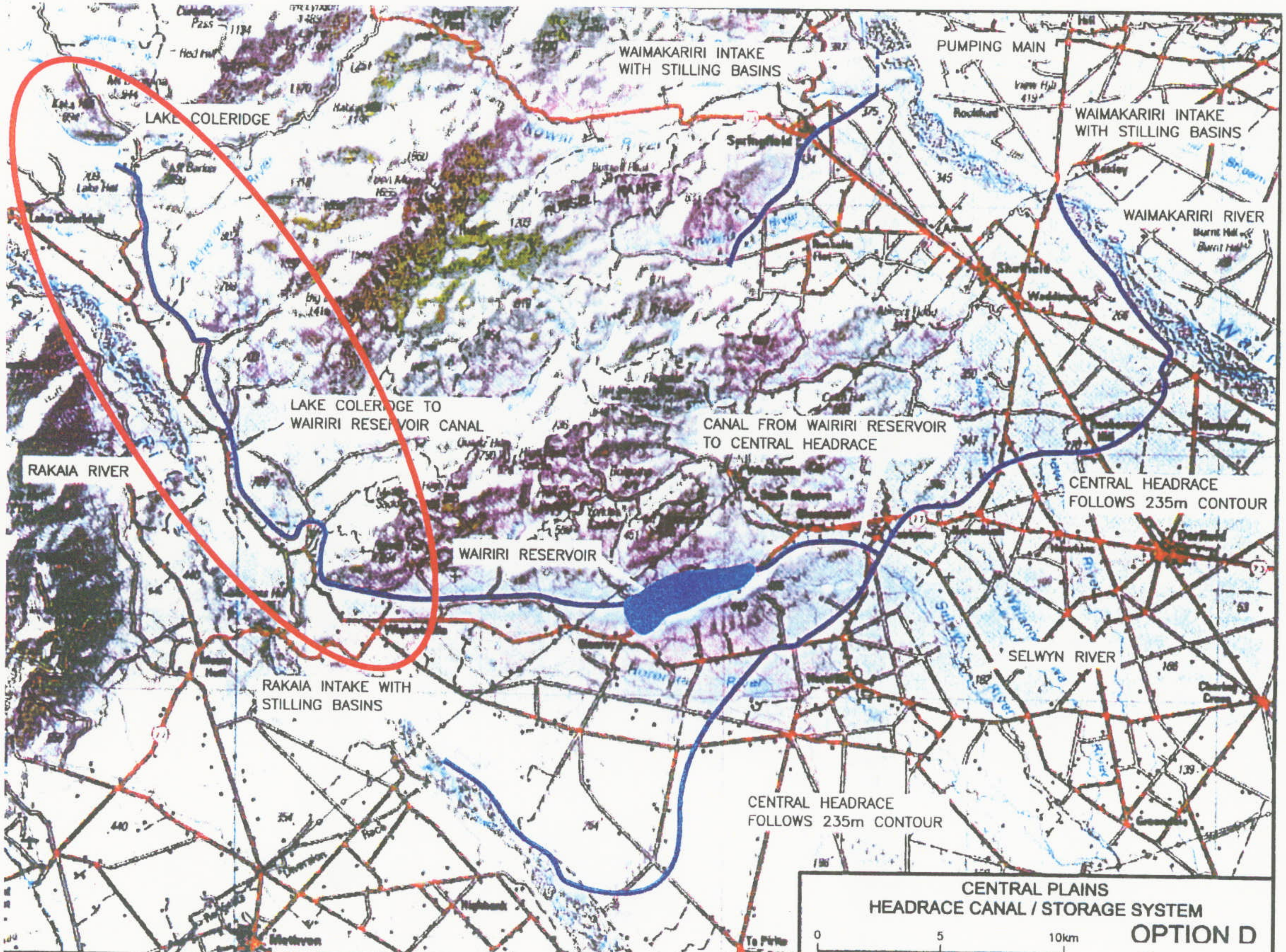

LAKE COLERIDGE
WAIMAKARIRI INTAKE WITH STILLING BASINS
PUMPING MAIN
WAIMAKARIRI INTAKE WITH STILLING BASINS
WAIMAKARIRI RIVER
RAKAIA RIVER
CANAL FROM WAIRIRI RESERVOIR TO CENTRAL HEADRACE
CENTRAL HEADRACE FOLLOWS 235m CONTOUR
WAIRIRI RESERVOIR
CANAL FOLLOWS
CONTOUR
SELWYN RIVER
PUMPING MAIN
RAKAIA INTAKE WITH STILLING BASINS
CENTRAL HEADRACE FOLLOWS 235m CONTOUR
CENTRAL PLAINS
HEADRACE CANAL / STORAGE SYSTEM
OPTION C
0
5
10km

Figure 3-4



OPTION D
Figure 3-5

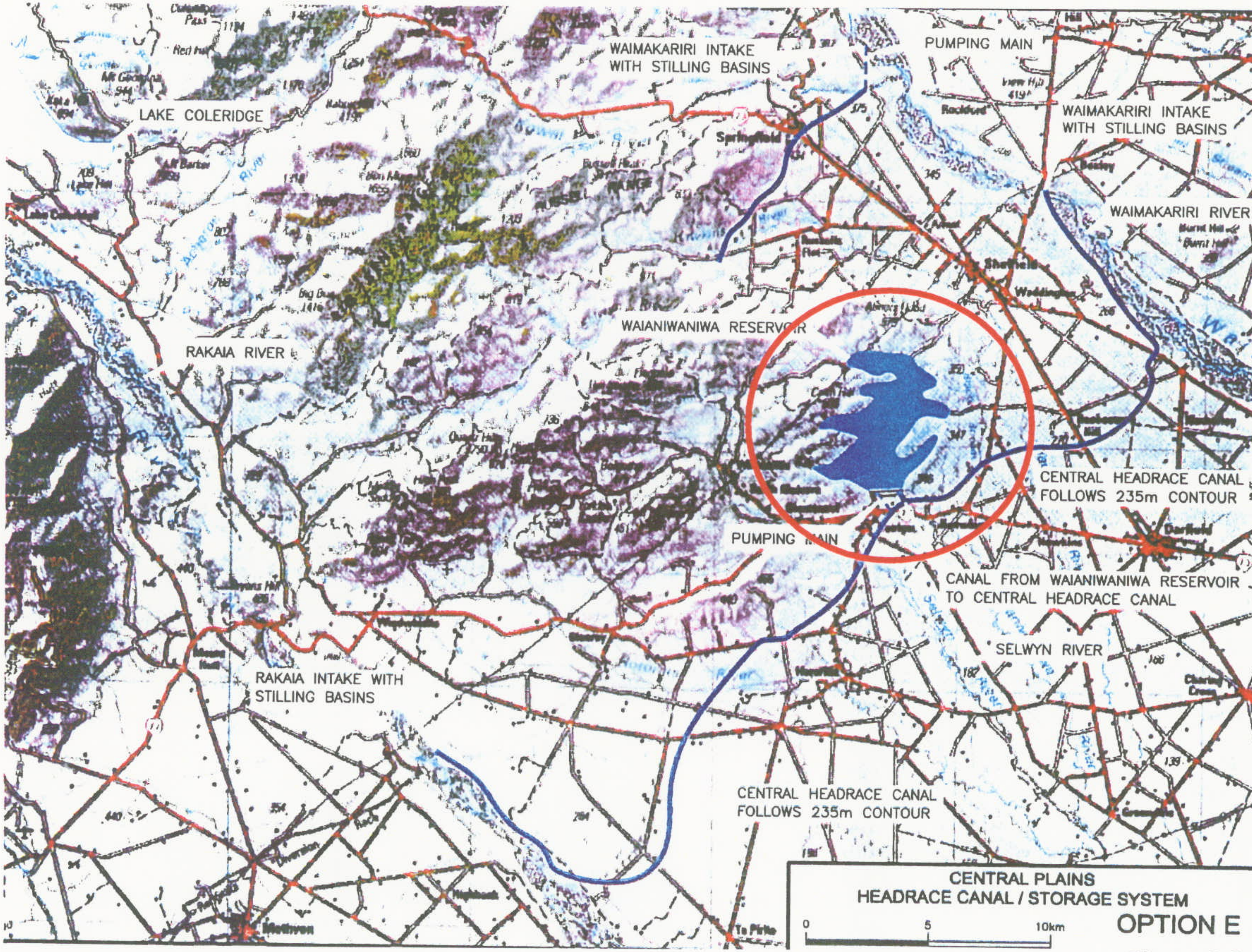

LAKE COLERIDGE
WAIMAKARIRI INTAKE WITH STILLING BASINS
PUMPING MAIN
WAIMAKARIRI INTAKE WITH STILLING BASINS
WAIMAKARIRI RIVER
RAKAIA RIVER
WAIANIWANIWA RESERVOIR
CENTRAL HEADRACE CANAL FOLLOWS 235m CONTOUR
PUMPING MAIN
CANAL FROM WAIANIWANIWA RESERVOIR TO CENTRAL HEADRACE CANAL
SELWYN RIVER
RAKAIA INTAKE WITH STILLING BASINS
CENTRAL HEADRACE CANAL FOLLOWS 235m CONTOUR
CENTRAL PLAINS
HEADRACE CANAL / STORAGE SYSTEM
OPTION E
0
5
10km

Figure 3-6

4.1 Introduction

In regard to the feasibility of the CPWE scheme, there were two crucial areas that required site investigations. These were the topography and geology of the Wairiri Valley. The topography is important to establish the volume of water that can be stored within the valley. The geology is important to establish if an appropriate dam structure can be built and how much it would cost. These investigations are reported in this section.

4.2 Survey of Reservoir

A topographical survey to an accuracy of $\pm$ 2m was undertaken using aerial photography and GPS (global positioning system) ground control. The contour plot was prepared by New Zealand Aerial Mapping with the ground control provided by Eliot Sinclair and Partners.

In addition to the ground control, a centreline survey of all of the roads in the valley was undertaken by GPS. This has been superimposed on the topographical survey and provides a very good fit in terms of level. The GPS survey is much more accurate than the contour plot.

Wairiri Valley has two main arms to it, the Wairiri Stream to the north, which encompasses the New Zealand Defence Force (NZDF) facilities, and Halls Stream that is the main valley through which the State Highway passes. The dam proposed would only flood the main valley, and therefore would leave the NZDF facilities in the Wairiri Stream valley dry.

The topographical survey has enabled the storage volume for each arm of the valley to be calculated. This is as contained in Table 4-1. This is further depicted in Figure 4-1, which also includes the available storage in the Wairiri Stream valley plus Hall Stream.

Table 4-1: Wairiri Valley Stage/Storage

R.L. (m)	Impoundment Volume Main Valley Only (m3)	Impoundment Volume Both Valleys (m3)
318	289,621,000	-
317	280,423,000	-
316	271,225,000	-
315	262,027,000	305,000,000
313.7	250,083,000	-
310	216,779,000	250,505,000
305	173,888,000	202,607,000
300	133,902,000	153,830,000
295	97,403,000	110,370,000
290	66,017,000	73,491,000
285	39,276,000	42,864,000
280	17995000	19301000
275	4877000	5058000
270	0	0

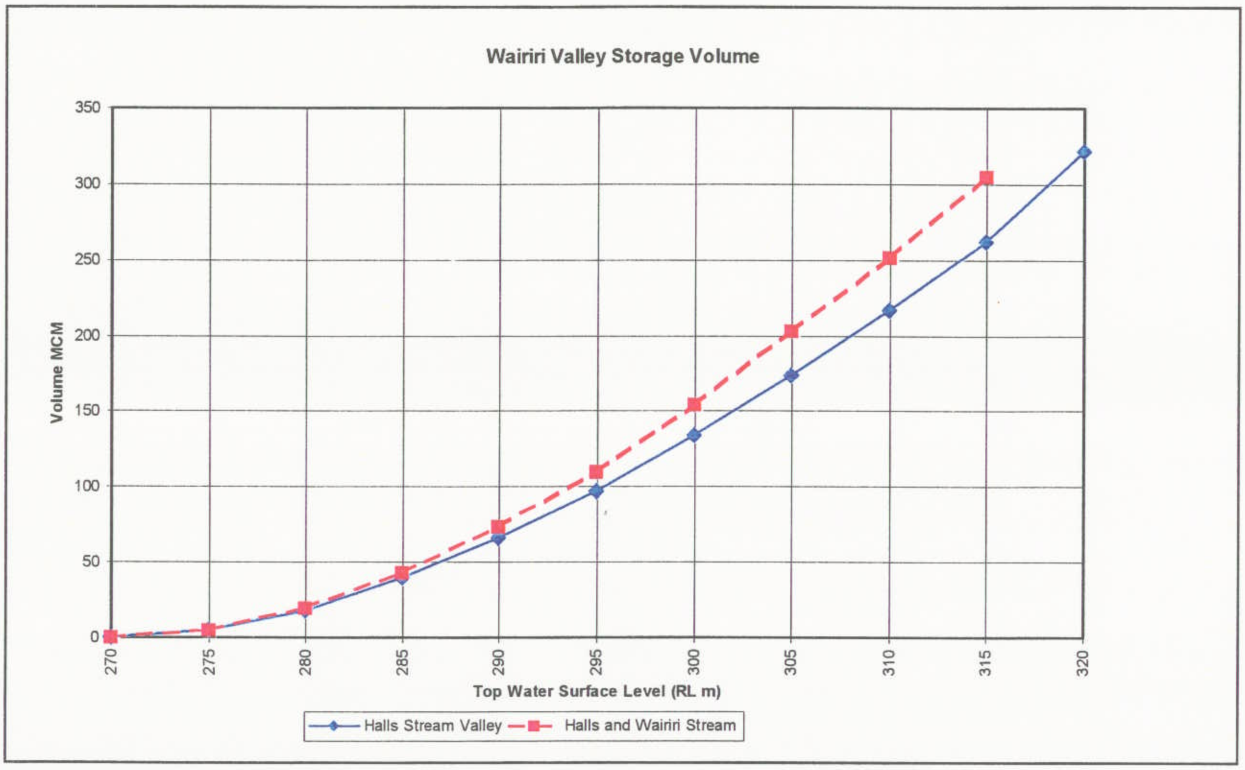
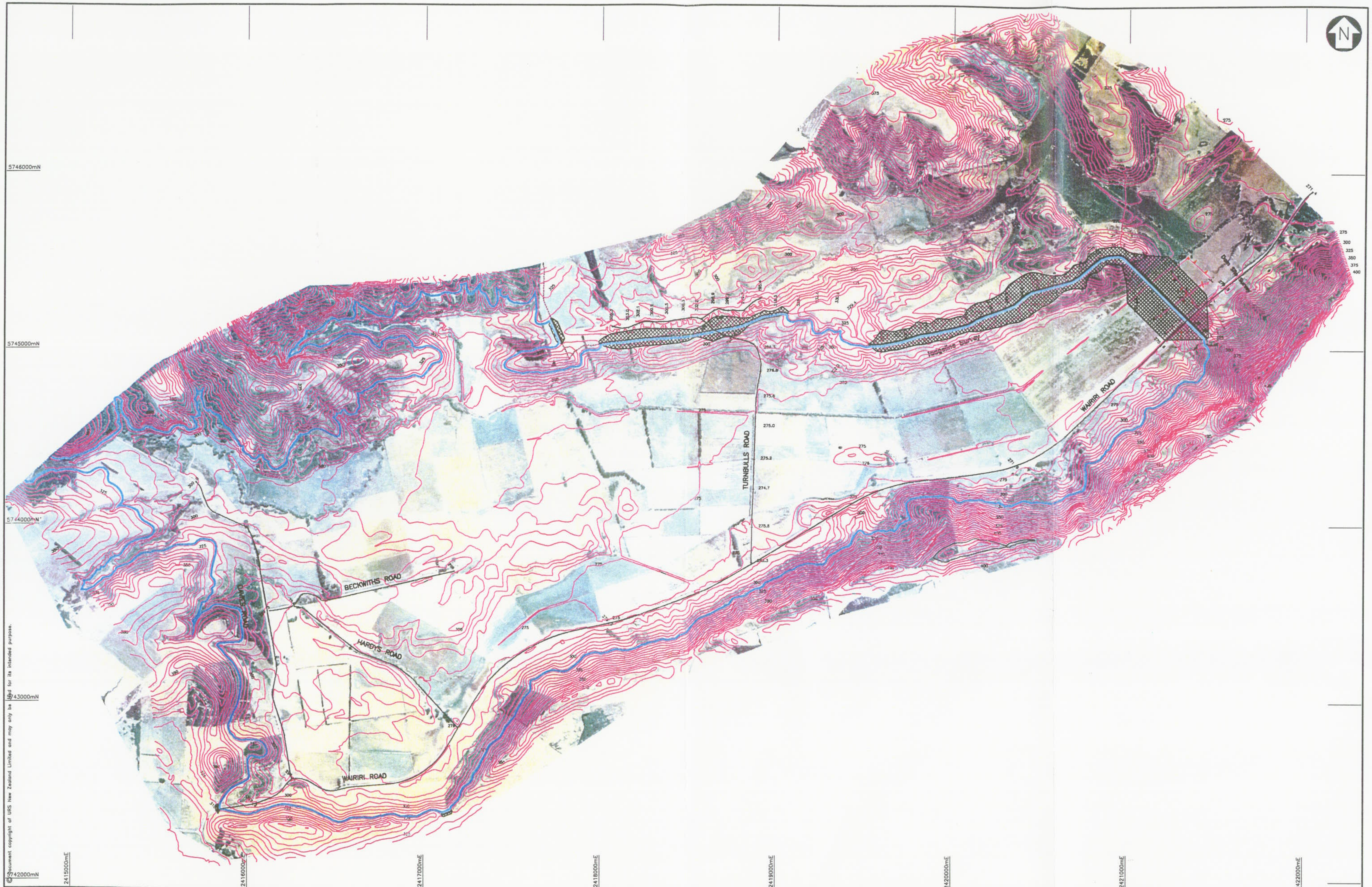


Figure 4-1: Stage Volume Relationship for Wairiri Valley

This enabled the storage volume of the valley to be accurately defined for a given top water surface elevation. Thus the "high tide mark" is now able to be physically located on site. The top water surface level in the main valley for a storage volume of 290 MCM is RL 318 m. Figure 4-2 depicts the contours of the valley with the top water surface shown, as well as the proposed dam footprint and ridge dams.

To achieve a top water surface level of RL 318 m, it is necessary to construct ridge dams along portions of the ridge between the Wairiri Stream and the main valley. These will be a maximum of 29 m high. The saddle through which access is gained to the NZDF facilities is at RL 307. Therefore an embankment approximately 13 m high would need to be constructed over this saddle. This would require relocation of the main office block and the workshop which both are positioned on top of the ridge.



REV	DESCRIPTION OF REVISION	BY	CHK	DATE
A	DRAFT ISSUE			

CENTRAL PLAINS WATER ENHANCEMENT

URS
Woodward Clyde
Dames & Moore

URS New Zealand Limited
Landsborough House
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CAD FILE NAME: S:\JOBS\48685\002\2000\6000 DRAWINGS\CPW002W007

TAB

XREF FILES: CPW002X001

SCALES: 1:10,000 (A1) 1:20,000 (A3)

ORIGINAL SIZE: A1

DESIGNED: CT

DRAWN: STT

CHECKED

PROJECT MANAGER

DATE: 28/11/01

PROPOSED WAIRIRI STORAGE RESERVOIR ($290Mm^3$)

STATUS: DRAFT

REVISION: A

DRAWING NUMBER: FIGURE 4-2

4.3 Geotechnical Investigations

Feasibility level geotechnical investigations were carried out for the CPWE scheme between March and August 2001. The majority of investigations were carried out around proposed site of the storage reservoir and dam. Additional notes on the investigations including geological logs and detailed testing results may be found in an earlier URS Technical Memorandum.

Previous preliminary investigations have identified several potential issues that are explored within this section of the report:

- Foundation geology (particularly suitability as foundation materials)
- Availability of suitable construction materials
- Presence of active faults within the dam footprint
- Presence of coal mining activities in the area

4.3.1 Scope of Investigation

Surface mapping and aerial photograph interpretation along with surface mapping of outcrops was carried during March and April 2001. A programme of subsurface investigations was then developed for the proposed dam in the Wairiri valley. Field investigations included test pits, cored drilling, geophysics and cone penetrometer tests.

Thirty exploratory test pits were excavated to a depth of up to 4.5m using a 20 tonne tracked excavator to examine near surface materials. The pits were located within the footprint of the proposed dam and along the western abutment ridge. A SASW (spectral analysis of surface waves) geophysical survey of the valley floor at the proposed dam site was conducted in order to characterise the valley fill materials and the shape of the underlying rock contact. Four fully cored holes were drilled, three located within the proposed dam footprint and the fourth located at a low point on the western abutment ridge, on NZ Defence Force property. Three Cone Penetrometer Tests (CPTs) were completed within the proposed dam footprint to measure in situ strength of the valley fill materials.

The field data and published literature have been used to assess the potential for coal mining activities within the Wairiri Valley to impact on the feasibility of the dam.

4.3.2 Geological Setting

Regional Geology

The eastern Southern Alps largely consists of Torlesse terrain rocks (greywacke sandstones and argillaceous mudstones) that locally form the basement. In Canterbury, these rocks are overlain by a sequence of terrestrial coal measures (Broken River Coal Measures), marine sandstones and mudstones (Eyre Group), and volcanigenic sediments and basalts (Burnt Hill Group) all of early to mid Tertiary age.

Fluvioglacial gravels of up to about 1,000,000 years age (Kowhai Formation) overlie the older rocks. Extensive outcrops of Hororata Formation, Woodlands Formation, Windwhistle Formation, Burnham Formation and Springston Formation underlie the proposed scheme corridor. The gravels generally become younger to the east.

The various elements of the CPWE scheme are located within or near the Canterbury foothills. Gravels generally underlie the scheme area, along with Tertiary aged marine sediments and other rocks, and a "basement" of Mesozoic aged greywacke sandstones.

Seismic Hazard

Recent studies by Stirling et al. (1999) and older studies by Smith and Berryman (1983) describe the regional seismic hazard in Canterbury. Stirling et al. (1999) use a Probabilistic Seismic Hazard Assessment method. Estimates of the level of shaking expected within the projected lifetime of an engineering structure (Table 4-2) are for Rangiora, which is considered to most closely represent the foothills area. Using this data we predict peak ground acceleration of about 0.31g for 150 years and 0.47g for 475 years for the scheme area.

Table 4-2: Estimates of Peak Ground Acceleration for the CPWE area

Return Period (years)	Stirling et al. (1999) PGA (g)
50	0.20
150	0.31
475	0.47
1000	0.58

Active Faulting

More than 20 active faults have been identified in Canterbury alone (e.g. Pettinga et al. 1998). Several of these structures pass within 20 km of the scheme, as shown on Figure 4-3, including the Porters Pass Amberley Fault Zone (PPAFZ), the Springfield Fault, the Hororata Fault and other structures.

The Porters Pass Amberley Fault Zone (PPAFZ) is the most active structure known in the vicinity of the scheme. Recent research (Cowan et al. 1996) indicates that the PPAFZ generates earthquakes of

Magnitude M_w7.2+ every 2000 years with approximately 8 m of lateral ground displacement. The PPAFZ does not directly cross any part of the CPWE scheme, but passes approximately 24 km north of the proposed Wairiri dam site.

The newly discovered Springfield Fault strikes approximately north-east from the upper Selwyn River to Springfield and has experienced repeated movement during the last 10,000 years and probably generates earthquakes of M_w7+ every few thousand years. The Springfield fault does not cross any structure of the proposed scheme and passes approximately 12 km north of the proposed Wairiri dam site.

The Hororata Fault passes within about 1 km of Hororata, strikes north-east and deforms young gravels at Racecourse Hill. Deformation of young gravels indicates that the fault may have experienced repeated movement during the last 10,000 years and probably generates earthquakes of M_w7+ every few thousand years. The Hororata Fault passes about 6 km south of the proposed Wairiri Dam site. The proposed head race probably crosses the Hororata Fault about 5 km south-west of Hororata.

The sequence of Tertiary aged sediments dip to the south east in the area of the proposed dam site as a result of tectonic uplift. While no active faults have been documented within the Wairiri valley, the potential for such structures still exists. Faults with small amounts of recent displacement were identified during investigations of a proposed Regional Landfill site near Cairn Hill. Small amounts of sympathetic movement on faults some distance from the seismogenic primary fault has also been reported from other sites (e.g. Allen and Cluff, 2000).

Strongly folded Tertiary rocks at the southern end of the Wairiri valley may indicate the presence of an active fold or fault, as may steep slopes along the western side of the valley. Both of these features lack prominent fault scarps suggestive of recent movement and neither are located within 2 km of the proposed dam footprint. While neither of these structures can be considered to be active based on present information, both should be more closely studied at the scheme design stage.

4.3.3 Wairiri Dam and Reservoir Site

Geology

As shown by Figure 4-4 the proposed Wairiri Dam is located within the east trending valley that is occupied by the Wairiri Stream and Halls Stream. The Harper Hills rise about 180 m on the south side and Mount Misery on the north side rises over 300 m above the valley floor. The location of drillholes, test pits, CPTs and geophysics surveys are shown in Figure 4-5.

Approximately 500 m downstream of the proposed dam (Figure 4-5), gravels are exposed in the valley floor and form a fan that has blocked off the mouth of the valley and impeded drainage. Field investigations (two drillholes, three CPTs, eight test pits and SASW seismic surveys) indicate that the valley floor is underlain by up to about 25 m of silt dominated sediments. The valley fill sediments beneath the dam footprint comprise mainly laminated fine sandy SILT and silty fine SAND, with various other thin layers of cleaner fine sand or silty clay. A gravely sand layer 1 m to 2 m thick occurs at the base of the sediments.

Below 23-25 m, the drill cores from DH 1 and DH 2 show a sequence of blue-grey very weak silty fine sandstone with some layers of cemented moderately strong fine sandstone and some layers of extremely weak sandstones and mudstones. A cross-section through the valley at the proposed dam site (Figure 4-6) indicates the inferred contact between valley sediments and the Tertiary rock.

Exposures in outcrop, test pits, and DH 3 on the right abutment show weak sandstones similar to those underlying the valley, and dipping about 20° into the slope. Slope failures involving soils and colluvium to a depth of about 0.5 m are common on these steep slopes. Parts of the right abutment are covered by a thin layer (2 to 3 m) of loess as seen in the small quarry at DH 3.

Test pits on the top of the left abutment exposed up to 2 m of loess. Weathered brown gravels estimated to be 10 m in thickness underlie the loess. These gravels correspond with Hororata Formation mapped by Wilson (1989). The abutment and most of the ridge forming the left side of the reservoir comprise extremely weak to moderately strong fine sandstones which dip about 20° to the south, though bedding dips varied between 5° and 30° and dip directions ranged from east to south-west.

Hummocky ground along the southern side of the abutment ridge is indicative of old slope failures. Given that bedding in the weak sandstone dips out of the slope, shallow failures involving these materials are to be expected. The slope angles are generally similar to the bedding dip, so large-scale failures are unlikely.

The gravels that cap the ridge are highly weathered and many of the greywacke clasts can be broken easily with a hammer. The insitu permeability of these materials has not been tested during this study.

Permeability and Groundwater Conditions

Permeability was measured using falling head tests in drill hole piezometers during September 2001. The depth to groundwater in the valley floor was 6 to 7 m. The measured permeability of the sand and gravel unit at the base of the valley fill alluvium is relatively high (approximately 2×10-5 ms-1). The permeability of the laminated silt and sand is expected to be comparatively low, though it was not measured during this investigation. The piezometers suggest significant no vertical groundwater gradient (i.e. measured groundwater levels in the lake sediments and underlying rock are essentially the same). The measured permeability of the Eyre Group sandstone/siltstone rock mass is very low (between 2.9×10-7 and 2.8×10-9 ms-1), as there is little jointing and a significant fines content within the rock. BH4 indicates that groundwater levels are higher in the ridge adjacent to the NZDF property.

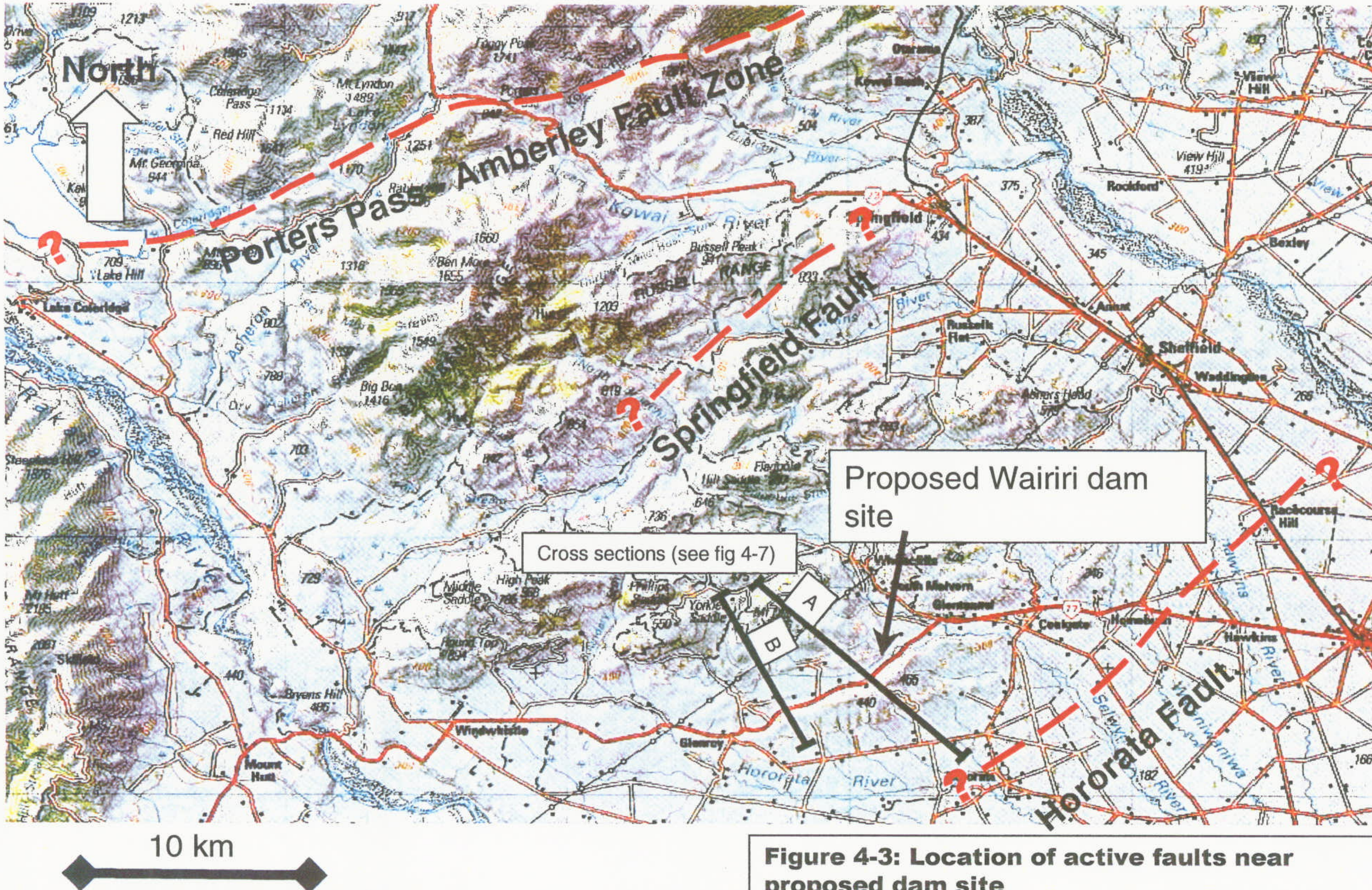
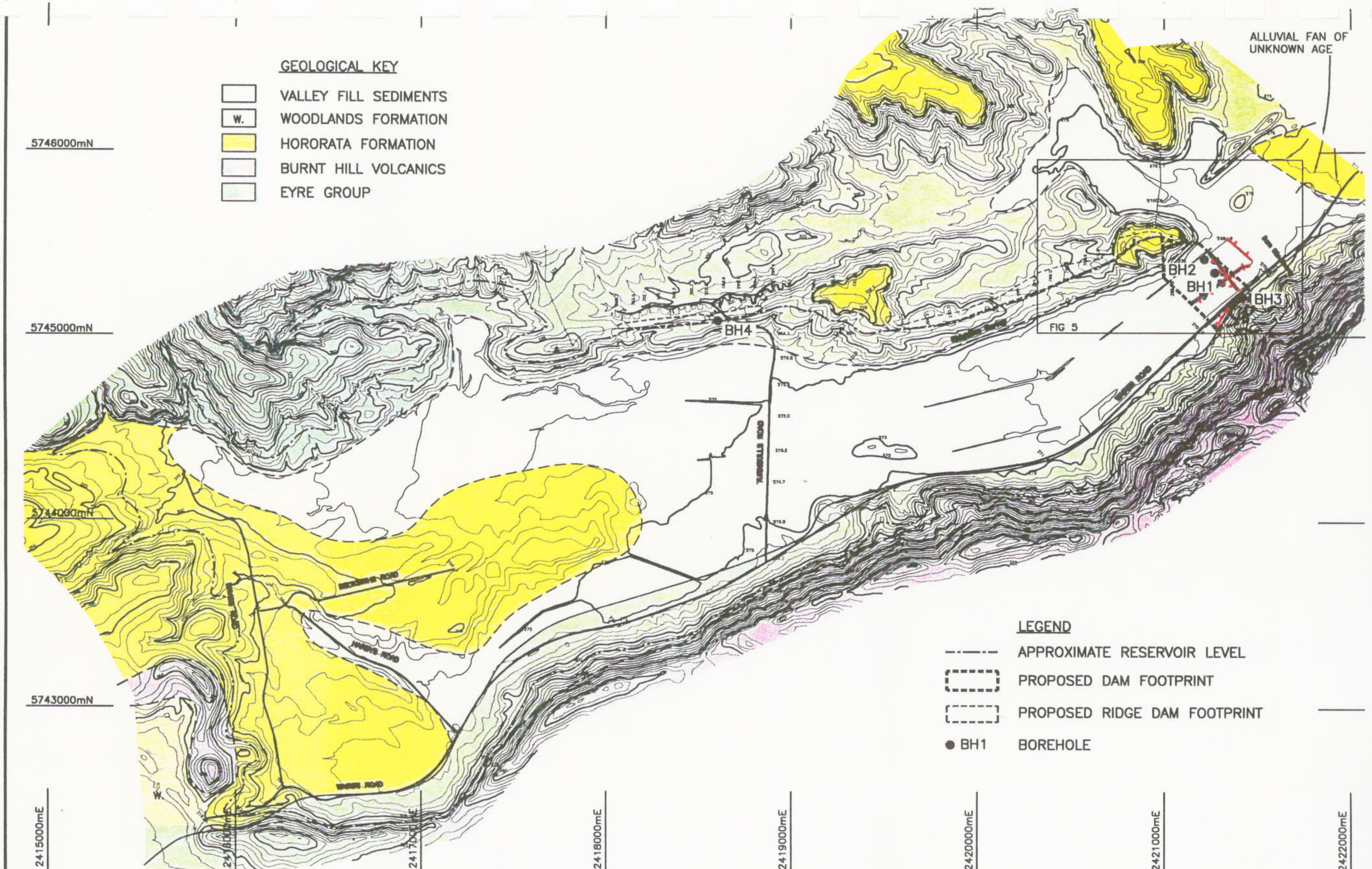


Figure 4-3: Location of active faults near proposed dam site



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Title
GEOLOGY OF THE WAIRIRI VALLEY

Figure No. 4-4

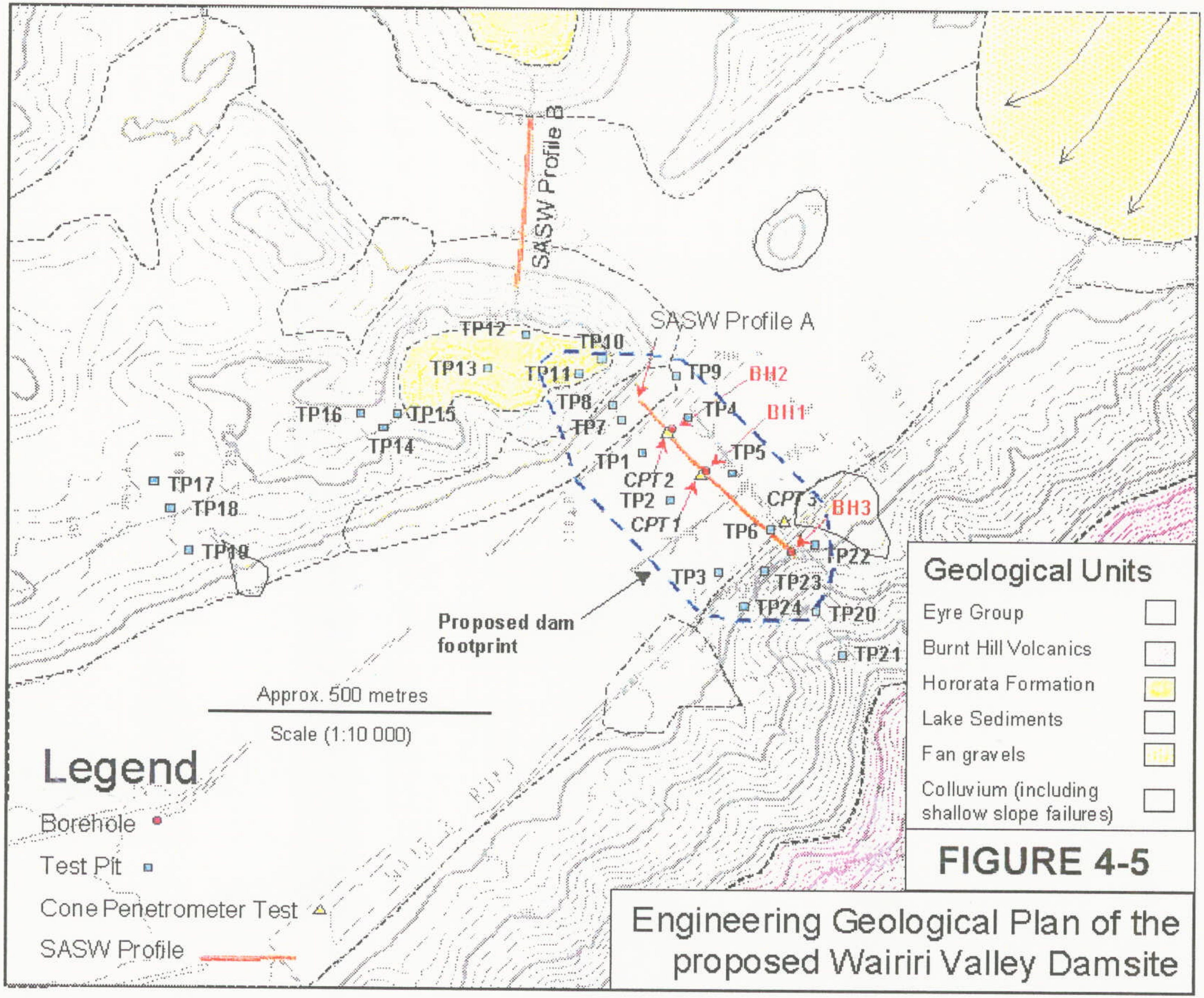

FIGURE 4-5

Engineering Geological Plan of the proposed Wairiri Valley Damsite

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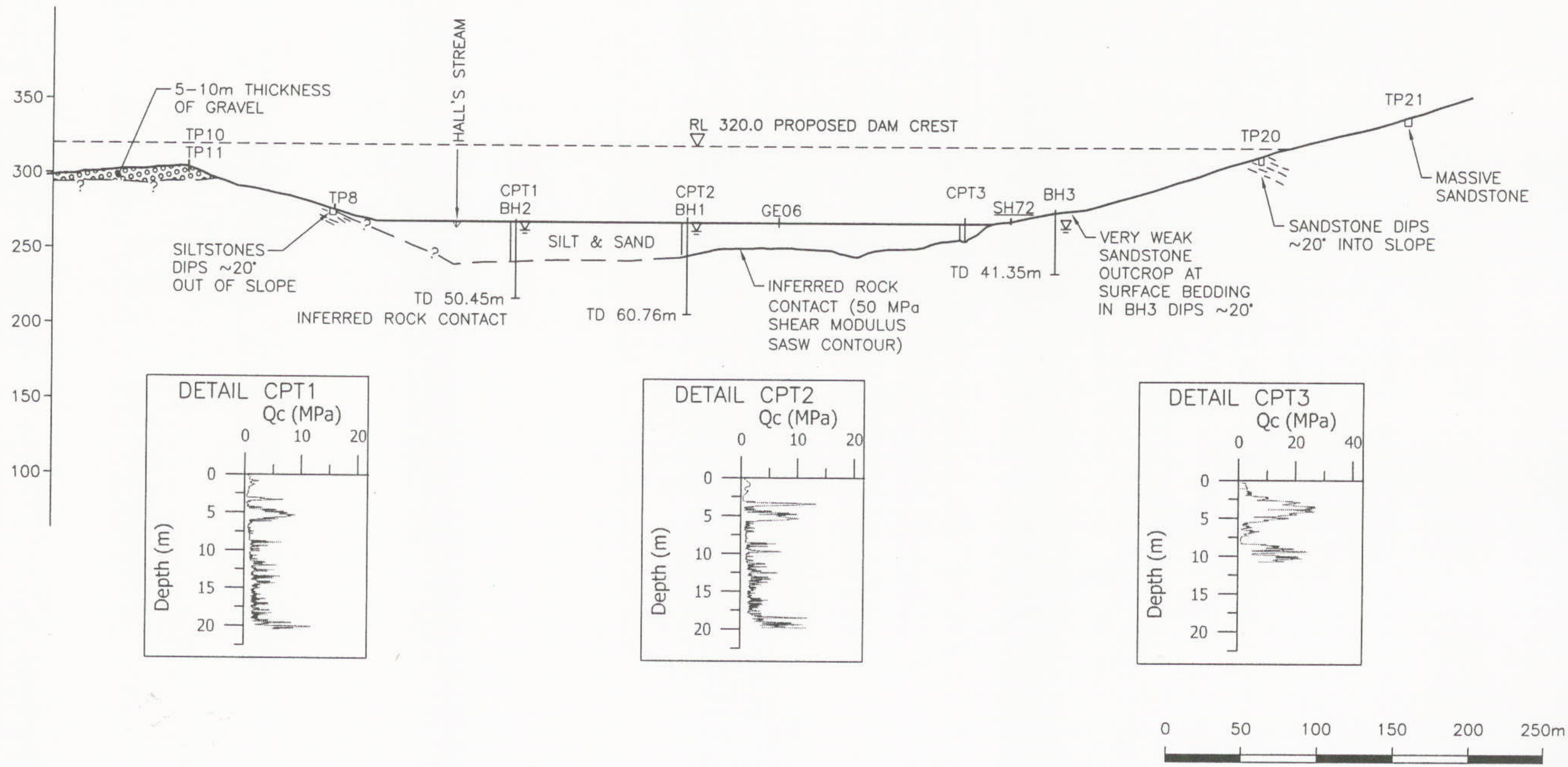

CROSS SECTION ACROSS WAIRIRI VALLEY AT PROPOSED DAM SITE

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Figure No. FIGURE 4-6

Geotechnical Properties of Valley Fill Sediments

Cone resistance in the saturated valley fill silts indicates shear strength generally less than 100 kPa. The sands are typically moderately dense. Geophysics results indicate that valley fill sediments generally have a static shear modulus of less than 30 MPa. This stiffness corresponds with loose to moderately dense consistency. The SASW results also pick up an abrupt increase in stiffness with depth for most of the profile length. The increase in stiffness is best interpreted as the contact between valley fill sediments and the underlying Tertiary rock, as it corresponds well with the depth to bedrock encountered in DH 1 and DH 2. The depth to bedrock increases away from the right abutment, from rock at surface at the right abutment to about 20 m depth of sediment near the centre of the valley. The SASW profile lacked energy to "see" the bedrock at more than 20 m depth at the left abutment.

Saturated loose sandy or silty materials can be prone to liquefaction during strong earthquake shaking. A preliminary analysis of the CPT results indicates that the valley fill sediments include materials that are sufficiently loose and of suitable grain size to be susceptible to liquefaction. Rigorous analysis of liquefaction susceptibility of these materials should be carried out prior to detailed dam design, because the propensity for liquefaction will strongly influence the design profile of the embankment.

The foundation for an embankment dam at the proposed site would either be directly on the valley sediments, or on Tertiary sandstone at a depth of approximately 20 metres. Design of the former will need to recognise the low strength and compressibility of the sediments, the potential for liquefaction during strong seismic shaking and the effect of a relatively permeable sand and gravel layer at the base of the sediments. The option of excavating these weak materials to found the dam on Tertiary material would eliminate or greatly reduce the possibility of liquefaction and deep bearing failure.

Geotechnical Properties of Tertiary Rocks

The Tertiary rocks that underlie the proposed dam site include extremely weak and very weak fine sandstones interpreted to be part of the Eyre Group sedimentary sequence. The extremely weak fine sandstones are expected to be relatively erodable when unprotected. The rock should be readily excavated with conventional earthmoving equipment.

Geophysics results indicate a static shear modulus in excess of 50 MPa on the rock outcropping at the right abutment, increasing to over 90 MPa at about 10 m depth. Observations of drill core and outcrop indicate that these materials typically have unconfined compressive strengths in the order of 1 to 5 MPa. Higher strength material (estimated UCS of up to 100 MPa) is restricted to layers less than about 1 m thickness.

The Tertiary sandstones are believed to be suitable foundation materials for an embankment dam. Dam design will need to recognise the low strength of the materials and the potential for some layers within the rock to be erodable.

4.3.4 Presence of Coal Seams

The geological model for the reservoir location is shown on the geological cross section in Figure 4-7. A sequence of Late Cretaceous and Tertiary sedimentary and volcanic rocks dips to the south east at about 20°.

At the base of this sequence is a remnant of Mount Somers Volcanics which forms Mount Misery to the west of the reservoir. Overlying this is a layer of Broken River Coal Measures several hundred metres in thickness.

These are mainly terrestrial rocks and include several thin coal seams that have historically been mined in the Malvern Hills area. Aubill mine and Steventon 1 mine are the closest to the dam and saddle dams and these lie about 1 km north-west of the dam footprints. These mines were active during the late 1800's and early 1900's and relatively small amounts of coal were won (generally from a few hundred to a few thousand tons). Underground workings are not expected to be extensive.

Overlying the Broken River Coal Measures are various mainly marine rocks, which are generally fine muddy sandstones. The rocks in this sequence have been referred to in geological literature by various names and include "Homebush Sandstone", "Selwyn Rapids Beds" and "Thongcaster Formation". Investigations within the dam and saddle dam footprints intersected materials consistent with this part of the geological sequence.

Wilson (1988) has included this sequence of sedimentary rocks (coal measures, marine and non-marine sediments) into a formation that he refers to as Eyre Group, and this report has adopted that nomenclature also.

Overlying the Eyre Group sedimentary rocks and forming the bulk of the Harper Hills is a sequence of a few hundred metres thickness of mostly volcanic rocks including tuffs and basalts referred to by Wilson (1988) as the View Hill Volcanics.

Underground coal workings within the dam or reservoir footprints

A geological map drawn by Speight (1928) shows an outcrop of coal seams along the saddle dam ridge. URS investigations, including a 30 m deep investigation bore, found no coal in this area. NZDF personnel know of no coal outcropping in this area or evidence of old workings other than the Steventon 1 mine described above.

In a report on old coal workings in the Malvern Hills, Sara (1972) gives co-ordinates for historic mines. These are mainly north-west of the saddle dam ridge. The locations are in agreement with this geological model for the area, except for South Brockley mine, which Sara's co-ordinates show to be located near Aitkins Road, 700 m east of the proposed dam footprint. Subsequent inquiries to Institute of Geological and Nuclear Sciences have revealed that South Brockley mine was incorrectly plotted by Sara and that its actual location was near to Mount Brockley, approximately 8 km west of the location given by Sara and at least 1 km west the reservoir area (personal communication Richard Sykes, IGNS coal geologist).

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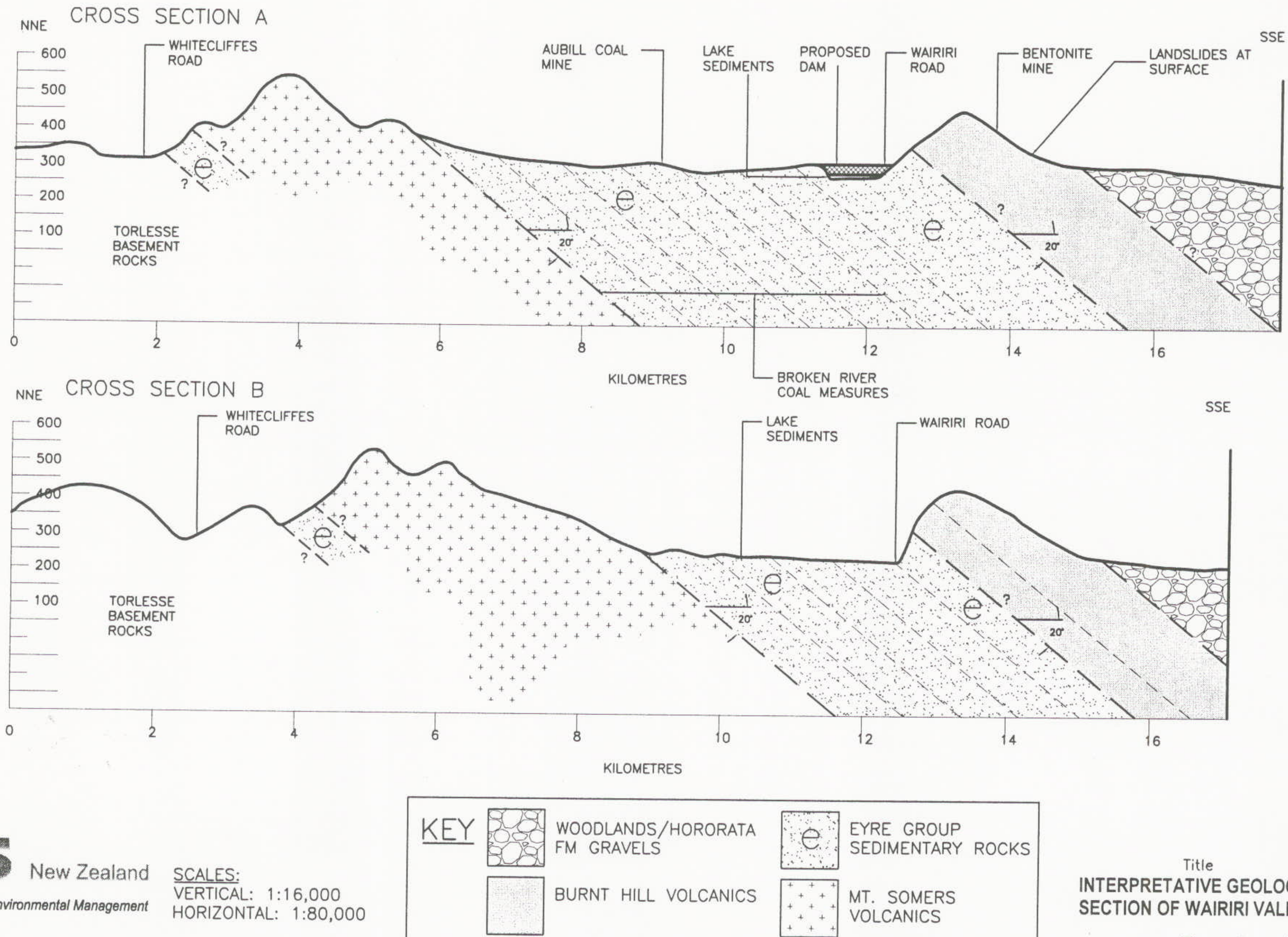

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Title
INTERPRETATIVE GEOLOGICAL CROSS SECTION OF WAIRIRI VALLEY

Figure No. 4-7

As shown in the geological cross section in Figure 4-7, the geological model predicts that coal seams will be present at a depth of about 100 m below dam foundation level. The likelihood of underground extraction of those coals having occurred at significant depth is considered to be negligible.

Design investigations for the dams will necessitate further exploratory drilling within the foundation footprint, including the saddle dams, and these should confirm that coal is not present in the near surface geology.

4.3.5 Outlet Canal Alignment

A 60 m^3/sec canal is proposed to carry water from the Wairiri Valley storage reservoir to the distribution canal as shown on Figure 2-5. The outlet canal would have a total width (including embankments) of between 30 and 50 metres.

The canal alignment follows the northern flanks of the Harper Hills and it would be constructed as a balanced cut and fill. Weak fine sandstones of the Eyre Group underlie the lower flanks of the Harper Hills in this area and grade into stronger volcanic rocks (tuffs and basalts) in the upper parts of the slope. These rocks are mantled with a layer of colluvium, expected to be up to a few metres thickness, incorporating volcanic boulders in a matrix of silty fine sand. It is expected that the canal would only encounter Eyre Group rocks and the overlying colluvium and loess, and would not encounter insitu volcanic rocks.

4.3.6 Head Race Alignment

The proposed distribution canal runs at an elevation of approximately 235 m between the Rakaia and Waimakariri Rivers. The canal will have a total width (including embankments) of between 40 and 50 metres and will be constructed using balanced cut and fill.

The majority of the canal will be constructed on outwash gravels of varying age. Tertiary sediments including weak sandstones are expected at the inlet site at the Rakaia Gorge. These should be readily excavatable by bulldozer or excavator. Erodability tests should be carried out if the design exposes the weak sandstones.

The outwash gravels that underlie the canal are expected to have low fines contents and relatively high permeability. The oldest gravels (and hence the most weathered and fines rich) will be encountered where the canal sidles around the foothills of the Harper Hills and Homebush Ridge. Lining may be required where the canal encounters particularly permeable gravels. The most likely places to find highly permeable gravels will be:

- Where the canal crosses young outwash gravels and colluvium covered slopes as it sidles out of the Rakaia and Waimakariri Gorges;
- Where the canal crosses modern river floodplains (particularly the Selwyn River floodplain) and the youngest terraces.

4.3.7 Construction Materials

Dam Construction Materials

Construction of the Wairiri Valley dam will require sources of low permeability materials to construct the dam core, coarse grained well graded materials for the dam shoulders, sands to construct intermediate filter zones, and rock riprap for erosion protection.

The valley fill sediments are mainly slightly clayey silts and fine sands. These materials may be suitable for core materials. Laboratory testing will be required to ascertain the engineering properties of the material. The moisture content is generally high and some conditioning will probably be needed to achieve optimum moisture content. As much as 60% of the valley fill sediments appear suitable for use as core construction materials. Selective removal of sandy layers may be required.

Silty gravel may produce a better core material than the valley fill silt, as it tends to form a stronger fill material when recompacted. Weathered Hororata Formation from within the reservoir area could provide a source for such material. Laboratory testing will be required to verify the engineering properties of recompacted Hororata Formation and determine whether it would form a suitable core construction material.

Shoulder materials could be sourced from gravels within the reservoir area. Terrace gravels of the Hororata Formation reportedly cover the valley floor at the west end of the Wairiri Valley (Wilson 1989). These materials were examined in test pits on the left abutment ridge and are described above. When compacted these gravels are expected to form a relatively strong fill, though the fines content is likely to give the fill a low permeability. Drainage within the dam should be designed accordingly.

An alternative source of shoulder material is the younger gravels present downstream from the dam site. Burnham and Springston Formation gravels are both present between the dam site and the modern Selwyn River. These gravels comprise similar greywacke sourced clasts, but are much less weathered, have lower fines content and will form a more permeable fill material. Abundant gravels are present close to the dam site. A disadvantage of these materials is that they must be borrowed from outside the reservoir footprint. Testing will be required to confirm the material suitability, but they are likely to be better shoulder materials than the Hororata Formation.

Sand suitable for filter construction is a more difficult material to source. Sand could be manufactured by screening young gravels from the modern Selwyn River bed or adjacent river terraces. Material sourced in this manner should be a more suitable filter material, though transport distances may be greater also. Testing will be required to confirm the material properties. It is common for filter to be manufactured to meet specific requirements. Alternatively, crushing of the weak sandstones within the reservoir area may provide suitable materials, though difficulty is expected in finding large enough volumes of consistently clean sand.

Canal Lining Materials

Where canal lining is required, the best source of lining material is expected to be the weathered old gravels that outcrop around the southern and eastern sides of the Harper Hills and Homebush Ridge. These materials should produce a strong low permeability fill when compacted. Compaction of the insitu gravels mixed with a clay material such as bentonite may be a viable alternative. Testing will be required to confirm the suitability of these materials as canal liners. This has been recommended for investigation in the next phase of the project.

4.3.8 Stability of the Harper Hills

The Harper Hills form the south side of the proposed reservoir, rising to 180m above the valley floor. Exposures in outcrop, test pits, and DH 3 on the right abutment show weak sandstones similar to those underlying the valley, and dipping about 20° into the slope. Slope failures involving soils and colluvium to a depth of about 0.5 m are common on these steep slopes. Parts of the right abutment are covered by a thin layer (2 to 3 m) of loess as seen in the small quarry at DH 3. Examination of aerial photographs has not indicated the presence of any old large-scale landslides, which would be of concern to the reservoir. There will be ongoing surficial slippage and erosion of this hill side, however this is not of major concern in relation to the suitability of the valley.

The strata dipping to the south (into the slope) within the Harper Hills make catastrophic failure of this slope an extremely unlikely event.

4.3.9 Springs

The Harper Hills are underlain by a sequence of south-east dipping sedimentary and volcanic rocks that include bentonite clays, and these rocks generally have low permeabilities (see cross section on Figure 4-7). Existing springs on the south-east side of the Harper Hills generally occur at 340 to 360 m RL or higher, which is at least 20 m higher in elevation than the proposed maximum reservoir level (318 m RL). As a result it is predicted that groundwater flows will not increase in existing springs on the south-east side of the reservoir.

Leakage from the reservoir is not expected to result in extensive new springs along the south side of the Harper Hills because of the long travel path and the low permeability of the rocks. At the western end of the Harper Hills the ridge narrows and in this area some engineering (such as a saddle dam or low permeability blanket) may be required to prevent excessive groundwater flow through the ridge.

5.1 Introduction

There are many aspects which determine the cost of water to the user. There are technical issues such as the size of the scheme, the choice of the scheme components, the particular geographical areas serviced, the level of service provided and the financial assumptions made around company structures, debt servicing and other financial parameters. This section outlines technical aspects which directly impact upon the cost, the financial and business structures, the price of the water and ultimately the ability of the farmers to pay for water and the schemes bankability.

5.2 Base Scheme Costs

The base scheme is defined as 84,000 ha including the Springfield/Sheffield area. This scheme option has a total capital cost of $227M with annual operating and maintenance costs of $6.7M/yr. These costs are presented in Table 5-1.

Table 5-1: Base Scheme Costs

Item	Cost ($) Including Springfield/Sheffield	Cost ($) Excluding Springfield/Sheffield
Total Capital Cost	$235,031,000	$219,178,000
Total Annual Operating and Maintenance Cost	$2,295,000	$1,165,000
Total Annual Energy Cost for pumping	$4,425,000	$3,790,000
Annualised Cost per hectare [1]	$344	$311

Note 1. The annualised cost is the whole of life cost assuming a 20 year loan period and an interest rate of 8.0% expressed in terms of 2001 nominal dollars, equally shared over 84,000 ha. This is not the price of the water.

There are many different possible arrangements for the final scheme that may ultimately be implemented, therefore it is important to understand how this base cost may vary depending on the assumptions made. A breakdown of the capital costs of the optimal solution developed for a range of scheme areas is presented in Table 5-2. The scheme area will depend upon the uptake and commitment from the farming community and funding bodies. Therefore a range of scheme areas, from 50% through to the full 100% (84,000 ha) has been costed.

Each optimal solution is defined by a supply area, a storage reservoir size, a re-supply pumping rate and an intake flow option. Approximately 38% of the costs are associated with the storage reservoir, 29% associated with the head race and intakes, 10% with the pumping infrastructure and 23% with distribution infrastructure below the head race.

Table 5-2: Summary of Costs for Different Scheme Areas ($,000)

Capital Breakdown
Pumping to Storage up Rakaia Terraces - without

Storage (million m3)	290	250	210	180	160	140
Area	**100%**	**90%**	**80%**	**70%**	**60%**	**50%**
Wairiri Dam and Reservoir						
Earthworks	$ 64,000	$ 53,430	$ 43,150	$ 35,760	$ 31,770	$ 28,480
Spillway	$ 10	$ 10	$ 10	$ 10	$ 10	$ 10
Outlet Tower	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500	$ 4,500
Relocation Roads	$ 9,162	$ 9,162	$ 9,162	$ 9,162	$ 9,162	$ 9,162
Relocation HVDC Lines	$ 500	$ 500	$ 500	$ 500	$ 500	$ 500
Sub Total	$ 78,172	$ 67,602	$ 57,322	$ 49,932	$ 45,942	$ 42,652
Head Races and Intakes						
Intake Structures	$ 4,296	$ 4,137	$ 4,003	$ 3,672	$ 3,405	$ 3,149
Earthworks	$ 27,469	$ 26,454	$ 25,596	$ 23,482	$ 21,771	$ 20,136
Bridges	$ 7,820	$ 7,531	$ 7,287	$ 6,685	$ 6,198	$ 5,732
Concrete Siphons	$ 7,575	$ 7,295	$ 7,059	$ 6,476	$ 6,004	$ 5,553
Control Structures	$ 5,844	$ 5,628	$ 5,446	$ 4,996	$ 4,632	$ 4,284
Drop Structures	$ 3,532	$ 3,401	$ 3,291	$ 3,019	$ 2,799	$ 2,589
Sub Total	$ 56,536	$ 54,447	$ 52,681	$ 48,329	$ 44,808	$ 41,442
Pump Infrastructure Rakaia						
Civil and Structural	$ 2,201	$ 1,860	$ 1,543	$ 1,366	$ 1,019	$ 890
Pumps	$ 7,934	$ 6,705	$ 5,565	$ 4,924	$ 3,674	$ 3,209
Valves and Pipes	$ 11,451	$ 9,676	$ 8,031	$ 7,106	$ 5,302	$ 4,631
Electrical	$ 2,914	$ 2,463	$ 2,044	$ 1,808	$ 1,349	$ 1,179
Sub Total	$ 24,500	$ 20,704	$ 17,183	$ 15,204	$ 11,344	$ 9,908
Distribution						
Earthworks	$ 33,768	$ 30,391	$ 27,014	$ 23,638	$ 20,261	$ 16,884
Drop Structures/Culverts	$ 10,584	$ 9,526	$ 8,467	$ 7,409	$ 6,350	$ 5,292
Road Crossings	$ 1,512	$ 1,361	$ 1,210	$ 1,058	$ 907	$ 756
Control Structures	$ 2,520	$ 2,268	$ 2,016	$ 1,764	$ 1,512	$ 1,260
Sub Total	$ 48,384	$ 43,546	$ 38,707	$ 33,869	$ 29,030	$ 24,192
Preliminary and General						
P&G	$ 11,587	$ 10,620	$ 9,666	$ 8,776	$ 8,091	$ 7,412
TOTAL Capital	$ 219,178	$ 196,918	$ 175,559	$ 156,110	$ 139,215	$ 125,606

Pumping to Storage up Rakaia Terraces - including

Note: Breakdown for the first four items is as above.

Area	100%	90%	80%	70%	60%	50%
Wairiri Dam and Reservoir	$ 78,172	$ 67,602	$ 57,322	$ 49,932	$ 45,942	$ 42,652
Head Races and Intakes	$ 56,536	$ 54,447	$ 52,681	$ 48,329	$ 44,808	$ 41,442
Pump Infrastructure Rakaia	$ 24,500	$ 20,704	$ 17,183	$ 15,204	$ 11,344	$ 9,908
Distribution	$ 48,384	$ 43,546	$ 38,707	$ 33,869	$ 29,030	$ 24,192
P&G	$ 11,587	$ 10,620	$ 9,666	$ 8,776	$ 8,091	$ 7,412
Pump Infrastructure Kowai						
Civil and Structural	$ 1,424	$ 1,424	$ 1,424	$ 1,424	$ 1,424	$ 1,424
Pumps	$ 5,134	$ 5,134	$ 5,134	$ 5,134	$ 5,134	$ 5,134
Valves and Pipes	$ 7,409	$ 7,409	$ 7,409	$ 7,409	$ 7,409	$ 7,409
Electrical	$ 1,886	$ 1,886	$ 1,886	$ 1,886	$ 1,886	$ 1,886
Sub Total	$ 15,853	$ 15,853	$ 15,853	$ 15,853	$ 15,853	$ 15,853
	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL Capital	$ 235,031	$ 212,771	$ 191,412	$ 171,963	$ 155,068	$ 141,459

Table 5-3 summaries the rates and quantities used to generate the total capital cost of the base scheme.

Table 5-3: Summary of Quantities and Rates for Base Scheme

SCHEDULE OF RATES - Central Plains Irrigation Scheme							
Pumping to Storage up Rakaia Terraces - without Springfield/Sheffield							
		Quantity	Unit	Rate	Ctngcy	Component Cost	Total Cost
1	**Wairiri Embankments and Reservoir (290 milliom m3 storage)**						
1.1	Embankment Earthworks						
1.1.1	Foundation - excavate to waste	3,008,433	m3	$3.00	20%	$ 10,830,359	
1.1.2	Shoulder Material - supply and place	3,659,453	m3	$5.50	20%	$ 24,152,390	
1.1.3	Transition Zone - supply and place	1,208,310	m3	$5.50	20%	$ 7,974,846	
1.1.4	Low Permeability Core - supply and plac	2,297,649	m3	$6.00	20%	$ 16,543,076	
1.1.5	Filter Drains - manufacture and place	249,963	m3	$15.00	20%	$ 4,499,328	
							$ 64,000,000
1.2	Spillway	1	ls	$8,333	20%	$ 10,000	
1.3	Outlet Tower	1	ls	$3,750,000	20%	$ 4,500,000	
1.5	Road Relocation						
1.5.1	SH 77 Diversion to Downs Road	1	ls	$5,492,308	30%	$ 7,140,000	
1.5.2	Defence Access Road Relocation	1	ls	$742,923	30%	$ 965,800	
1.5.3	Davies Road Diversion	1	ls	$812,308	30%	$ 1,056,000	
							$ 9,161,800
1.6	Relocation HVDC Transmission Lines	1	ls	$500,000	0%	$ 500,000	
	TOTAL Wairiri Dam and Reservoir						**$ 78,172,000**
2	**Head Races and Intakes (100% supply - 60m3/s)**						
2.1	Inlet Structures						
2.1.1	Waimakariri	1	ls	$2,426,129	40%	$ 3,396,581	
2.1.2	Rakaia	1	ls	$642,435	40%	$ 899,410	
							$ 4,295,990
2.2	Earthworks						
2.2.1	Waimak-Rakaia Headrace - cut to fill	3,159,374	m3	$5.00	46%	$ 23,047,457	
2.2.2	Windwhistle Headrace - cut to fill	204,920	m3	$5.00	44%	$ 1,475,423	
2.2.3	Outlet Canal - cut to fill	236,141	m3	$5.00	65%	$ 1,948,161	
2.2.4	Outlet Canal - liner supply and place	58,282	m3	$10.00	30%	$ 757,664	
2.2.5	Stilling Pond - cut to fill	36,983	m3	$5.00	30%	$ 240,392	
							$ 27,469,096
2.3	Bridges						
2.3.1	Double lane bridge	17	ea	$178,735	20%	3,646,194	
2.3.2	Single lane bridge	51	ea	$68,195	20%	4,173,534	
							$ 7,819,728
2.4	Concrete Siphons						
2.4.1	Waimak-Rakia Headrace - Hororata Riv	1	ls	$475,072	30%	617,594	
2.4.2	Waimak-Rakia Headrace - Selywn Rive	1	ls	$678,359	30%	881,867	
2.4.3	Waimak-Rakia Headrace - Hawkins Riv	1	ls	$1,676,256	30%	2,179,133	
2.4.4	Windwhistle Headrace - Hororata River	1	ls	$1,126,951	30%	1,465,036	
2.4.5	Outlet Canal - Beside Selwyn	2	ls	$482,090	30%	1,253,434	
2.4.6	Outlet Canal - Selwyn River	1	ls	$906,351	30%	1,178,256	
							$ 7,575,320
2.5	Control Structures						
2.5.1	Gates 30m3/s	7	ea	$399,825	40%	$ 3,918,285	
2.5.2	Gates 20m3/s	1	ea	$241,900	40%	$ 338,660	
2.5.3	Gates 17m3/s	1	ea	$161,763	40%	$ 271,345	
2.5.4	Gates 15m3/s	2	ea	$161,763	40%	$ 452,935	
2.5.5	Gates 10m3/s	3	ea	$129,363	40%	$ 543,323	
2.5.6	Gates 5m3/s	3	ea	$76,083	40%	$ 319,550	
							$ 5,844,097
2.6	Drop Structures	17	ea	$159,803	30%	$ 3,531,646	$ 3,531,646
	TOTAL Head Races and Intakes						**$ 56,536,000**
3	**Pump Infrastructure Rakaia (max pumping rate of 17.2m3/s baack to storage)**						
3.1	17m3/s Pump Station	1	ls	$20,416,500	20%	$ 24,499,800	
	TOTAL Pump Infrastructure Rakia						**$ 24,500,000**
4	**Distribution (100% area - 84,000 hactares)**						
4.1	Earthworks, Structures, Crossings, Land	84,000	ha	$480.00	20%	$ 48,384,000	
	TOTAL Distribution						**$ 48,384,000**
5	**Preliminary and General**						
4.1	P&G	1	ls	$ 11,586,662	0%	$ 11,586,662	
	TOTAL P&G						**$ 11,587,000**
TOTAL CAPITAL COST							**$ 219,178,000**

Table 5-4 summarises the total scheme costs including operations and maintenance costs and energy costs. Energy costs are based on a unit rate of 6.3 cents/kWh. Total costs are annualised with a discount rate of 8.00% over a 20 year term. For this analysis, as discount rate of 8% has been used as this is a realistic value to assume for the comparisons taking into account all of the costs over the life (20 years) of the scheme. This should not be confused with the finance rate of 7% used later in this section to establish a price for water. The price will be a combination of up front capital plus annual charges. This analysis does not take this into account.

Table 5-4: Scheme Costs for Different Land Areas

Item	Cost ($)	Cost ($)	Cost ($)	Cost ($)	Cost ($)	Cost ($)
Scheme Area %	**100%**	**90%**	**80%**	**70%**	**60%**	**50%**
Including Springfield/Sheffield						
Total Capital Cost	235,031,000	212,771,000	191,412,000	171,963,000	155,068,000	141,459,000
Total O&M Cost	2,295,000	2,066,000	1,852,000	1,713,000	1,495,000	1,395,000
Total Energy Cost	4,425,000	3,392,000	2,722,000	2,399,000	1,957,000	1,709,000
Annualised Cost/ha	$344	$338	$337	$346	$359	$392
Excluding Springfield/Sheffield						
Total Capital Cost	219,178,000	196,918,000	175,559,000	156,110,000	139,215,000	125,606,000
Total O&M Cost	1,665,000	1,436,000	1,222,000	1,084,000	865,000	766,000
Total Energy Cost	3,790,000	2,757,000	2,087,000	1,764,000	1,322,000	1,074,000
Annualised Cost/ha	$311	$301	$296	$299	$304	$326

Figure 5-1 presents the total annualised cost per hectare of land for each of the different scheme sizes. A scheme designed to supply water to 80% of the total 84,000 hectares is expected to achieve the lowest annualised cost of $326 per hectare assuming Springfield/Sheffield is included in the scheme area. This figure shows how the unit cost of irrigation increases for the larger scheme areas as well as the smaller scheme areas. The reason that the costs increase above the 80% area scheme option, is that there is a greater reliance of the scheme upon stored water, which is more expensive. In essence the next new farm to be added to the scheme area would have to be supplied water entirely from the storage reservoir. At the lower area end of the scale, the costs increase due to the loss in economy of scale.

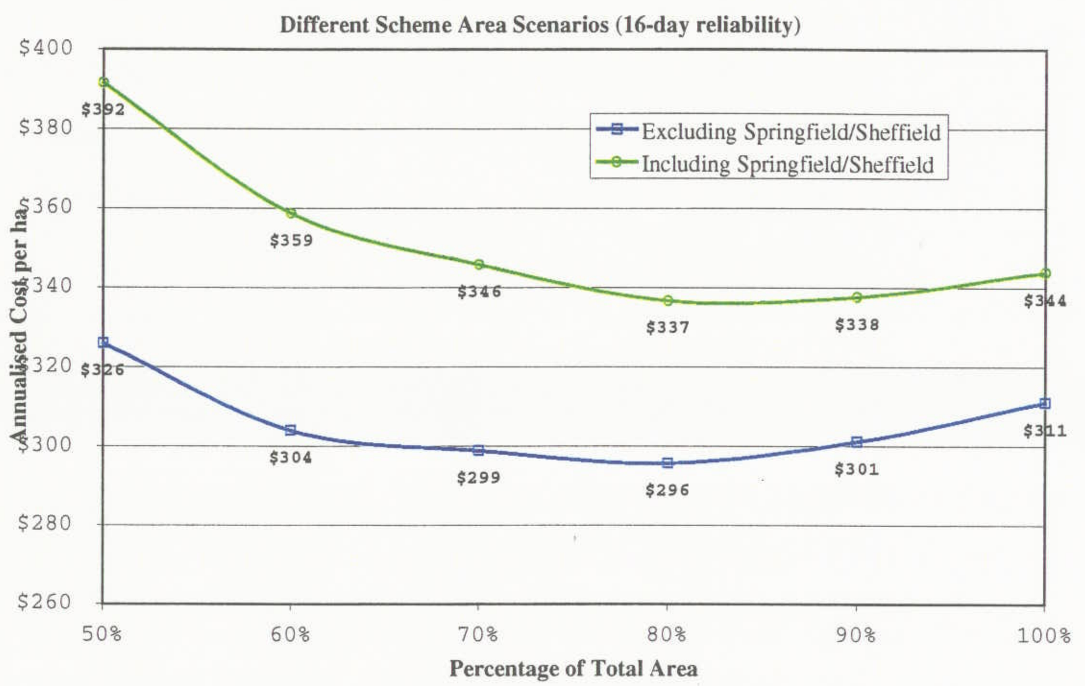


Figure 5-1: Total Annualised Costs for Different Land Areas

5.3 Scheme Optimisation

The total capital and operating costs of the scheme have been optimised in order to find the lowest cost combinations of the various components that will deliver the required scheme capacity and reliability. In order to achieve this result, the cost has been optimised on the following variables:

- The land area that the scheme is to supply;
- The reservoir size;
- The rate of pumping to re-supply this reservoir;
- The rate of take from the Waimakariri River;
- The rate of take from the Rakaia River.

The size and cost of each scheme component varies with the required total capacity and/or the reliability. As the land area (and hence peak water demand) increases it is necessary to increase the size of the head race, outlet canal, intakes and associated structures. The size and cost of the storage reservoir and pump structures, however, do not necessarily change with the land area, as they determine the reliability of the scheme rather than the capacity. To maintain the same scheme reliability, however, it is necessary to increase the size and cost of the reservoir and pumping infrastructure for the larger land area scenarios.

The rate of take from the rivers determines influences the ability to fill the reservoir and meet as much of the summer demand as practicable. Low take rates will not provide adequate water, while the infrastructure excessive takes will be expensive.

The first stage of optimisation involved developing a relationship between reservoir size and pumping rate to provide the same level of reliability for each given land area. As reservoir size decreases, the filling pumping rate required to maintain the same reliability increases exponentially. It was chosen to optimise the scheme costs based on a maximum of 16 continuous days with no available water supply over the full period of available flow records. This has been termed the 16-day reliability. Over a range of different reservoir sizes (between 120 and 300 million m^3) the pumping rate required to achieve a 16-day reliability was determined using river flow data between 1967 to the present.

For each result it was then possible to assign a cost to each component of the scheme, and to then optimise for the lowest-cost option. Head race and intake costs are determined almost entirely by the land area (water demand). Within each water demand scenario various combinations of pumping rate and storage reservoir size provides and optimal solution.

As water allocation from the Rakaia River is a maximum of 8 m^3/s – compared to 40 m^3/s from the Waimakariri River – the option of removing the Rakaia intake from the scheme was also considered. This alternative influences both the reliability and the required size of the head race and associated structures.

On Figure 5-2 an optimisation for the total capital cost is presented for each area-intake option. For each different area scenario (indicated with a red dot), the lowest cost option includes a Rakaia River Intake. Figure 5-3 shows the optimised costs based on the total annualised costs for the scheme. Each of these curves has been developed for the 84,000 ha case without Springfield/Sheffield included. This will not affect the selection of the optimal operational parameters at all.

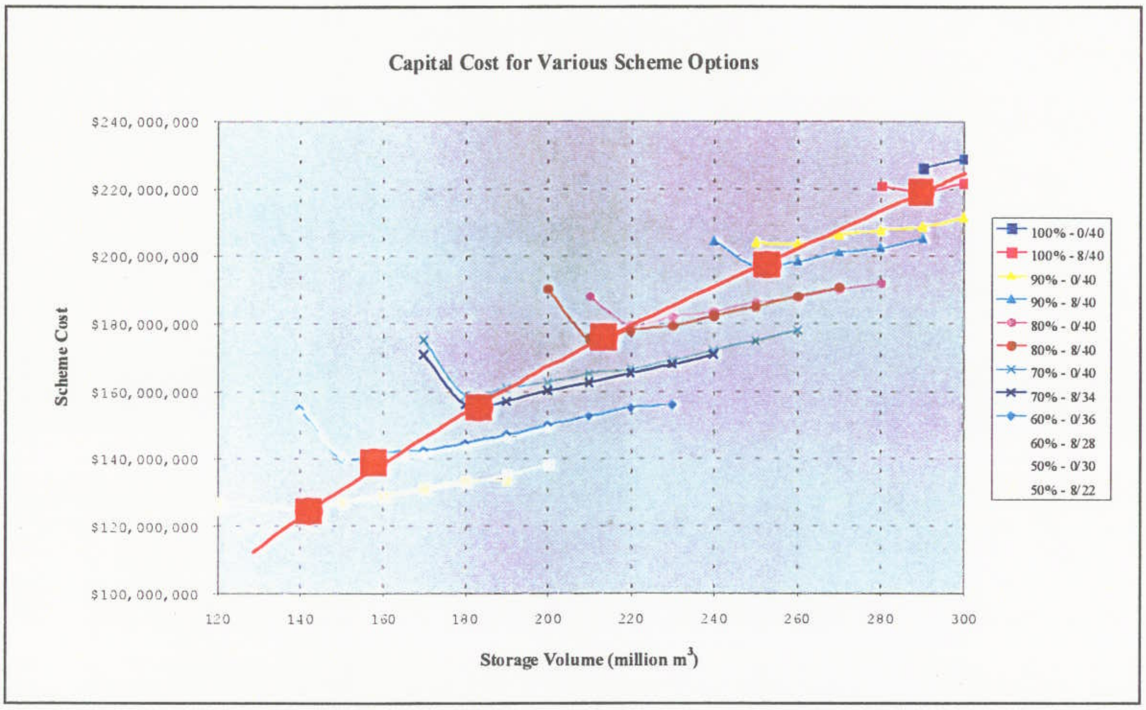


Figure 5-2: Optimisation Cost Curves for Total Capital Costs $

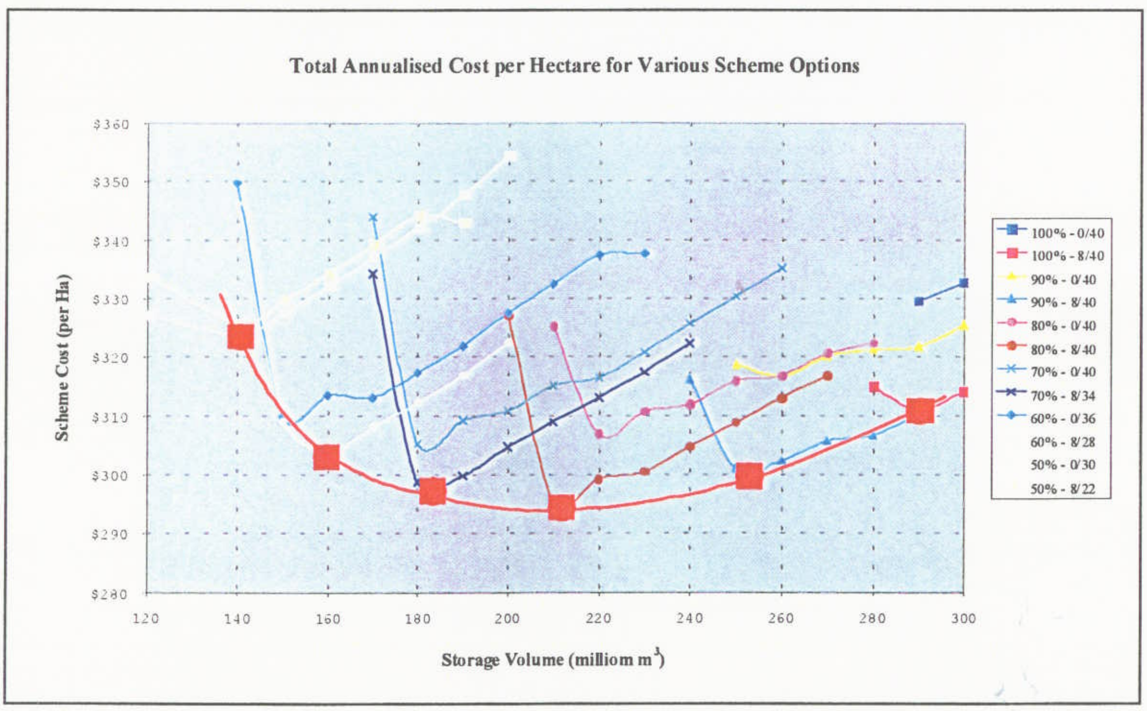


Figure 5-3: Optimisation Cost Curves for Total Annualised Costs $/ha

5.3.1 Reservoir Filling Options

Three different schemes were considered for re-supplying the Wairiri storage reservoir, including:

- Pumping directly to the reservoir from the head race near the Hororata River;
- Pumping up to the Windwhistle canal from the head race near the Rakaia intake;
- Siphoning water from the Rangitata Diversion Race Scheme (RDR) through a steel pipe down and across the Rakaia river and up to the Windwhistle canal.

The capital cost involved with siphon across the Rakaia River, from the RDR was approximately $44M which is approximately $20M more than the cost of building the pump station at the Rakaia Intake site. The siphon would operate by taking water during the winter when it is not used for irrigation and purchasing it to fill the reservoir as opposed to passing it through the Highbank power station. This would then result in a saving in energy costs of approximately $4M/yr. The net benefit of this option would therefore be in the order of $2M/yr. However to offset this, there would be a need to purchase the water from Trustpower as they will incur a lost opportunity cost. The structures involved would include a bridge across the river carrying at least two large steel pipes. This would be visually intrusive. There would be no opportunity to fill the reservoir over the summer period as all the RDR water would be used for irrigation on the south side of the river. In addition to this, there would be significant cultural concerns about bringing Rangitata River water into the area between the Rakaia and Waimakariri Rivers and further mixing these waters together. Therefore while there is a slight economic benefit, the environmental, social and cultural aspects make this an unlikely option to succeed.

Of the remaining two options, Rakaia pump station into the Windwhistle canal proved to be the most cost effective. The total capital cost of pumping near the Hororata River is approximately $15-20 million more than the same sized scheme with the pump station located near the Rakaia intake, and this large difference is due to the much longer length of steel riser pipe required to pump water from the headrace adjacent to the Hororata River up to the discharge point near Glenroy.

5.4 Piped versus Open Canal Systems

5.4.1 Background

A comparison between reticulation of water via a piped and reticulation via a channel system was carried out to assess the construction and operational costs for the two options. The comparison was carried using a sample area of approximately 9850 ha just north of the Rakaia river (see Figure 5-4). This area is typical of the proposed service area for irrigation scheme and the assessed costs are applicable to the total area.

Using a plan showing farm boundaries, outline designs were prepared for both the piped and channel system with water being supplied to each property. Farms sizes within the sample area vary from 10 ha up to 420 ha with the average size being approximately 100 hectares. The design supply rate for irrigation is 0.6 l/s/ha and it is assumed that 80% of the property will be irrigated

The piped system design provides water at a suitable head for operation of irrigation equipment. To allow direct comparison with the piped system, the channel distribution system includes costs for the water supplied to the farm boundary and also allows for on-farm pumping and operational costs.

5.4.2 Piping system

Reticulation via the piped gravity system utilises gradient of the Canterbury plains (approximately 1 in 170) to provide water to the farm boundary at a minimum head of 50m. This requires that the irrigation area is located approximately 11 km down-gradient of the headrace. The outline design for the piped system for costing purposes is shown in Figure 5-4.

For costing purposes the following assumptions were adopted:

- Construction of the pipeline is below ground as the visual impact and difficulties associated with providing road crossings and access to properties for an above ground pipeline were not considered practical;
- The supply is provided to nearest point of the farm boundary and terminates with a control valve;
- Every second off take will require a crossing to the opposite side of the road;
- No land purchase is required as the pipeline will be constructed in the road reserve were possible and with a depth of cover of 1m for major pipelines there will be no sterilisation of land.

The following pipeline design criteria were used:

- Pipeline velocities are kept below 2.5 m/s in larger pipes (> 600mm dia) to minimise the potential for water hammer effects. In smaller diameter pipes velocities are typically maintained below 1.5 m/s to minimise friction losses and maintain the required head;
- Steel pipe will be used for all pipe diameters greater than 600 mm. This pipe will be concrete lined to provide a suitable level of resistance to abrasion from suspended sediment;
- The steel pipe will be installed in trenches with a minimum bedding thickness of 300 mm of granular material of 10 mm diameter or less to ensure uniform support around the pipe. Minimum cover will be 1 m;
- Pipelines of 600 mm dia or less will be constructed from mPVC pressure pipe in trenches with a minimum cover of 600 mm.
- The outline design for the piped system uses steel pipe with wall thickness /diameter ratio of approximately 140 with a concrete liner.

The selection of the wall thickness of the steel pipe is based on maintaining a suitable level of pipe rigidity to minimise the potential for distortion of the pipe when laying and during service. The potential for distortion of the pipes increases with larger diameter pipes. In addition the increased thickness provides an increase in long term durability with allowance for loss of section due to corrosion. The concrete lining also provides additional stiffness, corrosion resistance and an ability to self heal any minor cracks.

Thin walled steel pipe (diameter / wall thickness ratios of approximately 190) with a 350μm thickness epoxy lining are available, and a comparison of the prices for wall thickness and lining are provided in Table 5-5.

Table 5-5: Variations in pipe costs

Option	1.5 m diameter $/m	1.8 m diameter $/m
Steel pipe (thin walled epoxy lined)	$1,237	$1,496
Steel Pipe (increased wall thickness, epoxy lined)	$1,397	$1,686
Steel Pipe (Increased wall thickness, concrete lined)	$1,609	$2,008

As can be seen from the above prices, savings can be made by adopting thin walled epoxy lined pipes, however, initial savings must be weighed against the robustness of the final product and the increased life expectancy, 20 – 50 years depending on the nature the water, sediment levels and ground in which the pipeline is constructed.

5.4.3 Channel system

The outline design layout for the surface water channel distribution network follows a similar route to that of the pipeline network with the exception of a small section to the east of the irrigation area adjacent to State Highway 1. See Figure 5-5.

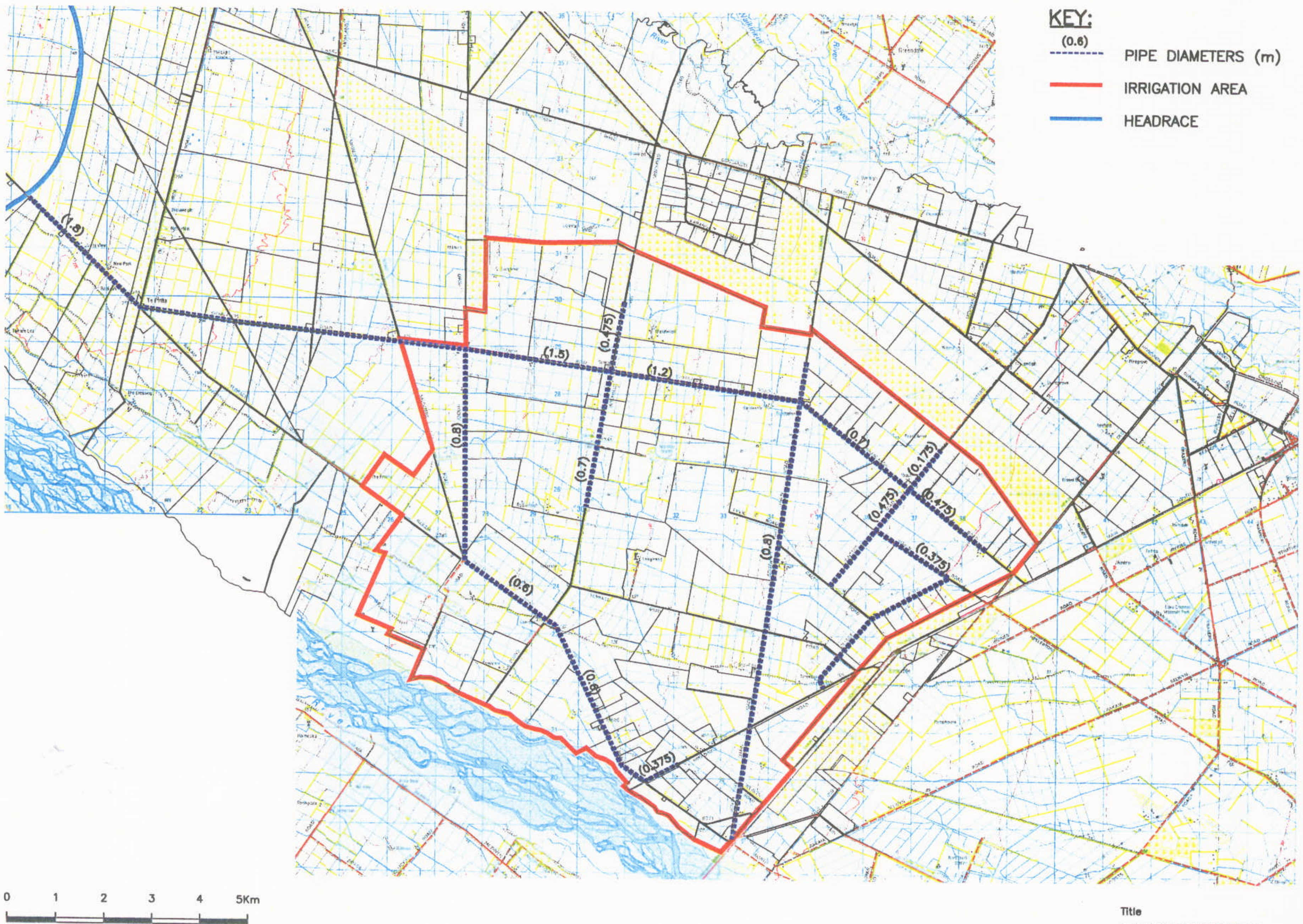
The costs for the channel includes the 11km long feeder channel from the head race as per the piped option, however this artificially inflates the cost for a channel system that is located closer to the headrace channel.

To allow an accurate comparison between the two options, the channel costings include the installation and operational costs for on farm pumping to allow for the fact that the piped option provides water at a head that requires no additional pumping for irrigation.

As discussed in Section 2, the following design criteria were used for the channel design:

- Channels are be constructed by excavation with spoil being spread to waste;
- Channel option costings allow for land purchase for the area of channel;

- Design flows for the channel include an allowance of 20% for losses within the channel;
- No allowance has been made for the lining of the channel as it is assumed that channels will self-seal with fine suspended sediment over time;
- The typical channel cross section has side slopes of 2 horizontal to 1 vertical with a bottom width of 1.2 – 3 m depending on the design capacity;
- The channel gradient has been designed to maintain flow velocities of approximately 0.8 m/s to minimise the potential for scour;
- Drop structures will be required at regular intervals along the channels;
- The design freeboard of the channel varies between 1.0 m immediately downstream of drop structures to 0.3 m immediately upstream of the drop structure;
- Control structures provided at junctions will control flow down the individual channels;
- Abstraction is via permanently mounted suction pipes fitted with footer valves where required;
- Overflow channels will be provided at the end of each branch drain to transport excess water to adjacent watercourses;
- Single lane channel crossings will be provided at approximately 450 m intervals for access to farmland and domestic properties.



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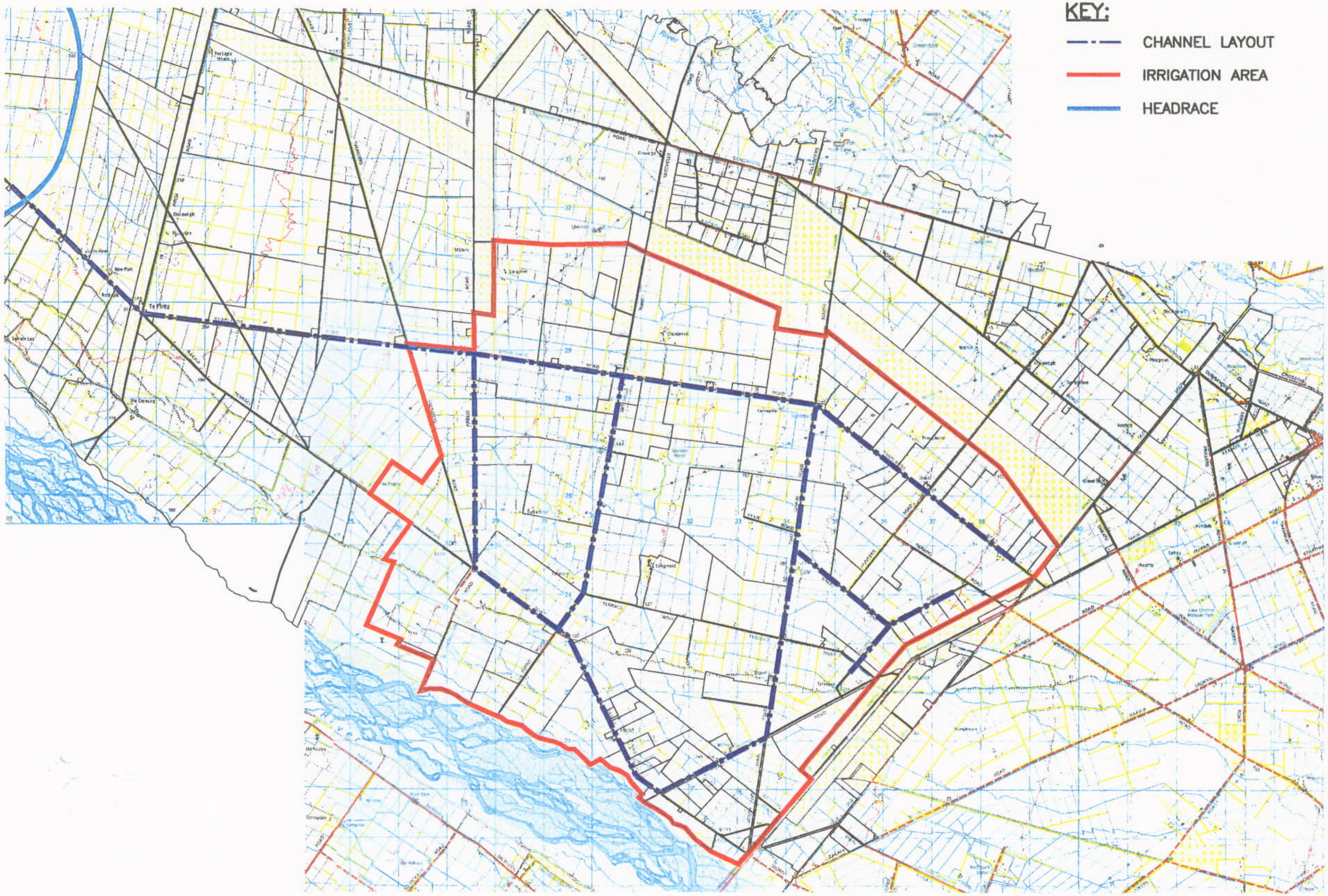
Title
LAYOUT OF PIPED DISTRIBUTION NETWORK

Figure No. **FIGURE5-4**



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LAYOUT OF CHANNEL DISTRIBUTION NETWORK

Figure No. **FIGURE 5-5**

5.4.4 Comparative Costs

The capital costs, annual operation and maintenance costs and Present Value cost based on operation over a 20 year period at 8% were calculated for each option on a per hectare basis. The cost comparisons for the two options are provided in Table 5-6.

Table 5-6: Piped Versus Channel Reticulation

Option	Capital cost $/ha	Annual O & M $/ha/yr	Annualised Cost $/ha
Piped – CLMS	5213	185	676
Piped - Epoxy	4126	146	535
Channel	1102	213	316

Factors not included in the above costing are:

- No allowance has been made for the cost of water that is discharged to overflows at the end of the distribution lines for the channel option;
- Operational control of the channel distribution is more complicated than the pipeline system which is an on demand system;
- Areas immediately adjacent to headrace can be irrigated only by the channel system due to insufficient static head to provide operational pressures in a pipeline system;

While the above analysis shows that the piped reticulation system is more expensive than a gravity channel system, it is a possibility that some farmers would be prepared to pay a premium for water delivered to the farm gate under pressure. The additional cost of having a piped distribution system is approximately $200/ha/yr. This therefore should remain an option that is open for discussion with the stakeholders during the next phase.

The pipe reticulation system relies upon a feeder pipe running approximately 11 km down gradient from the main headrace to achieve the pressure required at the farm gate. All properties closer than this to the headrace will require pumped assistance, and the economics would be more adverse for them. Figure 5-6 depicts the portion of the community supply zone where it would be possible to install a gravity pressure pipe distribution system.

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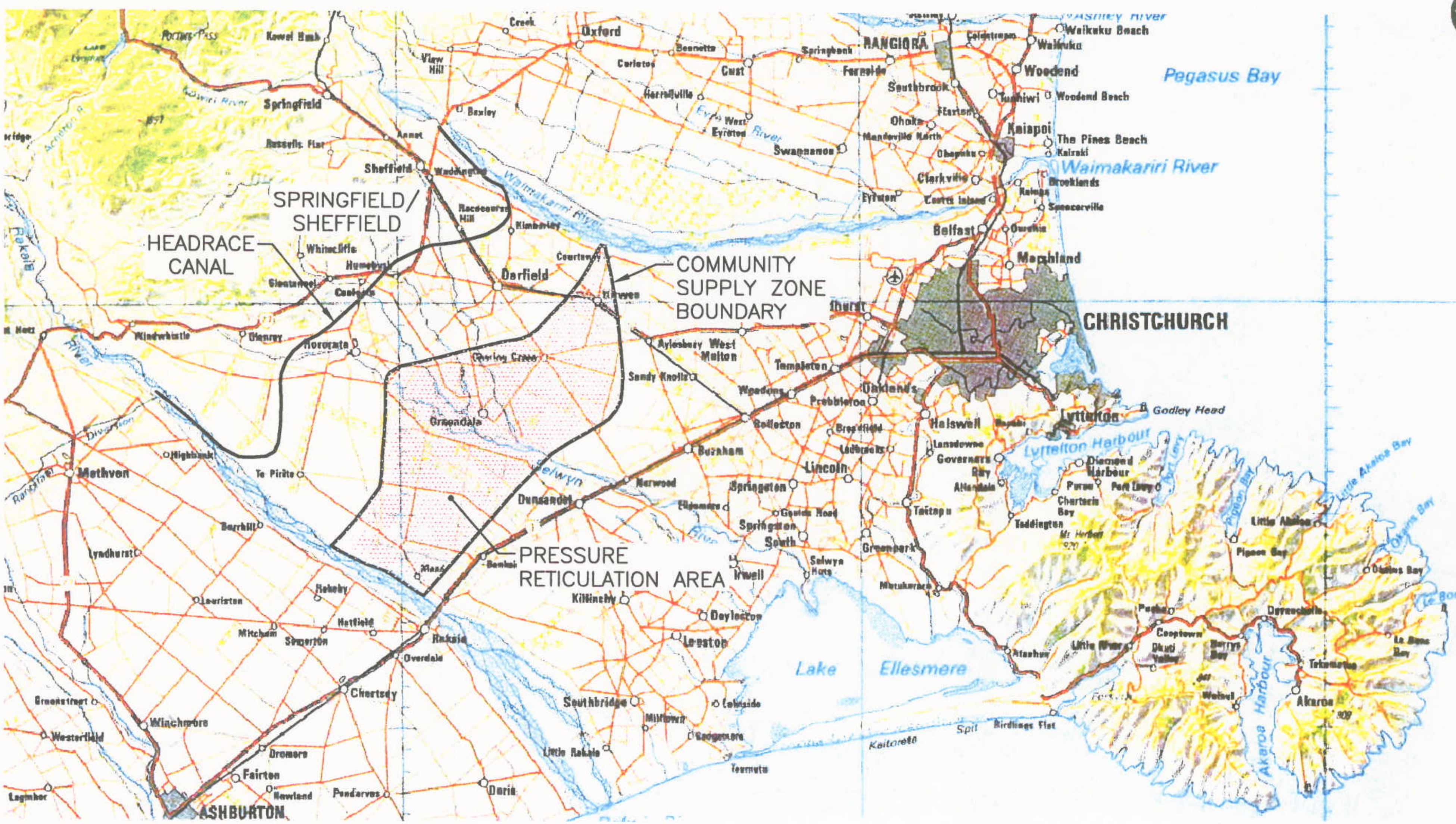

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AREA WHERE PRESSURE PIPES SUITABLE

Figure No. **FIGURE 5-6**

5.5 Springfield / Sheffield Issues

The Springfield / Sheffield area, approximately 9000 ha, is located up gradient of the main headrace channel and cannot therefore be serviced from the race by a gravity distribution system. The most cost-effective option for irrigation of this area is the provision of a separate pump station taking water from the Waimakariri River to supply a gravity distribution system a pressurised piped distribution system.

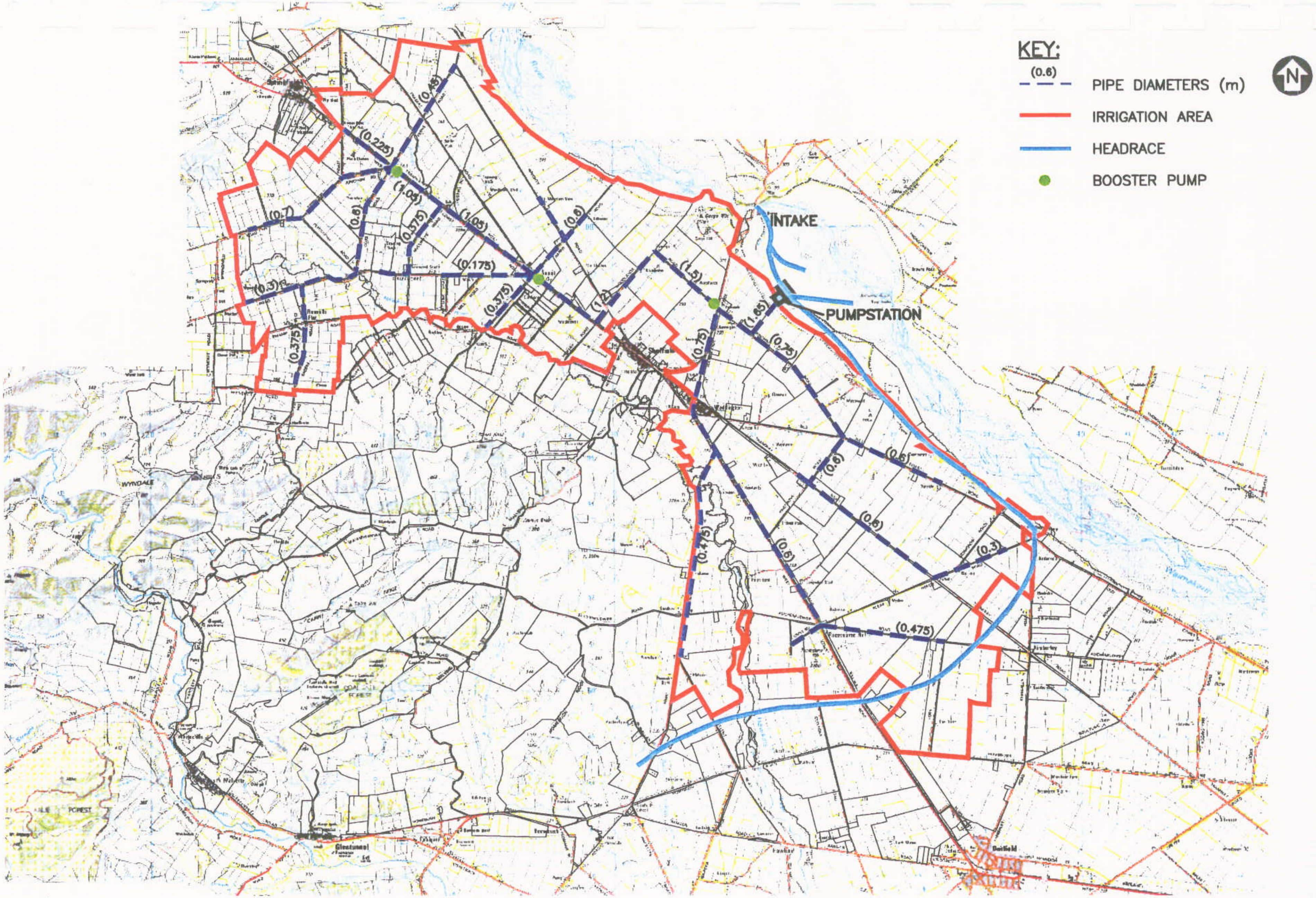
Supplying the whole of the Springfield / Sheffield area with a gravity distribution requires the location of a pump station at the upper end of the site, however, the only suitable location identified near the Kowai River has access issues that render this site impractical.

The proposed pumping station location is located approximately 2 km downstream of the Waimakariri Gorge Bridge and takes water from the intake channel from the headrace.

The siting of the pump station at this location requires that areas upgradient of Sheffield township are serviced by a pressurised pipe system. Areas downgradient of Sheffield would be provided with a gravity distribution system.

Two supply options were identified for irrigation of the Springfield / Sheffield area.

- Supply of the Springfield area by a pressurised pipe system with the Sheffield area supplied by a gravity pipe system See Figure 5-6;
- Supply of the a Springfield area by a pressurised pipe system with the Sheffield area supplied by a gravity channel system See Figure 5-7;
- Costings have also been supplied for the above options excluding the Springfield area.



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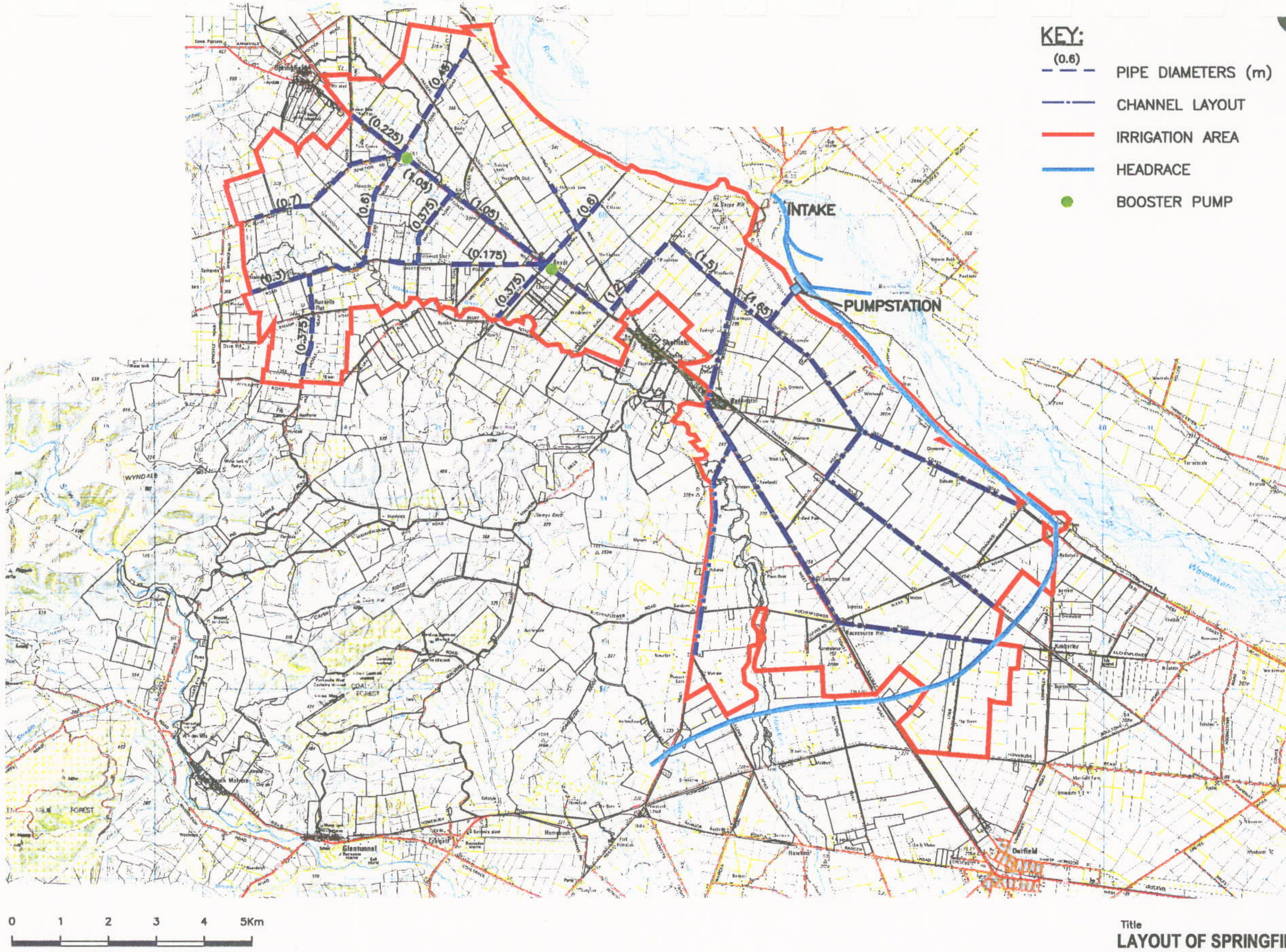
LAYOUT OF SPRINGFIELD/SHEFFIELD PIPED DISTRIBUTION NETWORK

Figure No. **FIGURE 5-7**



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LAYOUT OF SPRINGFIELD/ SHEFFIELD PIPED AND CANAL DISTRIBUTION NETWORK

Figure No. **FIGURE 5-8**

5.5.1 The Springfield Area

This area includes all of the serviced area northwest of Sheffield township. Distribution of irrigation water to this area would be via a piped system providing water at a minimum head of 50 m. The system would consist of the main pump station with a series of inline booster pumps to maintain the head in the system as ground levels rise.

The supply pressures would vary between 50 – 95 m depending on the proximity of the farm offtake to the supply or boost pumps.

The design criteria for the pipe system is similar to that for the pipe system outlined in section 6.4:

- The pipeline routes generally follows road alignments;
- Pipeline velocities are kept below 2.5 m/s in larger pipes (> 600 mm dia) and below 1.5 m/s for pipes 600 mm dia and smaller;
- Steel pipe will be used for all pipe diameters greater than 600 mm. This pipe will be concrete lined to provide a suitable level of resistance to abrasion from suspended sediment;
- The steel pipe will be installed in trenches with a minimum bedding thickness of 300 mm of granular material of 10 mm diameter or less to ensure uniform support around the pipe. Minimum cover will be 1 m;
- Pipelines of 600 mm dia or less will be constructed from mPVC pressure pipe in trenches with a minimum cover of 600 mm.

A preliminary analysis of the pipeline indicates that feed tanks or similar control devices will be required to control pressure surges in the pipeline in the event of pumps stopping suddenly due to power failure. The surge analysis was only a preliminary assessment involving many assumptions. Detailed design may vary these assumptions requiring greater or lesser levels or alternative methods of protection. Air valves will also be required at specific locations throughout the network to allow evacuation of air from the pipeline particularly during commissioning and following power failure.

This system supplying water to Springfield is the same for both options.

5.5.2 Sheffield Area

Piped Option

This option uses a pipe distribution system as outlined. The only variation from this design criteria outlined is that the initial surcharging of the pipe to the required minimum supply head is provided by the main supply pump taking water from the Waimakariri River. See Figure 5-6.

Channel Option

The channel distribution system would be to the same design criteria as that outlined previously. The only variation from these criteria is the allowance for the 700 m length of the route passing through Waddington to be piped using 1m diameter concrete pipes.

The comparative costs for the options outlined above are contained in Table 5-7. It should be noted that the costs in this table are comparative costs only. The Springfield/Sheffield area would also need to contribute to the cost of providing storage to achieve the levels of reliability defined for the scheme. This therefore requires a proportionate contribution to the intakes, pumping, headrace canal and storage. The full financial analysis includes all of these costs.

Table 5-7: Springfield/Sheffield Option Costs

Option	Capital cost $	Annual O & M $/yr	Annualised Cost $/ha/yr
Springfield/Sheffield Piped	$34,331,812	$1,576,962	$643
Springfield Piped / Sheffield Gravity	$30,241,205	$1,395,918	$567
Sheffield Gravity	$9,777,035	$812,524	$537
Sheffield Piped	$10,686,641	$751,228	$545

5.6 Pumping Costs

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 rate for electricity accounted for variations in price for evening and weekend operation. The average monthly rates for electricity are shown in Table 5-8.

Table 5-8: Average monthly electric rates (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 = 105 m
- Pump/System Efficiency = 85%

The annual pumping costs ranged between $600,000 and $6.6 M / year. The average for the 33 years was $3.6 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.

5.7 Power Generation

The generation of electricity as water is supplied to the head race canal from the reservoir was evaluated. The proposed pump station was modified to provide allowances for power generation. The generation of power was evaluated during the times of irrigation only. The energy lost in the system for pumping and power generation does not provide a profitable opportunity to generate power during the day and pump water at night.

The following assumptions were used:

- Maximum Head = 80 m
- System Efficiency = 85%
- Value of Electricity = 3 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 17.2 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 5-8. This figure also shows the portion of water not used to generate power.

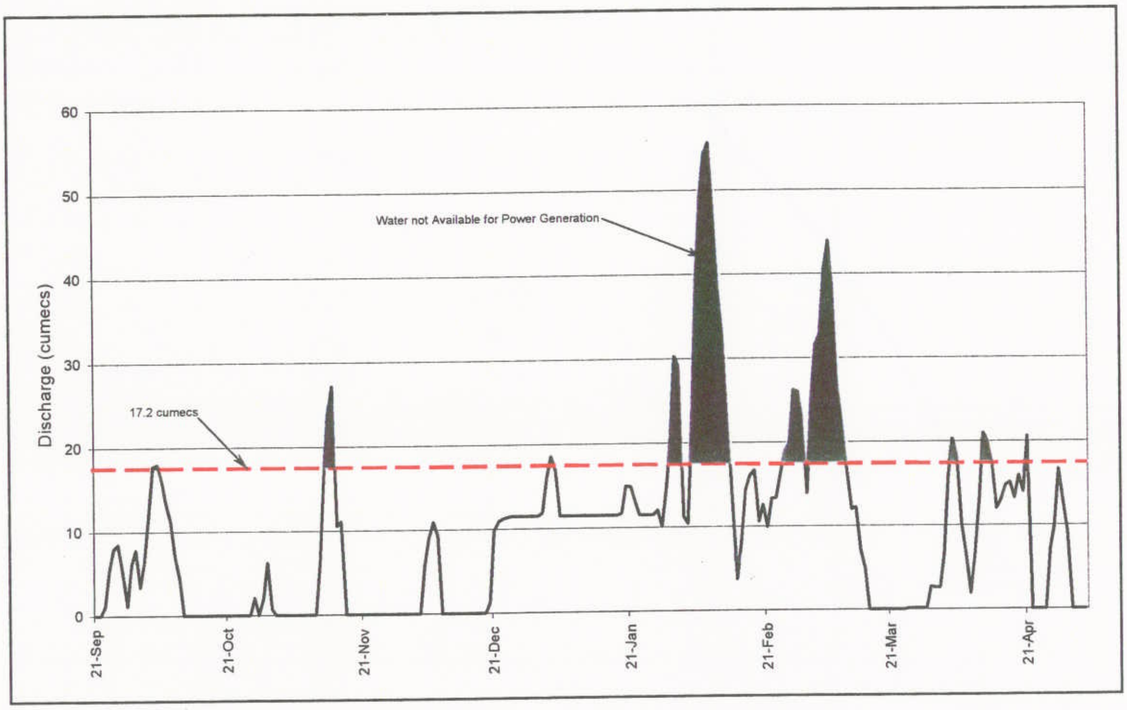

Figure 5-8: Water supplied from reservoir for an average year

The annual value of the power generated ranged between $200-800,000 with an average of $0.5 M. The relocation of the pump station provides a lower head requirement for filling the reservoir. This reduction in required head reduces the annual pumping costs by $0.9 M. The resultant benefit from power generation is approximately $1.4 M / year.

The increase in capital expenditures between the two systems, pump only and pump/generator, is in excess of 20 million dollars. The increase in cost is a result of the longer pipeline required for the pump/generator. The pump only scenario incorporates an open channel to reduce the length of the pipeline. The benefit of $1.4 M / year does not pay off the capital expenditure in 20 years.

5.8 Reliability and Level of Service

Ultimately it will be a purchasing decision on the part of the farmers as to the level of service they require at a given price point. Section 2 outlined a number of different reliability scenarios based around reduced storage. The reduction in storage directly reduces the scheme costs and also means that there is less water available during the dry years. To meet the requirement of maintaining some delivery to the farmers by invoking restriction, differing levels of reliability (level of service) result. These are presented in Table 5-9. This table has been taken from section 2, however the final row has been added, which is the annualise cost of the water for each of the levels of service. This indicates that there is an approximate 8% reduction in the price of water as the reservoir volume reduces from 290 MCM to 220 MCM.

Table 5-9: Effects of restrictions on reservoir size and water delivery (40 m^3/s)

Restriction (%)	22	32	38
Reservoir volume required for no days without water (MCM)	290	250	220
Percent of yearly demand supplied	98	95	91
Percent of yearly demand supplied during worst year on record	89	81	76
Percent of time when yearly supplies are greater than 95% of demand	82	53	41
Number of years where supplied values were greater than 99% of demand for the 34 years on record	21	15	9
Total Annualised Cost/ha	$335	$322	$313

5.9 Scheme Costs

A range of different scenarios have been costed for use in the financial modelling. These are detailed in this section. Table 5-3 summarised the total scheme costs including and excluding the Springfield/Sheffield area for different total scheme areas. Table 5-10 summarises the total scheme costs including and excluding the Springfield/Sheffield area for a range of different levels of reliability. The larger the reservoir volume, the greater the water available for dry periods and therefore the more reliable water supply to the irrigation area. The level of service to be provided will ultimately be decided by the stakeholders to any scheme implemented.

Table 5-10: Scheme Costs for Different Levels of Reliability

Item	Cost ($)	Cost ($)	Cost ($)	Cost ($)	Cost ($)	Cost ($)
	Including Springfield/Sheffield			Excluding Springfield/Sheffield		
Storage Volume MCM	290	250	220	290	250	220
Total Capital Cost	$235,031,000	221,770,000	191,412,000	$219,178,000	207,633,000	199,528,000
Total O&M Cost	$2,295,000	$2,295,000	$2,295,000	$1,165,000	1,665,000	1,665,000
Total Energy Cost	$4,425,000	$4,425,000	$4,425,000	$3,790,000	3,790,000	3,790,000
Annualised Cost/ha	$344	$331	$322	$311	$298	$289

5.10 Financial and Business Structures

5.10.1 Scope and Objective

The Ministry of Economic Development provided the following overview of the project objectives and purpose/scope for a study undertaken by Deloitte Touche Tohmatsu (2001), that has formed the basis for the evaluation of the financial and business structures. This was:

"...to provide a resource document that community based groups are able use to determine the most appropriate legal/business structures, funding structures and pricing mechanisms ...to facilitate the establishment and operation of the water use options..."

5.10.2 Nature of Irrigation and Stock Water Scheme Activities

Irrigation schemes have specific characteristics that differentiate them from other types of business activities. Having consideration for these characteristics is essential for selecting the most appropriate legal and funding structures. Specific characteristics include:

- Irrigation schemes are essentially infrastructure assets similar to roads and utility power lines and poles. These assets typically have a monopoly of the supply to customers.
- Irrigation schemes typically require significant upfront capital investment.
- Constructing and operating an irrigation scheme is a long term activity with a long term payback period.

- Irrigation schemes are often a catalyst for a change in land use by customers of the irrigation systems in the medium term.

5.10.3 Appropriate Legal/Business Structures

A range of possible legal/ business structures has been considered in detail within the study.

The legal structures include:

- Partnerships (and unincorporated joint ventures)
- Co-operative companies
- Limited companies (and incorporated joint ventures)
- Trusts
- Unincorporated associations
- Incorporated societies

Each structure has advantages and disadvantages. Selecting the structure that is most appropriate for CPWE will depend upon what the scheme stakeholders consider to be the most critical outcomes from a legal structure. This is explained in the following sections.

Control

The irrigation scheme is going to have a monopoly over the supply of water to the region controlling access to this extremely valuable resource. Preventing an external party gaining control of the scheme to the detriment of water users in the region may be seen as the most critical outcome for scheme stakeholders when considering legal structures.

The most appropriate legal structures for protecting and maintaining control over scheme ownership are:

- Co-operative company
- Trust

Taxation

Given that cost is generally the largest barrier to overcome when setting up an irrigation scheme, providing the most tax effective structure, allowing investors to offset their investment by accessing the scheme's tax losses for personal use, may be critical for the economic viability of the scheme.

The most tax effective legal structures are:

- Partnership
- Unincorporated association

Shareholder protection

Investment in an irrigation scheme is considered a relatively risky venture, particularly during the construction and initial operating phase prior to full take up. This risk is enhanced given the long term nature of irrigation activities and the potential for changes to the environment over that period. For these reasons protection of shareholder/member investment and personal assets may be seen as the most critical issue for scheme stakeholders.

The most appropriate legal structures for protecting shareholders/members are:

- Limited company
- Co-operative company

There are many other possible outcomes to be considered by stakeholders when selecting the most appropriate legal structure. It is common to use a combination of legal structures to achieve multiple outcomes.

By way of example, the Opuha scheme is operated by the Opuha Dam Partnership (ODP). A partnership structure was chosen primarily to allow investors to access the scheme's tax losses to offset other profits. The group of partners in ODP are both limited companies and co-operative companies providing the limited liability protection to shareholders.

One the critical considerations when selecting an appropriate legal structure will be how the scheme funding is structured.

5.10.4 Funding Structures

Irrigation schemes generally require a significant up-front capital investment. This can be funded from a mix of equity and debt.

Various sources of debt and equity are considered in the study and their implications on the trade off between capital contributed up-front, and the level of operating cost per annum. Generally the higher the debt funding, the higher the annual operating costs (including debt repayment and interest), and the lower the required initial capital contribution.

The level and cost of debt will generally be determined by a number of factors including ability to repay, length of contract, security available, etc. In normal circumstances it would be difficult to find a lender prepared to lend in excess of 50% of the cost of a project, with lower levels of debt funding expected in many cases.

Factors such as the required return on equity, cost of interest, local government support by way of funding, guarantee or security, and level of debt and debt repayment timeframe can have a significant impact on the operating costs (and therefore pricing) of irrigation schemes.

In order to determine the most appropriate funding structure it is important to understand the key issues and barriers of each of the key funding sources:

Water users

What level of equity are water uses able to contribute to the scheme? At what cost to the user does the scheme become uneconomic, or affect the level and/or speed of take-up? Are users prepared to provide guarantees to the bank supporting the scheme borrowings?

Bank

What level of debt is a bank willing to lend to, (history suggests not more than 50%), and at what cost? What level of security is required? What principal repayment terms are expected (indications are 20 years maximum)?

Local authority

What commitment is local Government prepared to make (if any) to support the scheme? i.e. Direct lending to the scheme, equity investment, provision of bank guarantees, commitment to special rating security.

Other

What are the other funding sources available? i.e. commercial investment, offshore funding, Central Government?

5.10.5 Pricing Mechanisms

At a minimum water charges need to be set to recover operating, funding and maintenance costs over the scheme's useful life. Funding costs are expected to be the largest component of the water charge.

Prior to determining the method to be used for charging water users, the first consideration is whether the costs are at a level that will make the scheme economically viable to users and therefore whether the required level of take-up will be achieved. In order to assess this CPWE must understand the water user price thresholds.

Once it has been determined that the scheme is viable for farmers and that the take-up commitment appears to be sufficient, alternatives for determining how to charge for water can be considered.

When determining which of the pricing mechanisms is most appropriate for the scheme and the users, it is important to consider the following key points:

- The majority of scheme operating costs are fixed. In order to reduce the scheme operating risk the water charge should also include a large fixed charge component.
- There is a strong relationship between pricing mechanisms and interest rates. The more certain the revenue stream, the lower the risk, therefore the lower the interest cost on debt servicing.
- An irrigation scheme is a long term activity and it is important that irrigators be encouraged to take long term supply contracts.
- KISS (Keep It Simple Stupid). Complex measurement and administration of pricing mechanisms can be costly for limited benefit.

The key pricing mechanisms discussed in the study include:

- Volume based pricing
- Fixed take or pay pricing
- Levied rate pricing

Given the high proportion of fixed costs required to operate an irrigation scheme, the most common method of charging water users is to have at least a large portion of the charge on a fixed cost take or pay arrangement.

5.11 Price of Water

5.11.1 Model 1 - Excluding Springfield/Sheffield

Scheme size

- The base case scheme allows for 84,000 hectares of irrigated land.
- The scheme storage facility is constructed to store up to 290 million cubic meters of water.

Capital Expenditure

The capital costs for this option are summarised in Table 5-11:

Table 5-11: Capital Costs for Base Scheme (no Springfield/Sheffield)

Area	$000
Wairiri Dam and Reservoir	78,172
Head Races and Intakes	56,536
Pump Infrastructure Rakaia	24,500
Distribution	48,384
P&G	11,586
Total	219,178

The timing of capital expenditure over the initial 8 year construction period is as follows in Table 5-12.

Table 5-12: Predicted Expenditure over Implementation Period ($000)

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Total
Scheme Land Construction and design	0	3,310	6,069	8,587	63,799	63,799	63,799	9,815	219,178
Other Capital Expenditure	260	1,110	1,060	690	390	290	290	170	4,260
Total	260	4,424	7,129	9,277	64,089	64,089	64,089	9,985	223,438

Capitalised Interest

As there will be no revenue generated over the first 8 years until the scheme is fully constructed, interest charges on borrowings through that period have been capitalised at 7% (i.e. paid for from additional borrowings). Capitalised interest, in addition to the capital expenditure detailed above, of $23.9 million has been included in the analysis.

Debt Funding

Debt as a percentage of total funding has been assumed at 50%. This is the likely funding ratio based historical funding for similar capital projects.

The finance rate is assumed at 7% over the life of the scheme (1% - 1.5% above long term Government stock rates). This rate assumes the scheme has the support of a secure guarantor i.e. Territorial Local Authority (TLA).

The loan principal repayment term is assumed at 20 years based on input from financial institutions and historical funding terms for similar capital projects.

Equity Funding

Equity as a percentage of total funding has been assumed at 50%. This is the likely funding ratio based historical funding for similar capital projects.

Equity is assumed to have a 0% return from the scheme. This is the most likely scenario where water users provide the equity contributions. A water user's return on the equity invested comes in the form of lower water costs, increased return from the land and therefore an increase in the capital value of the land.

Water Charges

Water charges are set at a level to allow the scheme to breakeven on a cashflow basis (i.e. to recover total cash operating costs plus loan principal repayments).

Water is assumed to be charged on a take or pay basis at a flat rate per hectare i.e. no differentiation based on land use or volumes of water taken.

The irrigation scheme will not begin generating revenue from water charges until scheme construction is complete as the reliability of water will not be sufficient until the storage facility is fully operational.

Operating and Maintenance expenses

Operating and maintenance costs have been estimated to allow for maintenance of the infrastructure to keep scheme operational over it's useful life. These are included in the cost summaries presented.

Energy Cost

Energy costs have been based on the estimated kilowatt hours required and a unit price on a monthly basis to reflect the higher power charges over the winter period when the reservoir will be filling. The unit cost per kilowatt hour over the life of the scheme is estimated to be 6.3 cents per kilowatt hour.

Depreciation

Capital costs are depreciated at Inland Revenue Department (IRD) prescribed depreciation rates based on a diminishing value (DV) calculation. Rates range from 0% to 9%

Taxation

Taxation is calculated at a rate of 33%.

Inflation

Inflation has been assumed at 2% per annum over the life of the scheme. This estimate is based on long term forecasts from the New Zealand Institute of Economic Research (NZIER).

5.11.2 Model 2 - Including Springfield/Sheffield – Water Charges Equalised

For Model 2 all assumptions remain the same as for Model 1 except as follows:

Scheme size

The base case scheme allows for 84,000 hectares of irrigated land. Approximately 10,000 hectares of this land will be within the Springfield/Sheffield area, the remaining 74,000 hectares will be outside of the Springfield/Sheffield area.

Capital Expenditure

The capital costs for this option are contained in Table 5-13.

Table 5-13: Capital Costs for Base Scheme (no Springfield/Sheffield)

Area	$000
Wairiri Dam and Reservoir	78,172
Head Races and Intakes	56,536
Pump Infrastructure Rakaia	24,500
Distribution	48,384
P&G	11,586
Pump Infrastructure Kowai	15,853
Total	235,031

The timing of capital expenditure over the initial 8 year construction period is given in Table 5-14. This scenario has been inflation adjusted (at 2%) to provide an indication of the cash values required in each year of development.

Table 5-14: Capital Expenditure Timing for Base Scheme (Incl. Springfield/Sheffield)

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Total
	($000)	($000)	($000)	($000)	($000)	($000)	($000)	($000)	($000)
Scheme Land Construction and design	0	3,310	6,069	9,074	68,671	68,671	68,671	10,565	235,031
Other Capital Expenditure	260	1,110	1,060	690	390	290	290	170	4,260
Inflation Adjustment	5	179	436	805	7,188	8,700	10,253	1,843	29,409
Total	265	4,599	7,566	10,569	76,249	77,661	79,214	12,577	268,701

Capitalised interest

Capitalised interest, in addition to the capital expenditure detailed above, of $25.4 million has been included in the analysis.

Water Charges

Water is assumed to be charged on a take or pay basis at a flat rate per hectare for the entire area i.e. no differentiation based on Springfield/Sheffield area, land use or volumes of water taken.

5.11.3 Model 3 - Including Springfield/Sheffield – Separate Water Charges For Springfield/Sheffield Water Users

The per hectare costs of Model 3 relate to Springfield/Sheffield land owners only. Under this model, land owners who are not in the Springfield/Sheffield area will pay the same amount as in Model 1 (as if Springfield/Sheffield had been excluded)

For Model 3 all assumptions remain the same as for Model 2 except as follows:

Water Charges

Water is assumed to be charged on a take or pay basis at a flat rate for the Springfield/Sheffield area and at a different rate for users outside of the Springfield/Sheffield area. There is no other differentiation in the water charge based on land use or volumes of water taken.

5.11.4 SCENARIO ANALYSIS

Using the three base case models a series of scenarios have been run to assess the scheme's price sensitivity to movements in key variables.

The following scenarios have been run:

Debt/Equity – Funding options

The base case assumes 50% debt, 50% equity.

Scenarios have been run based on the following:

- 60% debt, 40% equity;
- 40% debt, 60% equity .

The level of debt a scheme is able to borrow will depend on the level of risk incurred by the lender. For example, a scheme that has a Government or local authority guarantee and has long term supply contracts with users will have the ability to fund a greater portion of the capital cost through debt, than a scheme that did not have these securities in place. Historically, financial institutions have been reluctant to lend more that 50% of the capital cost.

Scheme Size

The base case assumes a scheme area of 84,000 hectares. Lower construction costs can be achieved by decreasing the area serviced by the scheme. However, the per hectare cost will increase as the number of hectares available to spread the costs decrease. In order to determine the optimal scheme size scenarios have been run based on the following variations:

- 90% of base case 75,600 ha
- 80% of base case 67,200 ha
- 70% of base case 58,800 ha
- 60% of base case 50,400 ha
- 50% of base case 42,000 ha

Reliability

Water reliability is dependant on the volume of water that can be accessed from a storage facility during drought conditions. The base case assumes a storage volume of 290 million cubic meters of storage capacity.

A reduction in the size of the storage facility will reduce scheme construction costs but will also reduce the level of water reliability. The impact of variations on the volume of the storage facility have been modelled based on the following scenarios:

- 250 million cubic meters
- 220 million cubic meters

Finance Rate

The base case assumes a finance rate of 7.0%. With the assumption that 50% of the scheme will be funded through debt, a movement in the finance rate will have an impact on pricing. There have been discussions surrounding accessing long term offshore debt at very competitive rates. To assess the potential impact this funding could have on the scheme we have included a scenario based on interest rate of 4%. The likelihood of achieving this rate and the wider issue of managing the exchange rate risk of borrowing offshore have not been investigated. The finance rate achievable for onshore borrowing again is dependant on the risk assumed by the lender.

The following variations in interest rate have been included:

- 4%
- 8%

Finance Term

The base case assumes a finance term of 20 years.The on going water charges include a component of debt repayment. Therefore the longer the repayment term the lower the initial operating the costs per hectare of the scheme. However, with a shorter repayment term the debt is repaid faster and on-going operating costs reduce significantly after the debt is repaid in full.

Financial institutions have stated that a 20 year term is the maximum available for funding a scheme. To achieve a 20 year term the scheme would need to be very low risk i.e. guarantees from a local authority. Based on discussions with local authorities they believe that there is the ability to spread the debt over a longer period, up to the term of the resource consent. The likelihood of negotiating a term in excess of 20 years has not been investigated in depth.

The following variations in repayment terms have been included:

- 25 years
- 30 years
- 35 years

Equity Return

Return on equity for the base case is assumed to be 0%. If equity were to be sourced from other than land owners, there would need to be an adequate commercial return on the investment.

If the equity was to be provided by a public organisation i.e. local authority, the return on equity may not be measured purely in terms of commercial return but could also include the wider benefit for the community. A commercial investor would require a return on the investment based on the level of risk involved. The lowest level of return a commercial investor is likely to require is between 10% and 12% after tax (or 15% - 18% pre tax).

The following variations in pre-tax return on equity have been included:

- 5%
- 15%

An equity return in excess of 15% is unlikely a viable option for the scheme.

Energy *Costs*

Energy costs for the base case have been assumed at 6.3 cents per kilowatt hour. Movements in energy costs are difficult to predict and it is therefore difficult to manage this risk over a longer period.

The following variations in energy costs have been included:

- 5 cents per kWh
- 8 cents per kWh

Delayed Uptake

The base case financial modelling has assumed that on day 1 of commissioning the scheme, revenue will be derived from the entire scheme area. This is not likely to be the case in reality, even given the experience with the Opuha and Waimakariri Irrigation experiences. To assess the impact of people joining the scheme at a later date, a variable uptake rate was modelled. This assumed that on day 1, 75% of the scheme area was subscribed and these farmers would contribute to their portion of the costs only (i.e. 75% of the costs). Then in year 2, a further 15% joined the scheme and in year 3 the remaining 10% joined the scheme as full financial members. Those members joining the scheme at a later date would therefore have to pay their share of the up-front capital contribution plus interest, as well as capitalising their share of the operating costs over the next 20 years of scheme life.

5.11.5 RESULTS - Scenario analysis

The following Table 5-15 provides a high level summary from the scenarios discussed above. All of the numbers are expressed in 2001 nominal dollars (i.e. the impact of inflation has not been considered).

Table 5-15: Price Options with Springfield/Sheffield In and Out

	Excl. Spring/Sheff	Incl. Spring/Sheff (equalised)	Incl. Spring/Sheff (separate)
Base case			
Up-front capital cost/ha	1,472	1,576	2,342
Operating cost/ha*	204	229	412
Capital Cost Range			
Lowest capital cost/ha	1,200	1,285	1,908
Highest capital cost/ha	1,732	1,854	2,757
Operating Cost Range			
Lowest operating cost/ha	168	191	356
Highest operating cost/ha	425	465	764

* Prior to repayment of debt

For detailed results see Appendix B.

Impacts of Delayed Uptake

The additional charges that farmers would pay if they join the scheme after its commencement are as listed in Table 5-16. Full details of the analysis are contained in Appendix B. If the scheme owners choose not to penalise late entrants, then assuming there is at 75%:15%:10% sign-on rate, then the additional capital required to fund this would be $6,522,000 for the base case, no Springfield/Sheffield scenario.

Table 5-16: Impact for water users who delay uptake.

Year of Entry to Scheme	One off Cost on entry $/ ha	Annual Cost over 20 yrs
No Springfield/Sheffield (Base Case)		
1	170	16
2	352	33
3	546	52
Including Springfield/Sheffield (Equalised Costs)		
1	189	18
2	391	37
3	607	57
Including Springfield/Sheffield (Not Equalised Costs)		
1	325	31
2	673	64
3	1,045	99

Taxation

Each of the scenarios results in significant tax losses over the 35 year operating period. We have not considered the value to the scheme of income tax losses within these financial models, as the ability for scheme owners to access tax losses and the method for accessing these will depend on upon the legal the structure of the scheme.

The operating cost per hectare included within the analysis is therefore a pre-tax number.

Where income tax benefits can be accessed by scheme owners the level of tax losses available can impact on the scenario that is chosen.

The following table summaries the accumulated income benefit available over the life of the scheme. A Detailed analysis of income tax benefits based on each of the scenarios above is included with Appendix B.

The tax benefit to the scheme is not impacted by equalisation or user pays for the Springfield/Sheffield area. The tax benefit is presented in Table 5-17.

Table 5-17: Tax Benefits to Scheme

	Excl. Spring/Sheff ($000)	Incl. Spring/Sheff ($000)
Base case	20,513	13,113
Lowest accumulated tax benefit	8,250	10,394
Highest accumulated tax benefit	22,997	26,187

5.12 Profitability and Affordability at the Farm Gate

5.12.1 Background

Calculation of the capital cost through the financial model created by Deloittes shows a base case scenario (without Springfield/Sheffield included) which would require farmers to pay an up-front capital cost of $1,472 per ha and then have an annual operating cost of $204 per ha for the first twenty years of the project operation. It is assumed that this cost would be the annual water charge. After this period, when the initial capital cost has been paid off the ongoing operating cost of the scheme is estimated at $65 per ha per year.

The base case scenario is influenced by a number of assumptions and variables including:

- Inclusion of the Springfield/Sheffield area.
- Scheme size.
- Debt/equity ratio.
- Finance rate.
- Repayment term.
- Equity return.
- Energy costs.
- Inflation.
- Depreciation type.

Unless otherwise specified, all comments and recommendations in this report refer to the base case scenario. The assumptions made in the base case scenario are that Springfield /Sheffield is not included, the equity ratio is 50/50 percent with landowners providing the 50 percent equity through an upfront capital contribution, scheme size 84,000ha with full reliability, a finance rate of 7.0 % on a 20 year repayment term with a nil equity return and energy costs of 6.3 cents per kilowatt hour. The impact of changing these assumptions and variables is detailed in the Deloittes report however it appears that the scheme costs are not greatly sensitive to any one individual variable although Debt/equity and Finance rate appear to be the most sensitive in terms of changes in annual water charge. There may however be savings that can be made by cumulative changes in the variables.

This section calculates and comments on the profitability of irrigated farming at the farm gate and therefore the affordability of a water charge of $204 per hectare. This information is important in the decision-making process to proceed with the scheme as it gives a lead to the agricultural practices and degree of land use change that would be required to make the scheme affordable. This gives an indication of potential uptake rates for water from within the farming community.

5.12.2 Farm Economic Environment

Present Position and Outlook

An important element in farmers decision on the uptake of irrigation is their outlook on future profitability. This drives their consideration of the likely profitability of irrigation development both in terms of land use change and the farming system which they would adopt. A commitment to uptake water in a community irrigation system requires farmers to be able to fund the significant on-farm irrigation development costs as well as their ability to make sufficient profits to pay the ongoing scheme costs reflected in water charges.

The present economic environment for farming is very favourable towards a positive attitude to irrigation development. Farmers have come through a number of decades where drought conditions have had a huge impact on farm productivity and therefore profitability of their businesses. Farmers are seeking to adopt farming systems which are protected from the impact of drought as this opens up much more profitable land use options to them.

At present farm values are at historically high levels with corresponding increases in equity and therefore ability to borrow additional capital. It is also significant that on the present land market there is a premium being paid for properties with irrigation, or the ability to carry out irrigation development. At the same time interest rates are at very low rates meaning that the cost of borrowing capital is lower than it has been for several decades.

At the same time, prices being paid at the farm gate for virtually all of our farm commodities, excluding arable crops, are at a level higher than they have been for at least twenty years. The medium-term outlook is for these high returns to continue. The demonstration of the historical returns for commodities and the medium-term outlook is shown in Figure 5-9.

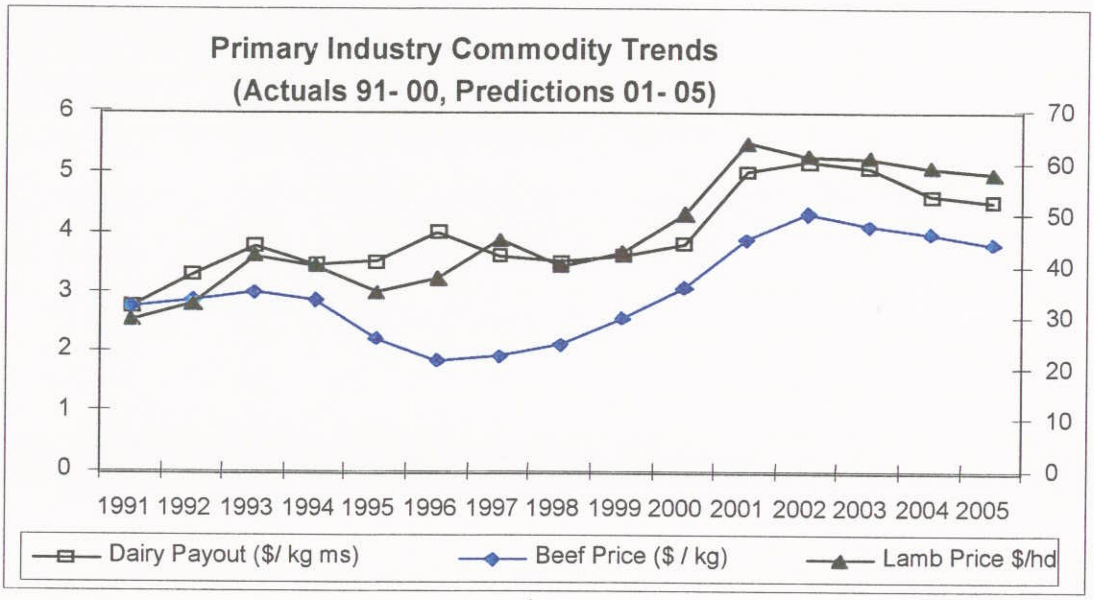

Figure 5-9 : Livestock Return Trends

Figure 5-9 shows historical trends for dairy, beef and lamb prices and from 1991 until the present were MAF Policy predictions of the outlook for these commodities over the next four years. The outlook for deer farming is very similar.

A combination of these factors means that farmers can expect to make reasonable profits in their farming businesses over the next few years, meaning that they will be in a stronger financial position to invest in further farm development in the short to medium term. It should be noted that these predictions are inside the expected period of development of the irrigation scheme. However farmers tend to make investment decisions based on the short to medium-term outlook therefore their attitudes towards investment in irrigation should be positive at present.

Farm Profitability

The present level of farm profitability is shown in Table 5-18.

Table 5-18 : Farm Profitability ($/ha/yr)

	Dairy	Arable	Sheep	Beef	Deer	Dairy Support
GROSS FARM REVENUE	5639	2228	3513	3376	4547	2543
CASH FARM EXPENDITURE	2511	1064	2691	2065	3347	1283
CASH FARM SURPLUS	3128	1164	822	1311	1201	1259

Table 5-18 shows the present day profitability of representative farming systems, details of income and expenditure for each of these farming models is attached as Appendix A. The cash farm surplus shown in the bottom line is that amount of money which is available for debt servicing, personal drawings, taxation and reinvestment.

Although there will be significant variation in farm profitability as a result of the combination of farm systems adopted the returns in the above table can be used as an indication of the relative profitability of land use options. Dairy Support represents the provision of supplementary feed and grazing to the dairy industry. Points to note from the table are:

- Dairying is by far the most profitable land use.
- Sheep farming is considerably lower in profitability than other land uses.
- The other options of arable, beef, deer and dairy support all show very similar cash surpluses.

5.12.3 Water Affordability

Analytical Framework

To be able to calculate the affordability of irrigation water charges farmers must first choose the land use and farming system they wish to adopt. They must then calculate the gross revenue, farm working expenses and therefore the cash farm surplus which they will generate. From this they must deduct the other expenditure in their farming business which would incur as a result of the irrigation development. This decision-making framework is depicted in Table 5-19.

Table 5-19: Affordability Framework

	Assumptions	Dairy Example
Gross Revenue	200 ha property	
- Cash Farm Expenditure		
= Cash Farm Surplus	@ 3610	72,200
- Servicing existing debt	300,000 @ 8%	24,000
- Drawings	30,000	30,000
- Interest on Development	@ 8%	224,320
- Interest on Capital Contribution	$1422 / ha @ 8%	22,752
- Capital Repayment	20 year term	169,420
- Taxation		58,032
= Surplus Available for Water Charges	200 ha property	193,636
Surplus per Hectare		$968

The above table uses the dairy farm example to demonstrate how the decision-making process works. Assumptions have been made on levels of existing debt, drawings and property size to be able to analyse the impact of these expenditure items on a farming business. By far the most significant item is debt servicing costs and capital repayment requirements as a result of the necessity to incur a significant increase in debt both in terms of irrigation development and other property conversion costs.

Results

The results of the water affordability calculations for the main land uses are shown in Table 5-19. It should be noted that these affordability calculations have been calculated based on the conversion of an existing dryland sheep farm to each of the irrigated land use options. This has been done because dryland sheep farming is by far the predominant land use in the command area. This table shows affordability over a range of productivity levels. The economic performance of the farms shown in Table 5-18 is taken as the median or average performance in profitability level. Affordability calculations had been carried out for a range of farm productivity levels around those averages. The detailed assumptions for each land use are at attached in Appendix A.

Table 5-20 : Water Affordability by Land-use Ranges

Cows /ha	DAIRY $/ha		ARABLE $/ha	S U / ha	SHEEP $/ha	S U / ha	BEEF $/ha	S U /ha	DEER $/ha	S U /ha	DAIRY SUP. $/ha
3.4	968	1.20	246	22	150	22	511	22	315	22	552
3.3	862	1.15	187	21	99	21	429	21	240	21	474
3.2	756	1.10	129	20	48	20	347	20	165	20	395
3.1	650	1.05	71	19	-4	19	265	19	90	19	316
3.0	543	1.00	13	18	-55	18	183	18	15	18	238
2.9	437	0.95	-45	17	-106	17	101	17	-60	17	159
2.8	331	0.90	-104	16	-158	16	19	16	-135	16	80
2.7	225	0.85	-162	15	-209	15	-63	15	-210	15	1
2.6	119	0.80	-220	14	-261	14	-145	14	-285	14	-77

In the above table, the column to the left of each land use shows the range of levels of productivity. For dairy farming this is expressed as cows per hectare, arable farming is expressed as a multiple of average production and all other livestock land uses are expressed in stock units per hectare.

The grey shaded areas in the table are those areas that do not provide sufficient surplus to be able to afford a water charge of $204 per hectare. The green shaded areas do provide sufficient surpluses. It should also be noted that the green shaded area exceeds $224 per hectare, which is the cost of the base scheme concept including the Springfield/Sheffield area.

Points to note from this shading are:

- Dairy farming and its supporting land use of dairy support can afford the water charge at below average levels of performance.
- Arable farming can afford the water charge at productivity levels which are 20 percent above average. It should be noted that specialist arable land uses such as specialist small seed production and processed cropping would easily be able to afford the water charge because of their high levels of profitability.
- Sheep farming at 22 stock units per hectare does not produce sufficient surplus to afford the water charge. However sheep farming systems above 23 stock units per hectare would be able to pay the water charge.
- Both beef and deer farming systems at 18 and 20 stock units per hectare respectively can afford the water charge.

In summary, the above table indicates that in order to be able to afford an up-front capital contribution of the $1,472 per hectare and an ongoing annual water charge of $204 per hectare (for the first 20 years of the scheme) that farmers are going to have to adopt a significant change in land use and achieve well above average levels of performance to be able to pay the additional costs of irrigation conversion and also make sufficient profits.

Existing Irrigators

There is already a significant area of irrigation within the proposed command area of the scheme. It may be that an important element in the uptake of shares in this irrigation scheme will be the ability to attract existing groundwater irrigators into the scheme. As it is proposed that the reliability of water from the scheme will be similar to that of existing groundwater irrigators. The next most important element will be the relative cost of the water. In the current scheme design, the command area has been created above a line where the calculated cost of gaining groundwater is above $300 per hectare. However the further up the plains that farmers are located the deeper they have to go to gain sufficient reliable water and therefore the more cost is involved in lifting that water to the surface before application. A calculation of the cost of lifting groundwater from a range of depths is shown in Table 5-21.

Table 5-21: Cost of lifting groundwater to the surface

Depth (meters)	Cost per ha ($/yr)
50	134
100	268
150	402

This table indicates that the attractiveness of joining the community irrigation scheme depends very much on the depth of present groundwater resources. In indicates that at present it would appear to be attractive for irrigators who are lifting water approximately 100 m.

There may be some other considerations for existing groundwater uses such as the reliability of their present groundwater resources, whether they have sufficient water to apply to their total farm area or whether their existing water supply gives them sufficient volume to optimise their irrigation application efficiency. In addition to this, is the added attraction that after 20 years, the cost of water will be very cheap at approximately $65/ha/yr.

Other Issues

There are other issues that have not been included in the water affordability modelling which farmers will take into consideration.

The ability to reduce the risk and variability in income is a very important element to some farmers and will be valued highly by them. Although irrigation is not a drought protection tool, the ability to smooth climate related influences on productivity and income is a significant element in farmer's confidence in their businesses ability to generate profit.

Some farmers, especially arable farmers, will see the ability to uptake irrigation as opening up a significant range of high-value niche or specialist farming options to them. There is an important number of specialist arable crop options which are only made available to farmers with irrigation capability. These will be seen as particularly attractive for existing arable farmers.

As already mentioned in this report, land which either has irrigation capability or the ability to be developed for irrigation attracts a significant premium in the land market. This offers some farmers the potential to increase their equity and, if they wish to sell their properties, achieve significant capital gains. Experience in other areas of New Zealand indicate that the potential increase in capital gains could be significantly more than the proposed capital cost of $1,472 per hectare.

Similar experiences from other parts of Canterbury which have developed irrigation show that if the shares were able to be traded in an open market that there could be significant capital value in the shares themselves if they can be traded separately from the land.

5.12.4 Summary

It appears that the proposed cost of the scheme is at the upper range of affordability as shown by the modelling and bears out the results of the focus group work. This will mean that existing dryland sheep farmers, who are the predominant land users in the command area, will need assistance in calculating the water affordability issues on their property.

To achieve a satisfactory level of water uptake commitment the Central Plains Water Enhancement Society will need to carry out an extensive education and farmer support program before seeking farmer's commitment to the scheme.

The ability to trade water entitlements independent of land may also be an important element that should be considered in accelerating uptake or commitment to the scheme.

5.13 Regional Benefits

While the above analysis indicates the potential returns from individual activities, the community scheme will be supply water for a mix of land uses depending upon farmer preference and land suitability. A range of different mixes of land use are described in the economic report (Butcher 2000) to provide a range of economic benefits from the proposed scheme.

The Butcher Report details the wider benefits in terms of employment and total value added to the economy that will flow on from this development. For a likely development scenario on the 84,000 ha community irrigation scheme, the likely economic benefits are as follows:

- An increase in the annual net output at the farm gate of $153 million.
- An increase in the total annual regional output of Canterbury of $647 million.
- An increase in the total value added on-farm of $76 million.
- An increase in the total regional value added of $241 million.
- An increase in employment on farm of 477 full time equivalents.
- An increase in the total regional employment of 2630 full time equivalents.

Annual net output describes the value of increase output, expressed in dollars, at the farm gate, or increased farm gross revenue. The increase in total annual regional output describes the dollar value of the flow on effect of the increased output on the Canterbury regional economy. This incorporates the direct and indirect impacts of the extra economic activity created in Canterbury. Value added expresses the extra profit created which is available for reinvestment. This is typically described as the return to the investment in land, labour and capital.

In addition to the cost of the irrigation scheme, the total on-farm development costs will be in the order of $300 - $400 million, and the further investment in off-farm processing plants etc could exceed $100 million. The increase in the total on-farm and regional value added will be required to service the capital investment for these items. It is clear that these amounts are sufficient to provide for this.

5.14 Benefits to Christchurch City and the Rural Towns

During 1999 Agriculture New Zealand carried out a survey of Canterbury farmers to determine the impact of the 1997-1999 drought. Data from this survey has been analysed to ascertain where farmers purchased their goods and services. They were given a choice of:

- Out of Canterbury
- In Christchurch
- In Ashburton/Timaru
- In a small town

The rural community was also divided into three sectors, being arable, livestock and dairy. Expenditure was categorised into farm working expenses (which was further split into expenditure categories), capital, personal and then total.

Analysis of the spending patterns of Central Canterbury farmers shows in Table 5-22, the percentage split of spending between Christchurch and the smaller servicing towns (eg: Leeston, Southbridge, Darfield, Dunsandel etc).

Table 5-22: Spending Patterns of Central Canterbury Farmers

	Christchurch	Small Towns
Stock Purchases	24%	60%
Wages	6%	92%
Animal Health	16%	83%
Crop Expenses	40%	59%
Electricity	77%	17%
Feed	1%	97%
Fertiliser	92%	6%
Freight	0%	99%
Seeds	58%	32%
Shearing	8%	92%
Weed & Pest	32%	61%
Vehicle	28%	67%
Rep & Maintenance	21%	79%
Administration	77%	19%
Rates & Insurance	40%	57%
Other	42%	24%
Personal	37%	17%
Capital	43%	51%

When these spending patterns are run across the modelled expenditure from the Economic Impact report for the two base scenarios (Base most likely and Base high performance) they indicate the likely changes in expenditure that would occur if the scheme where to proceed. These can be compared with what would occur without the scheme (Present scenario) to indicate the likely changes in throughput that would occur if the scheme were to proceed. This is detailed in Table 5-23.

Table 5-23: Change in Spending ($ million)

		Present	Base ML	Base HP
Farm Working Expenses	Christchurch	50.7	98.6	116.9
		Increase	+47.9	+66.2
	Small Towns	78.7	186.5	225.7
		Increase	+107.8	+147.0
Personal Expenditure	Christchurch	7.6	15.0	17.6
		Increase	+7.5	+10.0
	Small Towns	3.5	6.9	8.1
		Increase	+ 3.4	+4.6
Total	Christchurch	58.3	113.6	134.5
		Increase	+55.3	+76.2
	Small Towns	82.2	193.4	233.8
		Increase	+111.2	+151.6

Table 5-23 shows that the impact of the scheme on spending in Christchurch is of a lift of between $48m and $66m in expenditure from farm working expenses and a lift of between $7.5m and $10m in personal expenditure. This gives a total increase in expenditure in Christchurch of between $55m and $76m. This is a significant increase on the current $58m.

The impact on spending in the smaller servicing towns is of a lift of between $108m and $147m in expenditure from farm working expenses and a lift of between $3.4m and $4.6m in personal expenditure. This gives a total increase in expenditure in smaller towns of between $111m and $151m. This is a significant increase on the current $82m.

In addition to the permanent annual gains shown above there would be the gain of the one off expenditure of the on farm development. This is likely to add $131m to the Christchurch economy and $156m to the smaller servicing towns.

5.15 Affordability/Bankability

The assessment of affordability/bankability is not a fixed test, but rather a concept that encourages a wide consideration of the economic and financial issues to be considered. The final assessment of affordability/bankability must be made by considering all of the perspectives involved. These include:

- Affordability at the farm gate to the farmers;
- Strong regional economics to ensure down stream processing and marketing support;
- Sufficiently robust structures to provide confidence from the financiers;
- Community value in terms of jobs and wealth creation.

The price of water has been estimated to be within the range of an up-front capital contribution of $1,450 - $1,600/ha, plus annual charges of between $189 - $229/ha/yr. At the farm gate, there are sufficient cash farm surpluses from a range of farming activities including dairy, high end arable, above average beef and deer, and dairy support, which are sufficient to pay for the cost of the community supplied water.

At the regional level, this scheme could boost the total annual regional output of Canterbury by $647 million and increase the total regional value added by $241 million.

The financial structures that must be put in place have yet to be determined, and will depend upon the collective stakeholders priorities. It would be safe to assume at this stage of the study that there is a sufficient range of structural options available for all stakeholders needs to be met. It is premature at this stage to be specific on the guarantees that may be required by the funders of the scheme. These may include underwriting of debt by either local or national government.

It is anticipated that the scheme will increase the total regional employment by 2,630 full time equivalent jobs. This will significantly distribute wealth throughout the community. The creation of jobs would be across the whole spectrum of employment, including unskilled, skilled, trades and professional. It would be likely that this development would create a shortage of skilled workers within the rural communities.

On the basis of the above assessments, a community irrigation scheme is financially viable and will be economically beneficial to the whole Central Plains area and is therefore both affordable and bankable, remembering that this does require significant changes in land use practices.

6.1 Introduction

This section discusses the effects of the proposed scheme on the environment. A broad interpretation of the environment has been adopted, in keeping with the Resource Management Act, and includes:

- ecosystems and the constituent parts, including people and communities,
- all natural and physical resources,
- amenity values, and
- the social, economic, aesthetic and cultural conditions which affect the matters above.

Given the above definition of the environment, it is also helpful to consider the meaning of "effect" in the RMA:

"In this Act, unless the context otherwise requires, the term "effect", includes-

(a) Any positive or adverse effect; and

(b) Any temporary or permanent effect; and

(c) Any past, present, or future effect; and

(d) Any cumulative effect which arises over time or in combination with other effects- regardless of scale, intensity, duration, or frequency of the effect, and also includes-

(e) Any potential effect of high probability; and

(f) Any potential effect of low probability which has a high potential impact."

The term effect includes any adverse effect regardless of scale. The sections on the Environmental, Social and Cultural effects therefore must be considered together, as these all form integral parts of the environment. The separation into individual sections is for editorial purposes only.

6.2 Rakaia River

6.2.1 Rakaia Catchment Environment

The Rakaia River is the largest braided river in New Zealand. It has a total catchment area of 2,910 km^2, 91% of which is above the gorge. Its main tributaries are fed from the snowfields of the Southern Alps. For most of its course it consists of large shingle flats and fast flowing rapids and runs. Downstream of the Gorge the river spreads across a wide area, which is encroached upon by broom and lupin. Between the Gorge and State Highway 1 the river is incised in gravels of the Burnham Formation and has created high terraces. Through this reach the river is perched above the groundwater table (Bowden, 1983).

The Rakaia River and its tributaries are recognised as an outstanding natural characteristic in the form of a braided river and as providing outstanding wildlife habitat, outstanding fisheries and outstanding recreation, angling and jet boating features. These characteristics are protected by the National Water Conservation (Rakaia River) Order 1988 (NWCO).

Similar to other Canterbury rivers with alpine headwaters, the Rakaia River exhibits high flows during spring and early summer as a result of north-westerly rain and snowmelt. Freshes and floods are most frequent during the September to April period, and at this time the sediment load tends to be high. Rakaia River flows vary seasonally, tending to highest in the spring and early summer. Mean monthly flows (1948-1996) and the minimum flows set in the NWCO are shown in Figure 6-1. The mean annual flow measured in the Rakaia River Gorge is 203 m^3/s; the lowest monthly mean flow occurs in July and the highest in December.

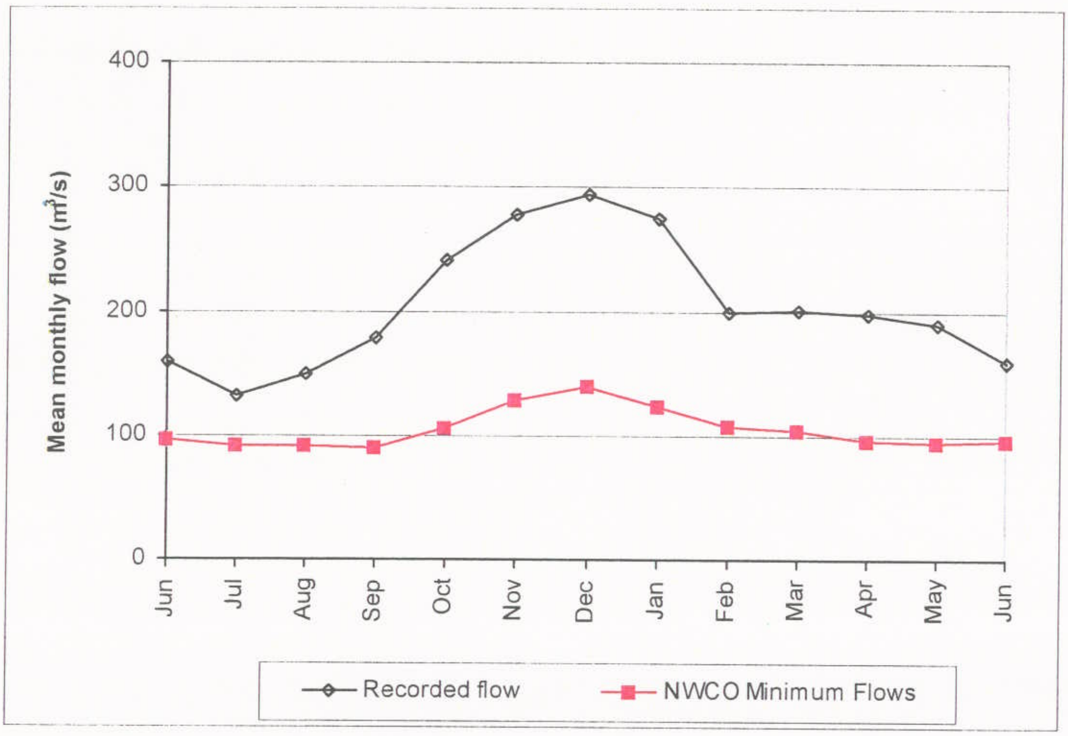

Figure 6-1: Mean monthly flows in the Rakaia River

A description of the water resources and water quality of the Rakaia River and an assessment of the recreational, fishery and wildlife values of the river are contained in Bowden (1983). This report details the hydrology of the river, the catchment run-off characteristics, the seasonal flow variations, the river water quality and the effects of river abstractions on water quality. It also details the riverbed vegetation, the aquatic invertebrate community, the fish community, the wildlife community, the value of the Rakaia River to fisheries and wildlife, the effects of abstractive developments upon fisheries and wildlife and the recreational uses of the river including boating and angling.

There is a demand for out of stream water usage, mainly for irrigation. There are seven irrigation schemes and many smaller scale abstractors on the river. The Selwyn and Ashburton District Councils take water for stock purposes from the river. Water is also used for electricity generation upstream of the gorge, with diversions from the Wilberforce and Harper Rivers into Lake Coleridge. The Highbank hydroelectric scheme discharges water at a mean annual flow rate of approximately 13 m^3/s into the Rakaia River, and is located approximately 3 km downstream from the proposed northern side intake.

6.2.2 Flows

The NWCO that is in force on the Rakaia River was established specifically to maintain the river in its natural state. Investigations and evidence presented at the NWCO hearings analysed the effects of abstraction on flow patterns, sediment flows and riverbed morphology (NWSCA, 1984). A system of minimum flows, and rules for sharing of flows in excess of these minimums, was put in place to achieve the desired protection of the natural characteristics of the river.

A plot of hydrograph for the Rakaia River for the period June 1970 – May 1972 is contained in Figure 6-2. This is a selected hydrograph for a low flow year for the Rakaia River. This figure contain the flow before and after the effects of the proposed take has been included and clearly demonstrates that the impact of the CPWE take on flows in the Rakaia River are negligible.

Therefore, water abstractions, which comply with the NWCO, have been judged to not significantly change the river from its natural state. As noted in the description of the water take the proposed activity will be in full compliance with the NWCO and hence have no significant adverse effects on the river and its associated values.

6.2.3 Geomorphology

The Rakaia River is an intensely braided river both upstream and downstream of the gorge. At low flows ($<120\ m^3/s$), 8 to 20 braids have been recorded between the gorge and SH1, and more than 20 braids in the slightly aggraded section between SH1 and the sea. A characteristic of braided rivers is that the amount of deep and fast water increases markedly as flow increases, whereas that of slow and shallow water (mainly marginal areas) shows little change (Mosley 1982).

Davies (1988) stated that bed movement in the Rakaia River starts at flows approaching 400 m^3/s, with most of the movement occurring at about 800 m^3/s on a flow duration basis. As the operation of the irrigation schemes will not appreciably alter flood peaks, there would almost certainly be sufficient bed movement to maintain the natural character of the braided channels and limit flood-plain vegetation.

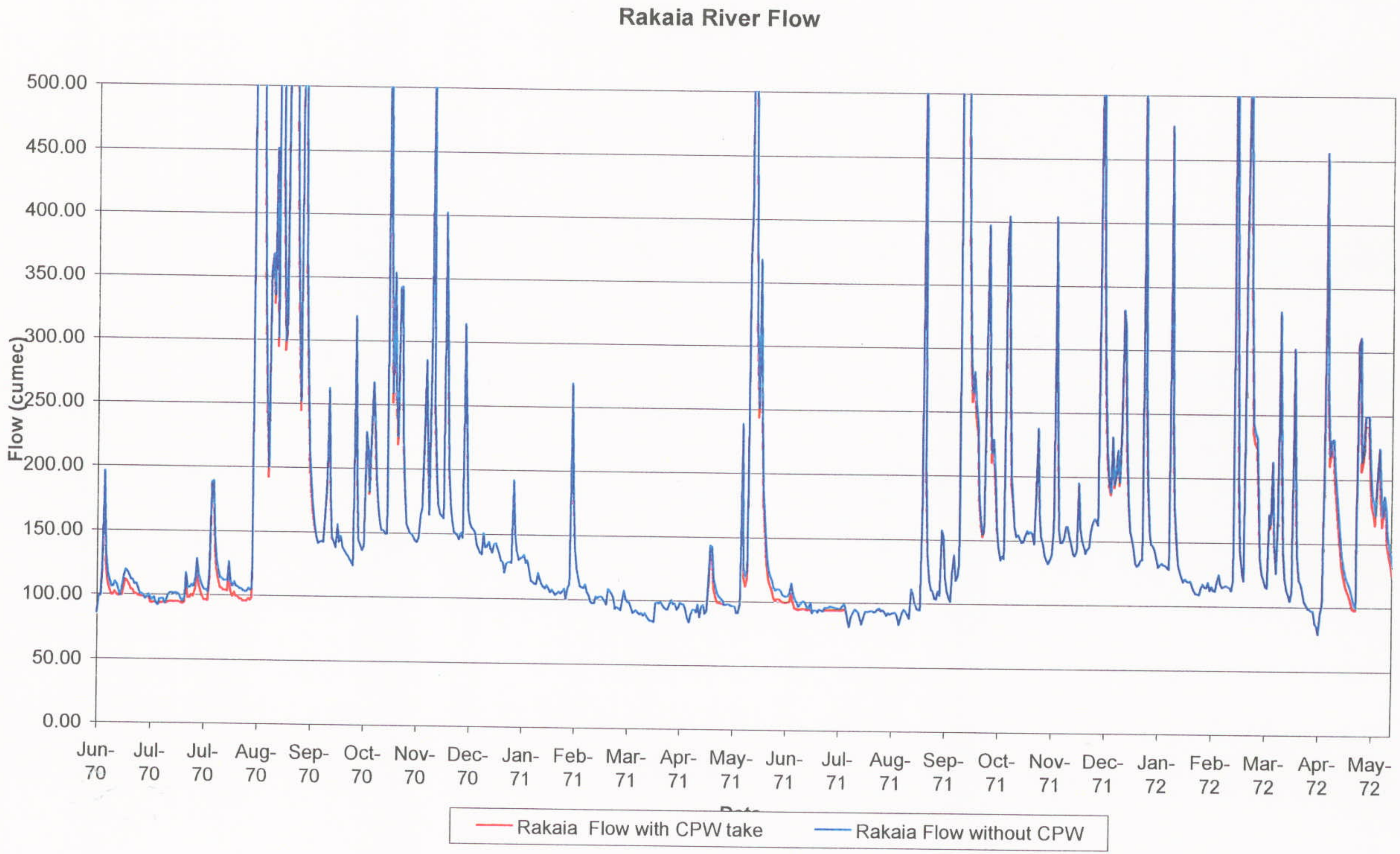

Figure 6-2: Rakaia River Flows 1970 - 1972

6.2.4 Sediment flushing from stilling basin

It is assumed that the sediment trapping efficiency of the stilling basin on the Rakaia River would be similar to that which exists on the Rangitata River for the Rangitata Diversion Race (RDR) scheme. Waugh (1983) reported that this trap has an efficiency of 84-92% in trapping sand-sized sediments, but those of the finer silt and clay particles largely pass through.

Ideally, flushing of sediments from the stilling basin to the river would have less impact downstream if conducted during floods, when natural sediment loads are high and the river has the capacity to handle additional sediment load. However, such an approach is likely to face practical difficulties similar to those experienced with the RDR scheme (Waugh 1983). Mainly, floods are likely to be too infrequent, the stilling basin will fill too rapidly, and the sediment in the trap will become too compacted if left for too long, requiring a bulldozer to dislodge it during flushing, which would result in greater disturbance downstream.

Relative to the size of the Rakaia River bed, flows, and sediment load, it is unlikely that the flushing of sediments from the stilling basin would have any major lasting effects on the river and its biota downstream. A high proportion of the sediments flushed from the basin would be expected to settle within about 5 km downstream. Thus, the impact on periphyton and benthic invertebrate communities, and possibly small bottom-dwelling fish (bullies, eels, torrentfish), would not be expected to be extensive and the sediments would be swept out by the next flood. However, during periods of prolonged low flows, as often occurs during late summer to early autumn (February-March), the flushing of sediments would be expected to have greater impacts downstream. However during these extended low flow periods the need for flushing would be reduced.

An issue of major concern would be the effect of flushing of sediments from the stilling basin on salmon fishing which occurs from November through April. As salmon fishing requires specific flows and water clarity (Davis et al. 1987; Glova 1988), it is expected that flushing of sediments from the stilling basin would adversely affect salmon fishing for variable distances downstream. An exception may be during periods of low flows and high water clarity, salmon fishing may actually improve slightly with sediment flushing due to reduction in water clarity for some distance downstream. Water clarity suitable for salmon fishing in braided rivers is when Secchi disk readings range from 0.5 to 1.0 m (Waugh 1983; Glova 1988). While the impact of sediment flushing on salmon fishing would be short-lived in most instances, it would nonetheless be an inconvenience to anglers to organise their fishing around such events. The recommendations made by Waugh (1983) to reduce impact of sediment flushing of the RDR scheme on salmon fishing in the Rangitata River could be incorporated into the CPWE scheme to achieve similar results on the Rakaia River.

6.2.5 Fish screening and bypass facilities

The Rakaia River is an important rearing area and corridor for a number of fish species moving to and from the sea (Davis et al. 1983). Because of the presence of young salmon and trout and other fishes in the river, the intakes of the CPWE scheme would have to be adequately screened to keep fish out of the races. If rotary screens are used, recommended mesh size for salmonid fry is 3.8 mm, whereas if oblique screens are used then mesh size could be increased to 5 mm (Clay 1995). With oblique screens, the fish tend to approach side-on rather than head-on, which helps move them along the face of the screens and into the bypass back to the river. Oblique screens have been used successfully for salmonids in some rivers in the United States (Clay 1995). Most of the many larval native fishes that are likely to be present in the river at various times of the year, would be too small to be kept out of the intakes by screens.

As an alternative to screens on large intakes, the effectiveness of underwater sonic barriers in keeping fish out is currently being tested by Fish Guidance Systems Ltd in the United Kingdom with quite promising results. The use of such barriers needs to be assessed for conditions in large New Zealand rivers with high sediment loads.

The approach velocity to screens will depend on the type of screens used and size of the smaller fish (usually salmonid fry (~ 30 mm long) or fingerlings (~ 75 mm long)) to be kept out of the intakes. Fish swimming ability is proportional to body size, and the recommended approach velocities are about four times the lengths of the fish (Clay 1995). Thus, for juvenile salmonids 30 mm and 75 mm long, the maximum allowable approach velocities for rotary screens are 0.12 m/s and 0.30 m/s, respectively. However, because salmonid fry are common in the Rakaia River in spring, the approach velocity for rotary screens would have to cater for the weaker swimming ability of the fry, rather than fingerlings. On the other hand, approach velocities 3-4 times the recommended 0.12 m/s for salmonid fry have been successfully used with oblique screens in some rivers in the United States (Clay 1995).

The bypasses would have to cater for a variety of fish species and sizes ranging from small bullies to large trout and eels, having different water preferences and migratory behaviours. Bypasses should present minimal interruption to the movement of fish and be readily accessible to both bottom-dwelling and free-swimming fish. They need to be strategically located relative to the screens and provided with an adequate flow to convey fish back to a major channel in the river. From our past experiences with flows and channel sizes in the Rakaia River (Glova and Duncan 1985), a channel with a 2 m^3/s flow is considered inadequate for adult salmonids and eels. To provide safe passage for all fish, a flow of say 5 m^3/s would be required in a bypass channel. As a discharge of this magnitude is likely to attract fish, a velocity barrier would have to be installed at the point of discharge to the river to prevent fish from entering the bypass at the downstream end.

Any bywash channels associated with the CPWE intakes would require a fish velocity barrier to prevent fish from entering, as well as a projecting flange along the top of the barrier on the downstream face to keep climbing fish such as elvers, adult lampreys, and certain juvenile galaxiids out. Also, bywash channels would need to be adequately sloped to avoid stranding of fish, when flows cease.

6.2.6 Riparian Vegetation

The vegetation on the Rakaia River bed at the proposed intake sites tends to be exotic, comprising broom, gorse and willows. This vegetation is assessed as having an low value. The presence and operation of the proposed intake structures on the Rakaia River is assessed as having a low potential to affect vegetation values. In addition the effect of the reduced downstream quantity of water is assessed as having a low potential to affect vegetation values (Lincoln Environmental, 2001).

6.2.7 Periphyton and Benthic Communities

Because of their inherent morphological instability, braided rivers contain a diverse range of habitats. Variations in gradients, substrate composition, size and duration of channels across braided rivers provide a variety of habitats for periphyton and benthic invertebrates. This results in markedly different extents of growth of periphyton and production of benthic invertebrates among the channels present in time and space. Consequently, not all channels are equally favourable for periphyton and benthic invertebrates. The periphyton community in the Rakaia River between the gorge comprises autotrophs (photosynthetic algae) and heterotrophs (fungi, bacteria, protozoa, etc.) of relatively low abundance generally (Biggs and Close 1989). In all seasons, the benthic invertebrate fauna consists mainly of larval mayflies, trueflies and caddisflies (Sagar and Eldon 1983).

Digby (1999) studied benthic invertebrate production in a variety of habitats in the Rakaia River, near Barrhill, and concluded that minor channels of seepage flows were significantly more productive for benthic invertebrates than were channels of all sizes of surface flows. In addition, seepage flows are important sources of colonising invertebrates following floods (Scrimgeour *et al.* 1988; Sagar & Glova 1992; Digby 1999).

Although an abstraction of up to 8 m^3/s in the Rakaia River below the gorge as per the rules of the NWCO is not likely to significantly reduce the area of physical habitat available for periphyton and benthic invertebrates, it is likely to result in a decrease in quality of the available habitat. This would occur by:

- greater siltation of periphyton communities, resulting in lower food value for benthic invertebrates;
- greater biomass of periphyton in channels with surface flows due to less sloughing of algae, resulting in less favourable habitat for grazing mayflies;
- dewatering of a greater proportion of important seepage channels than of significantly less productive major and intermediate braids with surface flows; and
- increased periphyton in seepage channels because of less dilution of enriched groundwater, resulting in fewer grazing mayflies in these important refugia in braided river floodplains.

6.2.8 Fish

Most native fish and juvenile salmonid populations in braided rivers tend to occupy areas of slow to moderate water velocities and relatively shallow depths (Davis et al. 1983). In the Rakaia River, at flows between 69 and 146 m^3/s, Glova and Duncan (1985) found no appreciable change in the available physical habitat for both native and salmonid fishes in two representative reaches upstream of the SH1 bridge.

Similar findings to those of the Rakaia River have recently been reported for the Waimakariri River (Duncan 2001) and Rangitata River (Duncan and Hicks 2001).

In summary, all three of the above studies showed little to no change in the available physical habitat with flow in the range of the mean annual low flow to about the median flow (flow that is exceeded 50% of the time). From the findings by Mosley (1982) for a greater range of flows in braided rivers, it is believed that the results of the above studies (i.e., Duncan 2001; Duncan and Hicks 2001) could be extrapolated to higher flows, such as the mean flow, with meaningful results.

The main implications of the findings of the above studies for the taking of water from the Rakaia River for the CPWE and AWCT schemes are as follows:

Firstly, the extraction of water at flows greater than the prescribed minima in the NWCO is not likely to result in significantly reduced physical habitat for any of the fish species present in the river.

Secondly, since there would be relatively little change in the amount of physical habitat with a maximum take of 70 m^3/s (the total allowed for in the NWCO), there seems to be little justification for 1:1 flow-sharing, or some other version (e.g., 1:3 sharing), between in-stream and out-of-stream users. Leaving slightly more water in the river, as would occur if the NWCO 1:1 sharing rule is applied, or some other sharing rule, would not result in considerably more useable habitat for fish. Having no sharing rule would be much easier to manage and comply with from an operational standpoint.

With the exception of some autumns and most winters, there are frequent freshes/floods in the Rakaia River at most times of the year. As a result, the periods of constant reduced flow because of abstraction for the CPWE scheme would be relatively short and the river would have sufficient variation in flow to flush fine sediments and remove filamentous algal accumulations.

6.2.9 Effects of takes on fish passage

The critical water depths for passage of adult salmon in braided rivers have been identified by Mosley (1982). As adult salmon are the largest fish in the river, it is generally accepted that if minimum flows are provided for passage of these fish, then the passage requirements of all other species will be catered for. The NWCO minimum flows for the Rakaia River adequately provide for passage of adult salmon and other fish. Since the takes for the CPWE scheme would be governed by the rules of the NWCO, the scheme is not be expected to present any fish passage problems – i.e., water depths along the thalweg of riffles in the main channel in critically braided reaches of the river would be adequate to allow for passage of all fish.

6.2.10 Birdlife

The water depth and velocity data that were used to model habitat dynamics for fish in braided rivers, were also used in an analysis of feeding habitat of the wrybilled plover (*Anarhynchus frontalis*), the only wading bird species in New Zealand for which there are adequate habitat data available. For the range of flows examined, the modelled results showed that the available habitat for the wrybilled plover decreased markedly as flow increased. Therefore, reductions in flow on the Rakaia River, as a result of abstractions for the CPWE scheme, are likely to have a positive effect on the wrybilled plover feeding-habitat. However, reduced flows may affect access to nesting areas of wrybills by mustelids, dogs, cats, and others.

6.2.11 Recreation

Fishing

Chinook salmon, brown trout, and whitebait constitute valuable recreational fisheries on the Rakaia River. Also, there is some commercial fishing for eels, as well as some customary takes of eels and lampreys in the lower river. With the exception of the salmon fishery, none of these fisheries is likely to be affected by takes for the CPWE scheme as they are adequately protected by the monthly minimum flows of the NWCO.

From catch rates of 20 experienced anglers in relation to river flows, it was identified that preferred flows for salmon fishing on the Rakaia River lie between 160 and 180 m^3/s (Glova 1988). These flows are considerably greater than the minimum flows adopted by the NWCO to protect the main period of salmon fishing (105.3 and 107.9 m^3/s for February and March, respectively). Fish and Game Council New Zealand (North Canterbury Region) has now accepted that flows between 160 and 180 m^3/s are optimal for salmon fishing on the Rakaia River.

The CPWE take would cause a slight shift the band of flows that is preferred for salmon fishing (i.e., 160-180 m^3/s) to occur earlier on the hydrograph, as well as change the proportion of time that such flows would occur. From measures of the differences between flow duration of the river with and without the CPWE for the 33 years of records, it is estimated that the take would result in an average 2.4% increase in time that flows would be preferable for salmon fishing on the Rakaia River. However the change to these preferred fishing days varies from year to year with the biggest increase being 5 days and the largest decrease being 6 days.

An additional factor of significance in the context of salmon fishability that is likely to be affected by the CPWE take is that of water clarity. Freshes and floods are periodically required to sufficiently entrain sediments from the riverbed, banks and headwater areas to discolour the water for optimal salmon fishing conditions. Ideally, river flows must not be too clear, nor too turbid (underwater visibility ~ 0.5-1.0 m) for salmon fishing (Glova 1987). From evidence presented on turbidity in relation to flows for the Rangitata River by Jowett (2001), it can be expected that on the falling stage of a fresh or flood the Rakaia River would clear more rapidly with the CPWE take due to increased settling due to lower flow velocities.

While it is likely that the duration of water clarity suitable for salmon fishing would be changed by the CPWE takes, it is not possible at this stage to predict by how much. But almost certainly, the effect of the take on water clarity would be greatest in the lower reach of the river.

The provisions of the NWCO in combination with the proposed fish passes and screens will ensure that the proposed activities will have insignificant effect on the numbers and distribution of fish within the Rakaia River. Potential effects on fish passage will be mitigated by the design of the intake structure and discharge points.

Other Recreational Activities

Other recreational activities that have the potential to be effected include boating, swimming, walking and other passive activities.

It is only the water-based activities that are likely to be directly affected by any water take from the river. The land-based activities will be affected by the availability of riverbed area and confinement of the river channels.

Not all these water users utilise the entire length of the river. Swimming and jet boating will only use the deeper areas whereas other users can use more shallow areas. Reducing the mainstream riffle depth is possibly of greater concern to activities that require longer lengths of river, such as the jet boaters and canoeists / kayakers, who require a minimum water depth of 0.2 and 0.1metres respectively.

The NWCO specifically protects the outstanding recreational, angling and jet-boating features of the Rakaia River. Therefore water abstractions which comply with the NWCO have been judged to not significantly alter the provision of recreational opportunities including jetboat access.

The intake structures will have appropriate signage warning recreational users of their location. In addition, the inlets to the box culvert intakes will be have steel grills placed over them.

The effect of the reduced downstream quantity of water is assessed as having a low potential to affect both instream and land-based recreation (Lincoln Environmental, 2001).

6.3 Waimakariri River

6.3.1 Natural and Physical Environment

The Waimakariri River is one of the largest braided rivers in New Zealand. It has a total catchment of 3,654 km^2. Of this 33% percent is arable land, 17% is mainly tussock and bush covered hill and high country, 4% is riverbed and 46% is steep mountain land. Its main tributaries are fed from the snowfields of the Southern Alps.

The source of the Waimakariri River is the main divide of the Southern Alps, within the rugged terrain of Arthur's Pass National Park, beyond this the river winds through the relatively unmodified Waimakariri Basin, before passing through a 25 kilometre gorge. The river emerges from the gorge and flows to the sea in a wide braided riverbed with constricted narrow reaches at the Waimakariri Gorge Bridge and downstream of the motorway bridge.

The Waimakariri River has a high degree of naturalness above Woodstock. Particular features of the natural character are the lack of structures and cultural modifications, high water quality, native wildlife, a sports fishery, indigenous vegetation in the bed and margins of the river, a relatively unmodified aquatic environment and unmodified flow characteristics. Much of the upper catchment is part of the Selwyn District Scenic corridor. Below Woodstock the Waimakariri River remains visibly distinct from the surrounding plains, and forms broad braids.

The plains contrast sharply with the upper Waimakariri River catchment Basin, where high attitudes, long cold winters and the inhospitable terrain, severely limit agricultural production. These same features, so adverse to agriculture, add to the attraction and value of the area for outdoor recreation and tourism. The upper catchment contains the last remaining significant areas of relatively undisturbed indigenous ecosystems within the catchment.

Over 90% of the river flow is derived from precipitation in the upper catchment. Winter snow and ice is stored and released in spring contributing to higher flows in the river during this part of the year. The period of lowest flows occur in late summer. Flood flows can occur at any time. The flow in the Waimakariri River is continuously recorded at the Old Highway Bridge where there are 27 years of recorded flows indicating that the river has a mean flow of 124 cubic metres per second, flood flows can exceed 4,000 cubic metres per second. The mean annual daily low flow is 41.5 cubic metres per second, and mean annual instantaneous low flow is 41.0 cubic metres per second.

The Waimakariri River presents a major flood hazard to Christchurch, and therefore an extensive system of flood protection works has been constructed on the lower river. The flood hazard from the river is identified and managed in both Regional and District Plans.

Water is abstracted for three major stockwater schemes and Darfield's domestic water supply. The Selwyn District Council, Malvern stockwater scheme takes water from the Waimakariri River at the Gorge and the Kowai River, and provides stockwater to approximately 47,500 ha. A second scheme at Halkett (the Paparua Stockwater Scheme) provides water from the Waimakariri River to approximately 17,000ha. The Waimakariri District Council Scheme has an intake at Brown's Rock which provides stockwater to 44,000ha. Mean monthly flows for the Waimakariri River are shown in Figure 6-3.

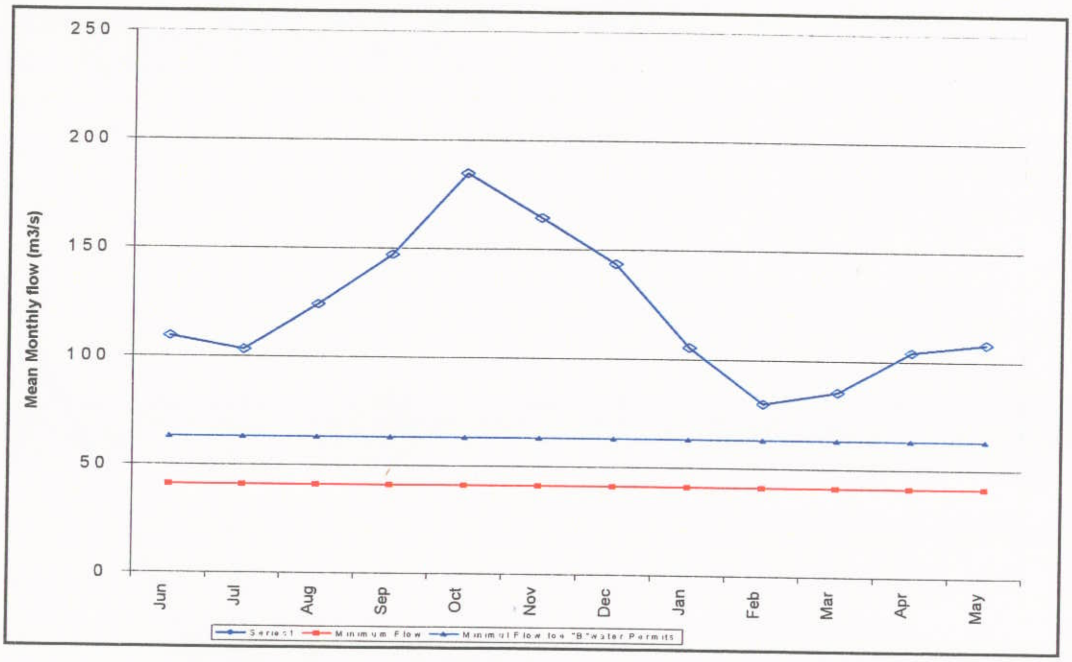

Figure 6-3: Mean monthly flows in the Waimakariri River

6.3.2 Flows

A plot of hydrograph for the Waimakariri River for the entire period June 1967 – May 2001 is contained in Figure 6-4. Figure 6-5 is the selected hydrograph for a low flow year for the Waimakariri River. Each of these figures contain the flow before and after the effects of the proposed take has been included.

Restrictions on takes for the CPWE scheme would occur mostly in February-March, although in exceedingly dry years, as occurred in 1971, severe restrictions would apply from February-April.

The maximum take for the Waimakariri is 40 m^3/sec. Of this 5 m^3/sec is "A" permit water and 35m^3/sec is "B" permit water. Restrictions start at an unmodified flow of 63 m^3/sec for the A Permit water, and decrease on a pro rata basis to zero at 41 m^3/sec.

The minimum flow in the Waimakariri River under the PWRRP is 41 m^3/sec, however the 4 m^3/sec for stockwater is not subject to restrictions therefore the actual minimum flow is allowed to go as low as 37 m^3/sec, measured at the Old SH1 Bridge.

B permit water restrictions would commence at an unmodified flow of 98 m^3/sec. This abstraction would decrease linearly to zero at 63 m^3/sec.

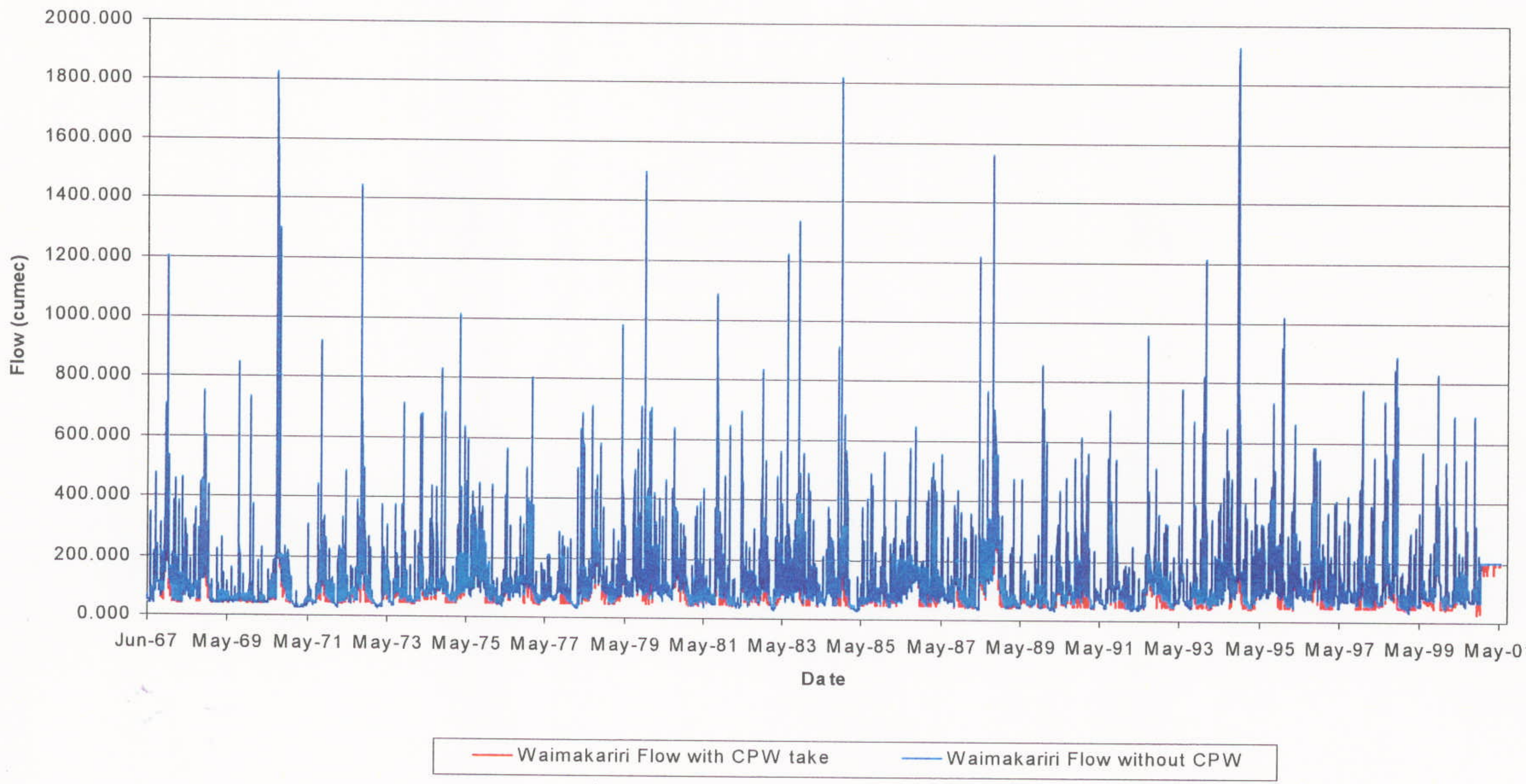

Figure 6-4 Waimakariri Flows 1967 to 2001

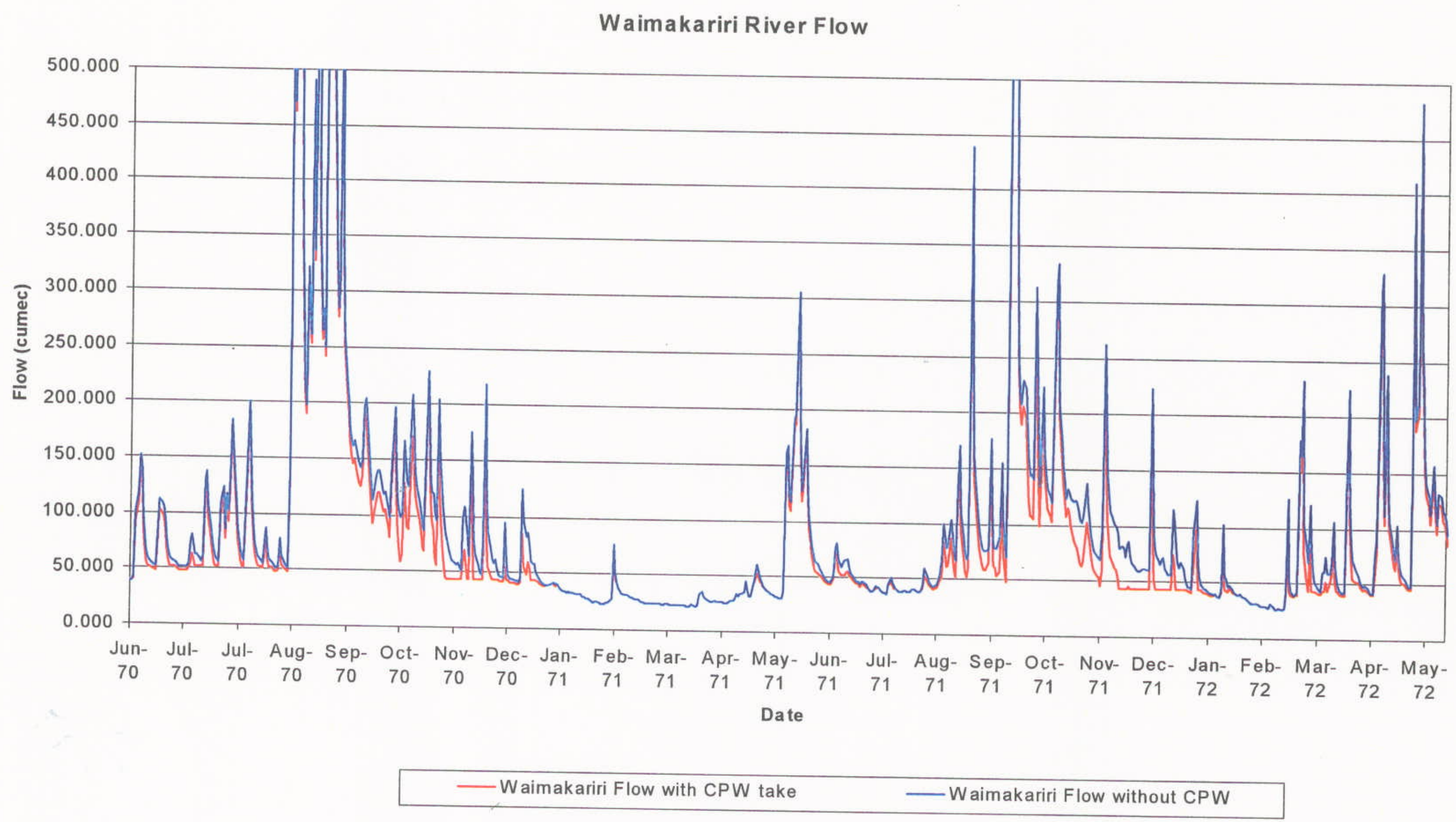

Figure 6-5: Waimakariri Flows 1970 to 1972

6.3.3 Geomorphology

The average annual bed load for the lower Waimakariri River has been estimated at 233,000 m^3 of sediment/year by Griffiths (1979), 209 000 m^3/year by Blakely and Mosley (1987), and 246,000 m^3/year by Carson and Griffiths (1989). A take of 40 m^3/s would be a similar proportion of the Waimakariri River mean flow as would be a 70 m^3/s take of the Rakaia River mean flow. Thus, the estimated 20% reduction in bedload transport with an abstraction of 70 m^3/s for the Rakaia River (Davies 1988) may roughly apply to an abstraction of 40 m^3/s in the Waimakariri River. If so, this would amount to a reduction in bed transport of about 46,000 m^3 of sediment/year in the lower Waimakariri River. Since much of the bedload in the lower river is derived from the bed and banks downstream of the gorge, an abstraction of up to 40 m^3/s at RL235 would be expected to have significant effects on bed transport in the lower river. Presently, it is not known if such an abstraction would result in aggradation downstream of the intake.

Bed movement in the Waimakariri River probably starts at flows of about 250 m^3/s, with most bedload occurring at flows greater than 500 m^3/s. A take of up to 40 m^3/s would not appreciably alter flood peaks, and so there would be sufficient bed-moving floods to maintain the braided character and floodplain vegetation downstream of the take.

The relative impact of the proposed take can be seen in Figure 6-4 where the peak flood flows would not be reduced significantly at all.

6.3.4 Sediment flushing from stilling basin

It is assumed that the sediment trapping efficiency of the stilling basin and problems associated with flushing of sediments and their resultant effects downstream in the Waimakariri River would be similar to those already discussed for the Rakaia River.

Similarly, the effects of sediment flushing on salmon fishing in the Waimakariri River would be expected to be similar to that discussed for the Rakaia River. However, the impact of sediment flushing may be less for the Waimakariri River because most salmon fishing occurs near the mouth (greater distance away from sediment flushing site), whereas on the Rakaia River the fishing is more widespread along the length of the river.

6.3.5 Fish screening and bypass

Like the Rakaia River, the Waimakariri River is an important rearing area and passageway for a number of fish species moving to and from the sea at most times of the year (Eldon and Kelly 1985). Therefore, the intakes of the CPWE scheme would have to be adequately screened to keep fish out of the races. Screen types and mesh sizes and approach velocities, as well as fish bypass and bywash requirements, would be similar to those already discussed for the Rakaia River.

6.3.6 Riparian Vegetation

The vegetation on the Waimakariri River bed at the proposed intake sites tends to be exotic, comprising broom, gorse and willows. This vegetation is assessed as having an low value. The presence and operation of the proposed intake structures on the Waimakariri River is assessed as having a low potential to affect vegetation values. In addition, similar to the Rakaia River (Lincoln Environmental, 2001), the effect of the reduced downstream quantity of water expected to have a low potential to affect vegetation values.

6.3.7 Periphyton and Benthic Communities

The periphyton community of the Waimakariri River is similar in character to that of the Rakaia River.

A study of seepage zones of the Waimakariri River (Biggs and Close 1989) revealed that a huge biomass of periphyton occurred during May-June, with the potential for further growth under reduced flows at other times of the year. Water velocities would not be lowered appreciably nor is the dilution of enriched groundwater inflows likely to be lessened and periphytic growth enhanced.

A take of up to 40 m^3/s is likely to result in enhanced periphyton biomass and decreased benthic invertebrate abundance. This would arise primarily because of the proportionately greater dewatering of productive seepage channels than of the various braids with surface flows. It is envisioned that the physical habitat favourable to benthic invertebrates and periphyton in major and minor braids in the Waimakariri River would not be seriously affected by the CPWE take. This indicates that the ecological balance within the river would be maintained.

6.3.8 Fish

The Waimakariri River is an intensely braided river downstream of the RL235 contour and is probably most pronounced about 18 km from the mouth. A characteristic of braided rivers is that as flows increase the proportion of deep and fast water increases, but the proportion of slow and shallow water increases only slowly (Mosley 1982). As a result, since most New Zealand native fish and juvenile salmonids prefer slow and shallow water, the amount of physical habitat available for them increases only slightly as flows increase.

As mentioned previously, changes in water depths and velocities with flow (range 41-85 m^3/s) were just recently investigated in detail in a 3-km reach of the braided Waimakariri River at Crossbank (Duncan 2001). An analysis of the results showed that weighted useable area (WUA) for juvenile salmon and trout increased only slightly with flow, which is consistent with that of results of such studies conducted in braided reaches of the Rakaia (Glova and Duncan 1985) and Rangitata (Duncan and Hicks 2001) Rivers.

In essence, the available habitat for juvenile salmonids would not be expected to change appreciably with a 40 m^3/s take for the CPWE scheme. The effects are likely to be similar for other fish species in the Waimakariri River as was reported by Glova and Duncan (1985) for the Rakaia River.

There are frequent freshes in the Waimakariri River, except in some autumns and most winters. As a result, the periods of constant flows would not be overly extensive and the river would experience sufficient variation in flow to flush fine sediments and remove nuisance algal accumulations.

6.3.9 Effects of takes on fish passage

Like in the Rakaia River, a high proportion of the fish fauna in the Waimakariri River is diadromous, with species moving to and from the sea at most times of the year, with the estuary being an important transitional zone between the river and the sea.

The native diadromous fishes generally migrate upstream in the spring and downstream during autumn to early winter. In contrast, chinook salmon migrate upstream in late summer to autumn and downstream in the spring. Brown trout move down to the estuary, and possibly to the sea, in spring to feed, and back upstream in late autumn to spawn.

Ten of the diadromous species known to occur in the lower Waimakariri River migrate upstream as juveniles, while four species migrate upstream as adults. Those that migrate upstream as juveniles include eels, galaxiids, bullies and torrentfish, all are small fish (usually ranging from 20-60 mm long) with relatively weak swimming abilities. Those that migrate upstream as adults include lampreys, smelts, and chinook salmon, with the latter often remaining for some time in the lower river before migrating upstream to spawn.

The takes for the CPWE scheme would not be expected to affect passage of any of the native fishes present in the Waimakariri River. However, passage of adult salmon and possibly that of large adult trout, may be affected in extensively braided sections, as occurs in the vicinity of McLeans Island. Although there would be no abstractions when river flows fall below 41 m^3/s, the results of radio-tracking studies (Glova and Docherty 1986; Glova et al. 1988; Glova and Washbourne 1990) have shown that salmon migration is affected by low flows, which may be further exacerbated by abstraction for the CPWE scheme. The radio-tracking studies were undertaken during a time of sustained low flows, in the order of 30 m^3/s from mid March to mid May, with the exception of a small fresh early in April. At flows of 41 m^3/s or above, passage would have been easier through some of the critically braided areas, and therefore the Central Plains take would not have affected such a situation.

Migration of salmon is triggered by changes in conditions such as flow, turbidity and temperature, often as a result of a fresh. Eventually salmon waiting to migrate for spawning will attempt to run upstream irrespective of conditions, due to their advanced state of maturation.

There will be some increases in flows that may have stimulated upstream movement of salmon that will not be accompanied by changes in turbidity and temperature. If the abstraction by Central plains removes all of this increased flow, then the stimulus for salmon migration will be removed. However, other freshes that result in increased turbidity may stimulate migration without the flow increasing due to the abstraction by Central Plains. Therefore in these circumstances the stimulus for salmon migration remains. This is a difficult area to predict with certainty and further assessment of flow depths for passage, and water clarity will be required.

It can be concluded that the impacts on the salmon spawning runs is unlikely to have an impact on the long term sustainability of the salmon population.

Take of 6 m^3/s at the Kowai River confluence

Pumping 6 m^3/s of water from the Waimakariri River within the immediate upstream vicinity of the Kowai River confluence is not expected to have any significant effects on flows downstream to Bleak House Corner. This reach is not extensively braided, and water losses to groundwater and subsurface flow are not major (North Canterbury Catchment Board and Regional Water Board 1986). As a result, this take would be expected to have minimal effects on instream habitats.

Return feed of 6 m^3/s at RL 235 from Wairiri Reservoir

Water from the Wairiri Reservoir will have originated from the Rakaia catchment and may influence the migrations of some fish species in the Waimakariri River. In particular, the precise homing ability of chinook salmon relies on water odours specific to their stream of origin and may be affected by the mixing of water from these two rivers. Although 6 m^3/s would constitute a relatively minor proportion of the total flow during periods of moderate to high river flows, during low flows of say <50 m^3/s in summer, a return feed of 6 m^3/s at RL 235 would constitute a significant proportion of the flow. This has the potential of increasing the incidence of occurrence of Rakaia River salmon entering the Waimakariri River during their return migration from the sea. Currently, the greatest contribution of salmon straying from other catchments into the Waimakariri River comes from the Rakaia River, although salmon from the Hurunui to Waitaki Rivers have been recorded (NIWA, unpublished data). In all likelihood, salmon straying of Rakaia River origin would increase to some extent with flow augmentation to the Waimakariri River from the CPWE scheme.

Also, a return feed of 6 m^3/s would be of sufficient discharge to attract fish (including salmon) moving up the Waimakariri River to seek entry into the irrigation race. To prevent this from happening, an appropriately designed fish velocity barrier would have to be installed at the outlet to the Waimakariri River.

6.3.10 Birdlife

The same basic water depth and velocity information that was used to determine the relationship between habitat and flow for fish, was used to examine habitat for wrybill plover in the Waimakariri River Glove et.al.,). The WUA declined markedly with flow over the range of flows examined. However, much of the reduction in WUA for feeding of Wrybills occurred between 41 m^3/s and 63 m^3/s, with minor reductions thereafter. Reductions in flow as a result of takes for the CPWE scheme are likely to benefit feeding habitat for wrybills.

6.3.11 Recreation

Fishing

The fishability of the lower Waimakariri River for salmon is likely to be affected by takes for the CPWE scheme. The flows naturally are quite low in late summer, which would be further exacerbated by takes for irrigation. Moreover, the effective 37 m^3/s minimum flow set for the river by PWRRP is considerably lower than the flow required for salmon fishing in a large braided river.

Studies conducted on the Rakaia and Rangitata Rivers in the 1980s have indicated that quite specific flows and water clarity are required for salmon fishing. On the Rakaia, salmon catches by experienced anglers were greatest when flows at Fighting Hill ranged from 160-180 m^3/s and water clarity ranged from 0.5 to 1 m, following a fresh or flood (Glova 1987; 1988). For the Rangitata River, flows suitable for salmon fishing were lower and differed with season, with a mean discharge of 128 m^3/s providing ideal water clarity for fishing during October-December, and 66 m^3/s during March-April (Davis et al. 1987). The differences between rivers may be attributable to the steeper gradients and faster water velocities of the Rangitata, which maintain higher turbidity levels at lower flows. The flows required for salmon fishing in both these rivers are considerably greater than the 37 m^3/s minimum flow that would exist under the PWRRP.

The flows suitable for salmon fishing in the lower Waimakariri River have not been documented. However, the effects of flows on salmon fishing for this river are not likely to differ appreciably from those of the Rakaia River, as these rivers are reasonably similar morphologically and hydraulically from the gorge to the sea. Given that the mean flow of the Waimakariri River (125m^3/sec) is approximately 58% of that of the Rakaia (214 m^3/s), and given that flows <100 m^3/s are unsuitable range for fishing on the Rakaia (Glova 1988), it seems reasonable to surmise that flows <60 m^3/s would be unsuitable for salmon fishing on the Waimakariri River. Existing takes from the river would have priority rights over takes for the CPWE scheme. However, it can be expected that with the CPWE scheme, the available time that flows and water clarity would be suitable for salmon fishing would be less, particularly in dry years.

The change in the fishable days per year for the Waimakariri was evaluated for the proposed diversion scheme. The definition of a preferred fishable day was when the river discharge was between 93 and 105 m^3/s. The flows were prorated from the fishable days definition for the Rakaia, 160-180 m^3/s, using the mean flows for each river. The analysis of the Waimakariri indicated a range showing an increase of 7 days to a decrease of 19 days per year. The average number of preferred fishable days between November 1 through April 30 decreased from 11 to 7 days per year. Moreover, angler concentration near the mouth may increase, because fishing there is likely to be less affected by reduced flows than the braided sections upstream.

Other recreational Users

Other recreational activities that have the potential to be effected include boating, swimming, walking and other passive activities.

It is only the water-based activities that are likely to be directly affected by any water take from the river. The land-based activities will be affected by the availability of riverbed area and confinement of the river channels.

Not all these water users utilise the entire length of the river. Swimming and jet boating will only use the deeper areas whereas other users can use more shallow areas. Reducing the mainstream rifle depth is possibly of greater concern to activities that require longer lengths of river, such as the jet boaters and canoeists /kayakers, who require a minimum water depth of 0.2 and 0.1 m respectively.

The intake structures will have appropriate signage warning recreational users of there location. In addition, the inlets to the box culvert intakes will be have steel grills placed over them.

The effect of the reduced downstream quantity of water is assessed as having a low potential to affect both instream and land-based recreation.

6.3.12 Amenity and Landscape

The Waimakariri River below the gorge has distinctively different landscape values than the reaches above the gorge. The landscape values of the river at the proposed intake sites are assessed as being very important. The presence and operation of the proposed intake structures on the Waimakariri River is assessed as having a low potential to affect landscape values. There is already an existing small intake at the proposed site. In addition the effect of the reduced downstream quantity of water is assessed as having a low potential to affect landscape. The effects of the reduction at the time where the most water is being taken from the river will be to lead to longer times of lower flows, i.e., reducing the variability of the flow.

The reduced flow will not result in any appreciable difference visually in the river.

6.3.13 Waimakariri River Recharge of Christchurch Aquifers

Gaugings of the Waimakariri River have been conducted at various times since the 1950's. Since 1995 ECan have concentrated on measuring the flow at the gorge and the Old Highway Bridge sites (where there is a better chance of measuring the entire flow) along with all takes and return flows. Figure 6-6 shows the computed net flow loss vs flow at the gorge - the estimated measurement error in the computed loss term is shown in the error bars.

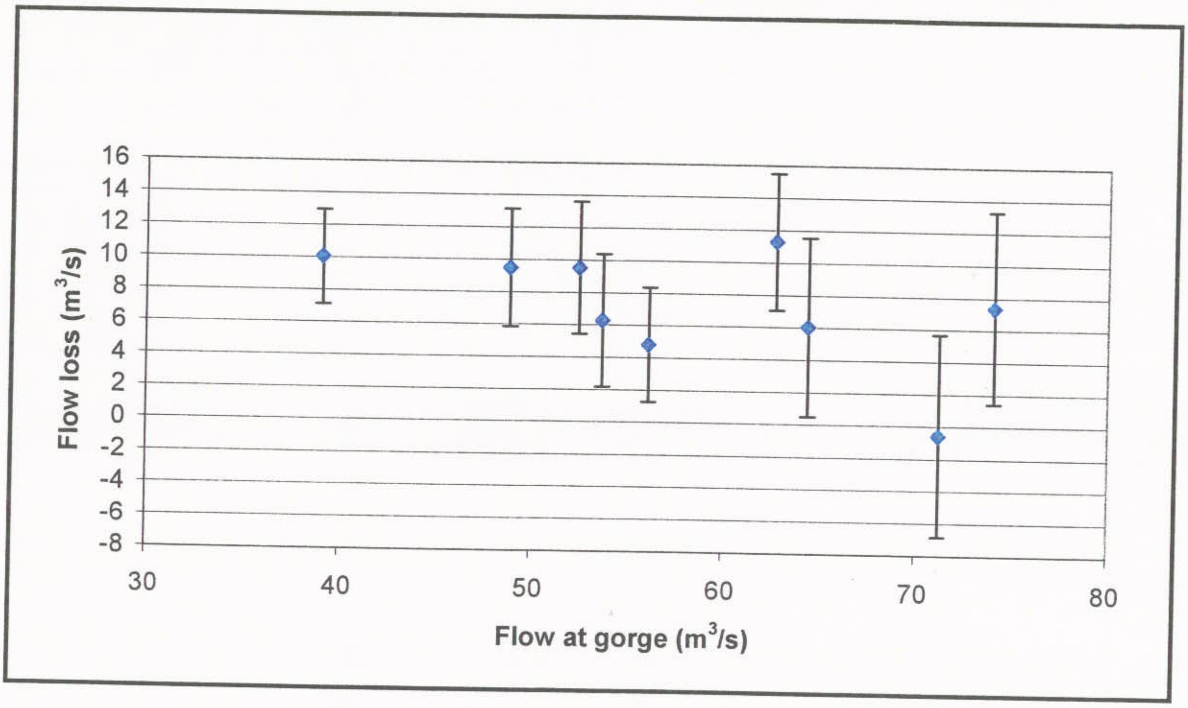

Figure 6-6: Flow loss from Waimakariri River vs. River Flow

The data suggest that there is no significant correlation between flow loss and discharge. However, there is a slight trend of decreasing flow loss with increasing flow at the gorge. This seems anomalous for two reasons:

- An increase in river level, associated with greater flows, should result in a steeper groundwater gradient and hence a greater velocity of flow to groundwater.
- The increase in saturated area at times of higher flow should increase the flow loss/recharge area.

Given the data presented in Figure 6-6 it is evident that the recharge to groundwater does not vary significantly at different flow rates but that flow loss generally varies between –1 and 12 cumecs. Therefore the take from the Waimakariri River is not expected to affect the recharge to the Christchurch/West Melton aquifer system.

The Institute of Geological and Nuclear Sciences (IGNS) in conjunction with Environment Canterbury are in the later phases of a three-year study to define the relationship between groundwater recharge and river flows in the Waimakariri River.

6.4 Wairiri Reservoir Water Quality

At the time of undertaking the assessment of the water quality in the proposed Wairiri Reservoir the scheme being considered consisted of a 250 million m^3 reservoir with a pumping rate of 19 m^3/s into the Reservoir. This was determined on the basis of the 1972 to 2000 period of records. Subsequent to this the period of record was extended to cover the period 1967 to 2001. This resulted in the required storage volume changing to 290 million m^3 and pumping rate reduced to 17.2 m^3/s. Time constraints prevented the assessment of water quality issues being reassessed so the results reported here are based on the original design. While this is not ideal it is considered by NIWA that the changes will not change the conclusions reached. It is also noted that while the base case has a reservoir capacity of 290 million m^3 this is not necessarily the optimum solution and the final option selected may be closer to 250 million m^3 than 290 million m^3.

The results reported in this section are therefore based on a 250 million m^3 reservoir with a pumping rate of 19 m^3/s into the Reservoir.

The proposed 250 million m^3 Wairiri Reservoir would be approximately 6 km long, with maximum and mean depths of about 40 and 25 m, respectively. It would flood approximately 10 km^2 of the valley.

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 limnological characteristics of the reservoir such as mixing (wind and seasonal factors), light penetration, and biological productivity, all of which are affected to some extent by the source of water, richness of the soils being flooded, and operation of the dam.

Water quality issues in the reservoir are assessed on the basis of the reservoir being fed from the Rakaia River as the preferential source of water, followed by the Waimakariri River.

The incoming water to the reservoir would be quite turbid, as water would be extracted from the river primarily during freshes and floods. Extensive fluctuations in water levels of the reservoir are likely to occur due to major variations in river flows and irrigation demands.

Based on the availability of water from flow data for the Rakaia River (1972-2000) and estimated irrigation demand, it is predicted that the reservoir would go completely dry in two out of 28 years, and be drawn down to less than half its volume in six out of 28 years (Fig. 6-7). Mean water volume of the reservoir over the 28-year period would be 195 x 10^6 m^3, 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 (Fig. 6-8). It is estimated that a mean 132 x 10^6 m^3 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.

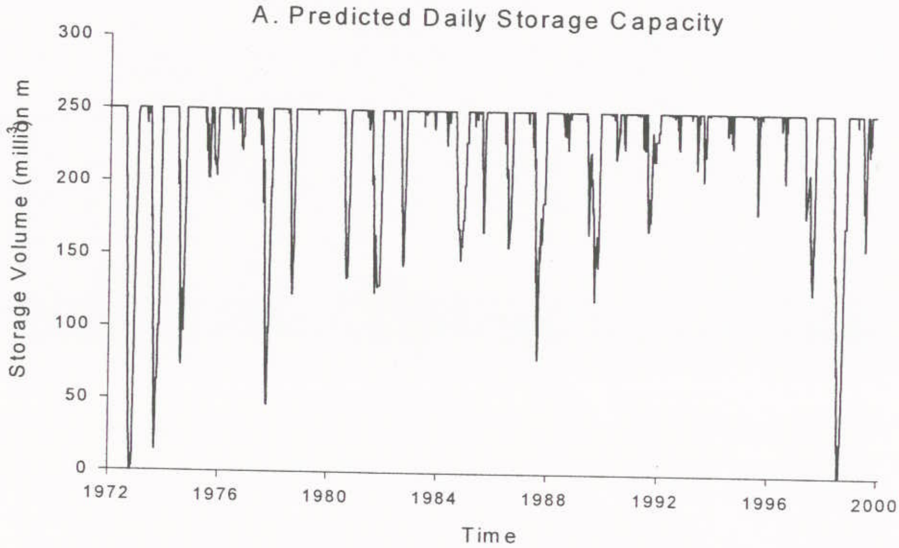

Figure 6-7: Predicted storage volume of the Wairiri Reservoir

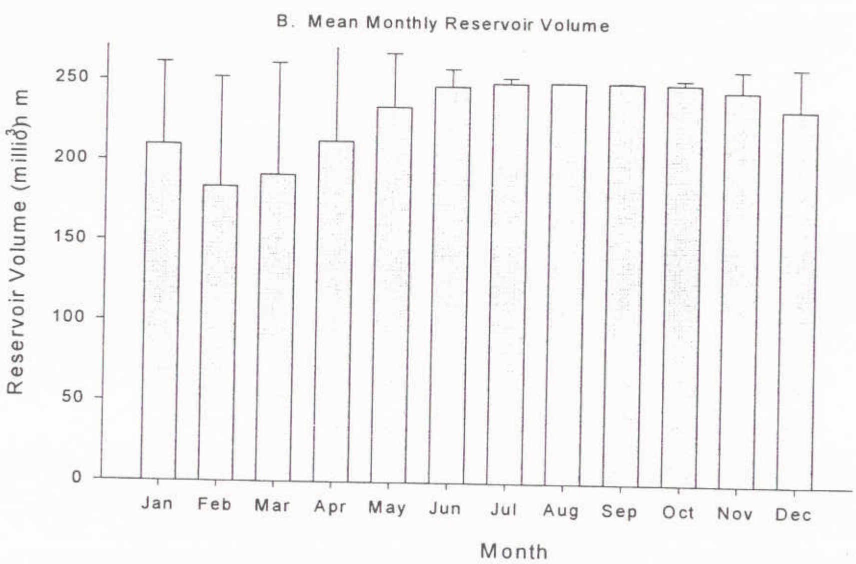

Figure 6-8 Predicted mean monthly water volumes of the Wairiri Reservoir

6.4.1 Eutrophication and weed growth

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

Water quality problems in reservoirs are frequently associated with high phytoplankton production (Hoare et al. 1987). However, in the Wairiri Reservoir, it is likely that phytoplankton production would be largely limited by light penetration. The Rakaia and Waimakariri Rivers have high concentrations of suspended sediments during freshes and floods, and it is expected that 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 reservoir would probably be between those of Lake Pukaki (1.56 m^{-1}) and Lake Tekapo (0.63 m^{-1}). This would correspond to a euphotic zone (depth to 1% irradiance) of 3-8 m in depth. Also, relatively high production of humic acids and algal blooms are likely during the initial years (1-3) of operation of the reservoir due to decomposition of inundated soils and vegetation. This is likely to result in a yellowish-brown (humic acids) to greenish (phytoplankton) colouration, which would further diminish light penetration.

The relatively short water residence time in the reservoir would tend to reduce eutrophication problems because of the mass export of nutrients from decomposition of vegetation and soils. Over time, nutrient levels in the reservoir should approach those of the source (i.e., the two rivers), which would be relatively low and would not support algal blooms. It is unlikely that large rooted aquatic plants (including water weeds) 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.

6.4.2 Stratification and anoxia

The occurrence of hypolimnetic oxygen-depression in newly formed reservoirs has been 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 (Jolly and Irwin 1975).

Hypolimnetic oxygen-depression is expected to occur in the Wairriri Reservoir during the first few years of operation, particularly during summer. The duration of thermal stratification would be the main determinant of the extent of oxygen depression. Winds are the main force in mixing between surface and bottom layers in lakes (Green et al. 1987).

For New Zealand lakes, Davies-Colley (1988) modelled the depth at which the thermocline (greatest change in temperature in water column) would occur by the equation,

$$Z_e = 7.69 \times A^{0.232}$$

where E_z = epilimnetic depth and A = lake area.

For the Wairiri Reservoir, it is calculated that the thermocline would occur at about 11 and 13 m from the surface when the reservoir is half full and full, respectively. Some basic limnological features of the reservoir at different levels of fullness are summarised in Table 6-1.

Table 6-1: Some predicted limnological features of the Wairiri Reservoir; (Z_e) and fetch at varying reservoir capacities.

Parameter	Reservoir fullness		
	100%	50%	25%
Volume (106m3)	250	125	64
Area (km2)	10	6	3
Mean depth (m)	25	21	21
Thermocline (m)	13	11	10
Fetch (km)	6.2	4.5	3.6

The long and narrow shape of the reservoir would encourage mixing by winds, particularly south-westerlies and north-easterlies travelling along the length of the reservoir. It is anticipated that the reservoir would be somewhat sheltered from the prevailing north-westerlies in summer and prone to becoming stratified, with possible anoxia in the hypolimnetic zone during the initial years of operation.

Oxygen depletion is unfavourable for most aquatic organisms, and can have significant effects on water chemistry, particularly at the sediment-water interface. The extent of such effects would largely depend on the duration of summer stratification. However, given the relatively short residence time of water in the reservoir, these conditions would be expected to improve with time (say after five years of operation). In the Opuha Reservoir in South Canterbury, such conditions persisted from January-April 1999, one year after the reservoir was filled (Meredith 1999), and still occur to some extent when stratified in summer (B. Spigel, NIWA, pers. comm.). It should be noted that in the Auckland water supply reservoirs, deoxygenation of the bottom waters is a dual occurrence that has persisted for more than 20 years.

6.4.3 Sediment-related issues

Reservoir inflows

In our calculations, sediment loading for the reservoir was based on restrictions imposed by the NWCO, the PWRRP and existing water allocations. Assuming there would be no reservoir storage restrictions, from flow data for the Rakaia River at Fighting Hill (1990-2000)and the Waimakariri River, it was estimated that the average annual volume of water available for pumping from the Rakaia River would be 81.4 x 10^6 m^3, and from the Waimakariri River the available volume would be 616 x 10^6 m^3. This assumes that extractions by gravity flow would take precedence over the pumped option, as the latter would be more costly. In practice, the amount of water that could be pumped would be restricted by the available storage in the reservoir. The long-term average storage that would be available monthly was estimated from reservoir capacity (290 x 10^6 m^3) and mean monthly storage volumes. Taking into account the available storage, it was estimated that the pumped water volume would be reduced to 173 x 10^6 m^3/yr. It was assumed that inflows to the reservoir from tributaries in the Wairiri Valley would be negligible, and so the average total inflow was taken as 173 x 10^6 m^3/yr.

Suspended sediment inflows

The efficiency of the sediment trap is likely 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 Wairiri 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. Thus, Wairiri inflows would carry a suspended sediment load consisting of all of the silt-clay fractions and 16% of the sand fraction present in River water. The intake structure would be adequately designed to divert bed-load.

From suspended sediment samples collected during a flood (2,844 m^3/s) in the Rakaia River at the SH1 bridge in 1995, the suspended sediment concentration was 5,627 mg/l. The sand, silt and clay fractions of those samples based on particle-size analysis are tabulated in Table 6-2. In the absence of similar data for the Waimakariri River, the same particle-size distribution has been assumed. The mass fractions for the Wairiri Reservoir inflows show the proportion of the sand, silt and clay fractions, after allowing for 84% removal of the sand fraction within the intake structure. As there are no major tributaries to the rivers between the Gorges and SH1 bridge, the particle size distribution of suspended sediments at the intakes of the CPWE scheme would be expected to be similar to that found at the SH1 bridge.

Table 6-2: Sand, silt and clay mass fractions for the Rakaia River at SH1 bridge (sampled) and for Wairiri Reservoir inflows (estimated).

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

Calculations of suspended sediment inflows were based on integrating the product of the suspended sediment concentration and flow over time using synthetic time-series of the following:

- **15-minute pumped flows**. These were derived from Rakaia and Waimakariri River flow data, as well as applying the abstraction rules proposed for the CPWE scheme, existing water allocations, and reservoir storage restrictions.
- **15-minute suspended sediment concentrations**. These were estimated by applying a sediment rating to the Rakaia flows and factoring down the sediment concentrations to allow for the reduced sand fraction (assumed 84% trapping efficiency at the intake).

It is estimated that, on average, the suspended sediment load into the Wairiri Reservoir would be 25,400 t/year. The amount of sand trapped at the Rakaia intake is expected to be between 1,680 and 1,840 t/year (assuming a trap efficiency of 84-92% of the sand fraction) and the Waimakariri intake is expected to trap between 5,880 and 6,440 t/year.

6.4.4 Deposition

Based on estimates of trap efficiency of the Wairiri Reservoir (Table 6-3), almost all incoming sediment would be trapped within the reservoir. The reason for this is the high capacity/inflow ratio (or residence time), as a result of the need for adequate storage when inflows would be reduced in drier than average years.. Trap efficiencies for the Wairiri Reservoir have been derived from Brune's 1953 empirical relationship (Vanoni 1977).

Table 6-3: Trap efficiency for Wairiri Reservoir

	Reservoir (% full)		
	100%	**50%**	**25%**
Capacity/inflow ratio (or Residence time (years))	3.18	1.59	0.85
Trap efficiency (%)	100	100	95

Incoming sediment would be deposited mainly in shallow areas of the reservoir, which would be subject to periodic wetting and drying. Applying the Lara-Pemberton method (Morris and Fan 1997), it was estimated that the specific weight of the depositing clay-silt-sand fraction (refer to Table 6-2) in the reservoir would amount to 0.88 t m^{-3}.

The suspended sediment yield of 25,400 t/year equates to a deposition volume of approximately 28,900 m^3/year, which is considered to be negligible (~0.01% of reservoir capacity).

6.4.5 Water clarity

The estimated settling time for 1-µm clay particles over an average depth of 25 m in the reservoir is 174 days. This is not considered long compared with the residence time for water of 3.18 years when the reservoir is full. The settling time for clay particles would be even less than the residence time for water in the reservoir when 25% full (see Table 6-3). Thus, fine particles would have ample time to settle and water in the deeper areas of the reservoir would be expected to clear somewhat with time.

Re-suspension of sediments by wind waves may be a potential problem in the reservoir. Based on wind records from 1978-1993, the predominant winds at the Hororata recording station are north-westerlies and north-easterlies, although the strongest winds (>20 m/s) come from the north-west. Although moderately strong winds (10-20m/s) tend to come from the north, west and south-west. The proposed reservoir would be fairly sheltered from north-westerly winds, and the fetch in this direction would not be great. This precludes significant wind-wave effects from north-westerlies. Because of the reservoir orientation, the greatest exposure would be to north-easterly and south-westerly winds.

Table 6-4 shows a NARFET analysis (Smith 1991) of wave base-depth based on a 20 m/s wind for one hour at 10 m above the ground for winds from the south-west, west and north-east (variable fetch in Table), for the reservoir at 100% and 25% full (low dam option). 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-depth for a 20 m/s wind with the reservoir 100% and 25% full is estimated to be 10.3 m and 9.2 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. Some re-suspension of deposited sediments in littoral areas by winds is expected.

Table 6-4: Wave base-depth for a 20 m/s wind for 1 hour duration at 10 m above the ground for the Wairiri Reservoir.

Fetch (km)	Wave base-depth (m)	Location
Reservoir 100% Full		
5.8	10.6	Southern shore at dam
5.7	10.4	Southern shore at dam
3.7	8.6	Southern shore at Turnbull's Road
Reservoir 25% Full		
3.3	7.7	Southern shore at dam
3.3	7.3	Southern shore at dam
2.7	6.9	Southern shore at Turnbull's Road

6.4.6 Water quality for recreation

Boating

The reservoir would be of sufficient area (maximum 10 km^2) and depth (mean depth 25 m) for recreational boating. The water level fluctuations of the Wairiri-Pumped option may present some difficulties with the launching of boats.

It is likely that during initial stages of operation of the scheme, poor water quality and algal blooms would detract from the aesthetic and recreational values of the reservoir with either option.

Contact recreation

Water quality during the first few years of operation of the reservoir would be expected to be marginally suitable for contact recreation (e.g., swimming, wind surfing, jet skiing). However, with the relatively short residence time of water in the reservoir it is expected that conditions would improve within a couple of years. The water level fluctuations of the Wairiri-Pumped option may result in exposure of mudflats, and necessitate the need to provide access sites for recreationists.

Fishing

Owing to the relatively turbid conditions in the reservoir with the Wairiri-Pumped option, conditions would not be ideal for development of a sports fishery, although quite substantial fish populations do exist in turbid lakes (e.g., Lakes Ruataniwha and Pukaki; James and Graynoth 2001).

However, anoxic conditions are likely to occur in the bottom water during thermally stratified periods which would adversely affect fish populations. This is most likely during the establishment phase as organic material decomposes. Moreover, the occasional drying-out of the reservoir would make it an unattractive site in which to establish a fishery on a long-term basis. Stocking the reservoir with trout is not recommended, but should further study indicate that water quality would be favourable for fish, then an assessment of stocking the reservoir with trout should be conducted. It is expected that various native fishes (eels, bullies, galaxiids), mainly from drainages within the Wairiri Valley, would to some extent, self-populate the reservoir.

Water quality for irrigation

It is recommended that water for irrigation be drawn from the epilimnion (surface layer) of the reservoir, as this will 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 irrigation and livestock watering 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 (Burns and Powling 1981; Prepas et al. 1997). The possibility of anoxia may decline as water quality improves, although in the case of the Auckland water supply reservoirs, annual anoxia has been a feature for over 20 years.

6.5 Canterbury mudfish populations

A fish survey was conducted in streams of the Wairiri Valley and Glendore catchment to the west on 4 May 2001, during a period of low flows. The fish populations were sampled with a DC backpack electroshocker. All fish were released at the site of capture, with the exception of a few galaxiids that were retained for species verification in the laboratory.

6.5.1 Within Wairiri Valley drainages

Two Canterbury mudfish *Neochanna burrowsius*, measuring 65 and 120 mm in body length, were identified in swampy habitat of a small tributary of the upper Wairiri Stream at Hardys Road crossing (Fig. 6-9). No other fish were taken at this site.

The Wairiri Stream was sampled at both the Turnbulls Road crossing (Fig. 6-10) and the Wairiri Road crossing near the Selwyn River at Glentunnel. No Canterbury mudfish were found at either of these sites, but upland bullies *Gobiomorphus breviceps* of all sizes were common and a few longfinned eels *Anguilla dieffenbachii* (size range 300-800 mm long) were present.

6.5.2 Other sites

The Canterbury mudfish was found at two sites in the Glendore catchment. Two mudfish, 79 and 80 mm in length, were captured in a small pool under the bridge at the road crossing of upper Glendore Stream. Also, two mudfish, 70 and 94 mm long, were found in swampy habitat at the road crossing of Steventon Stream (Fig. 6-11), a small tributary of the middle reach of Glendore Stream. Cattle were present nearby and the habitat was badly trampled along the margins. No other fish were taken at either of these sites.

Figure 6-9: Swampy habitat of small tributary of upper Wairiri catchment (at Hardys Road crossing), where Canterbury mudfish were found.

Various sizes of the common river galaxias *Galaxias vulgaris* and upland bully were common at other sites sampled along the length of Glendore Stream, with an example of the habitat in the middle reaches of the stream shown in Figure 6-11. Also present at these sites were a few large longfinned eels, some 700-800 mm in length.

6.5.3 Mitigation/habitat creation

The Canterbury mudfish is a rare and endangered species and any impact on populations in the Wairiri Valley would have to be mitigated. As mudfish do not require access to the sea, viable self-sustaining populations can exist in isolated water bodies of sufficient size, with appropriate food and cover.

As the Wairiri Reservoir would inundate existing mudfish habitat in the valley, it would be advisable to capture and transfer these fish to a reserve specifically designed for them, possibly in the Glendore catchment. Such a reserve could be a ponded area 1.5-2.0 m in depth in swampy habitat with a mud/peat bottom and an abundance of marginal vegetation (watercress, flax, raupo and others). Some stocking of the reserve with food organisms such as ostracods, snails, amphipods and oligochaetes may be necessary to expedite their colonisation. As large eels are major predators of mudfish, it is important that eels be excluded from the reserve.

Figure 6-10: Wairiri Stream (looking upstream) at Turnbulls Road crossing.

Figure 6-11: Swampy habitat of Steventon Stream

6.6 Groundwater Impacts from the proposed scheme.

Figure 6-12 shows a schematic cross section through the Canterbury Plains. Existing recharge to the gravel aquifers that form the groundwater system beneath the proposed CPWE area is in part by drainage of rainfall, generally during the winter months. Additional drainage also occurs associated with leakage from the beds of streams and rivers where they cross the plains, including the Selwyn River and its tributaries, and the Rakaia and Waimakariri Rivers.

Drainage seeps downwards and joins the underlying groundwater system. In the upper Central Plains area, the depth to groundwater can be up to 70 metres. Groundwater then generally moves in an eastward direction from beneath the CPWE area towards the coastline between the southern edge of Banks Peninsula and the Rakaia River. Between the coastline and the proposed CPWE area further drainage from rainfall, rivers and irrigation contributes to the groundwater system. In addition the depth to groundwater steadily reduces eastwards across the plains until at some locations groundwater intercepts the ground surface, forming a series of springs that contribute towards flows in spring fed streams and rivers, including the LII, Harts Creek and Irwell River.

East of the spring zone the gravels of the Canterbury Plains become interbedded with thick beds of silt and clay forming a series of confined gravel aquifers. The results presented in this study relate to the groundwater level in the unconfined gravels in the western part of the study area and the first (or upper-most) confined aquifer in the eastern area.

Therefore, it is important to note that the results presented in this section do not reflect increases that will occur in the shallow groundwater table in areas such as Tai Tapu, Leeston and Southbridge. The results relate to the underlying confined aquifer, generally found in these areas beneath a layer of low permeability silts and clays that is several metres thick. Nonetheless, an increase in groundwater level or pressure in the deeper aquifer may affect drainage or the near surface shallow groundwater system.

Irrigation associated with the proposed scheme will result in additional drainage to the underlying groundwater system. Soil moisture will be maintained at higher levels during the irrigation season and additional drainage will occur either directly from irrigation or due to rainfall incident on the irrigated soils.

Additional drainage will also occur from the headrace canal where it crosses the plains and the irrigation distribution system.

Drainage through the soil horizons has the potential to carry with it chemical constituents into the groundwater system associated with agricultural and other land use practices. Development of the CPWE scheme is likely to result in changes in land use in the area and this may also result in changes in the chemical characteristics of the drainage entering the groundwater system. This may impact on down gradient groundwater users and the receiving environments such as spring fed streams.

In summary, the anticipated issues associated with additional drainage and changes in land use practice addressed in this report are:

- Increases in groundwater levels or pressures in the unconfined and confined groundwater systems in this section of the Canterbury Plains due to additional drainage.
- Increased flows to the spring fed streams located along the eastern side of the Plains due to increased pressure.
- Changes in groundwater quality.

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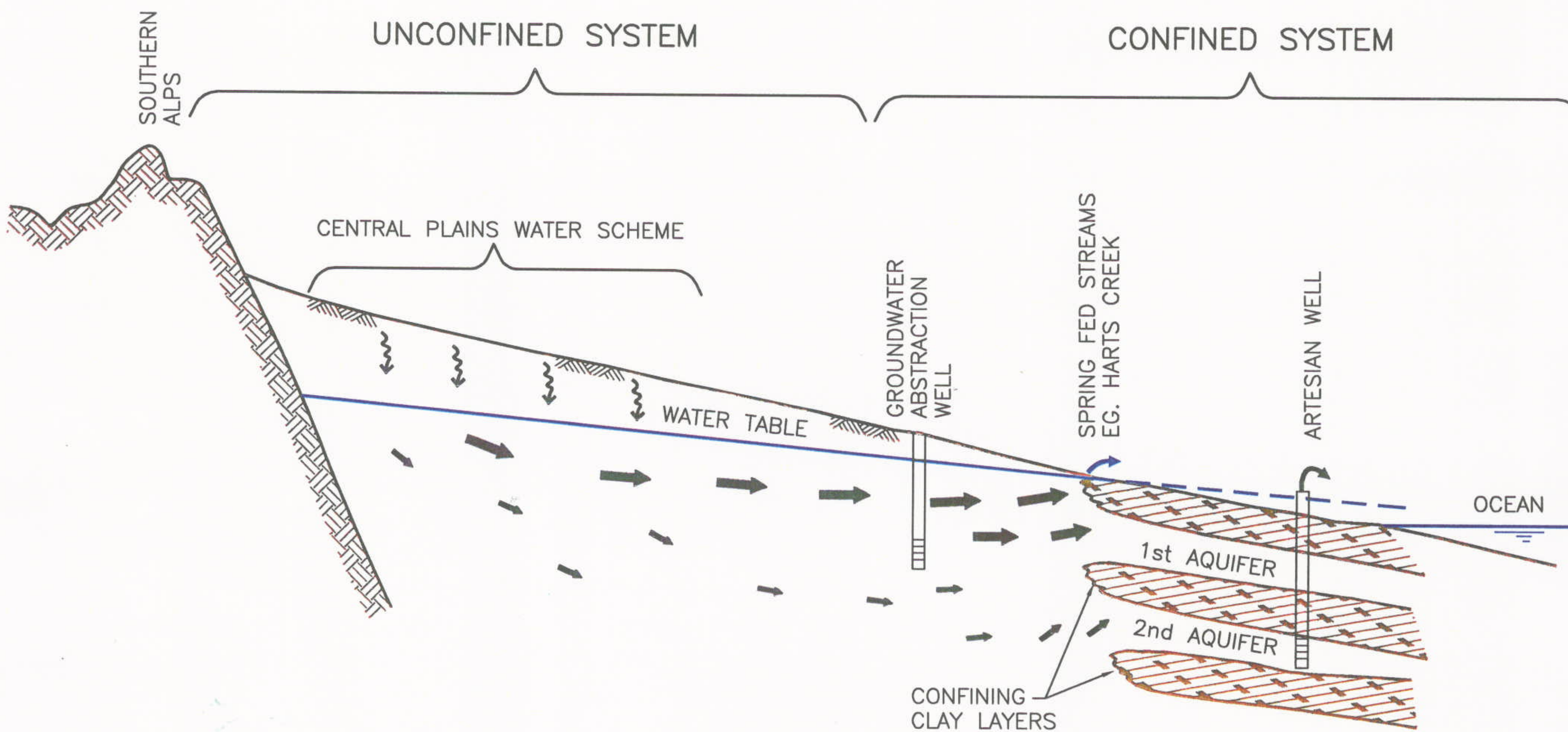

SCHEMATIC GROUNDWATER SYSTEM – CANTERBURY PLAINS

URS
Woodward Clyde
Dames & Moore

Figure No. **FIGURE 6-12**

6.6.1 Methodology

The proposed CPWE scheme covers a significant section of the Canterbury Plains. The underlying groundwater system is relatively complex. Therefore, the potential effects associated with the CPWE scheme have been simulated using a numerical computer model. This task was sub-contracted by URS to the Institute of Geological and Nuclear Sciences (GNS). GNS, in association with Environment Canterbury (ECan), are currently in the process of completing the development of a MODFLOW groundwater flow numerical model of the Canterbury Plains between the Ashley and Ashburton rivers. This model encompasses the CPWE area and incorporates the key inputs and outputs to the groundwater system, including drainage, rivers and stream seepage, abstraction wells and springs, see Figure 6-13.

The model has been calibrated by GNS to observed groundwater fluctuations during the period July 1994 to June 1999. The potential effects associated with the CPWE scheme have then been assessed by varying the drainage data for the area shown on Figure 6-13 to allow for the additional drainage that will occur with the implementation of irrigation over 84,000 hectares of the upper plains.

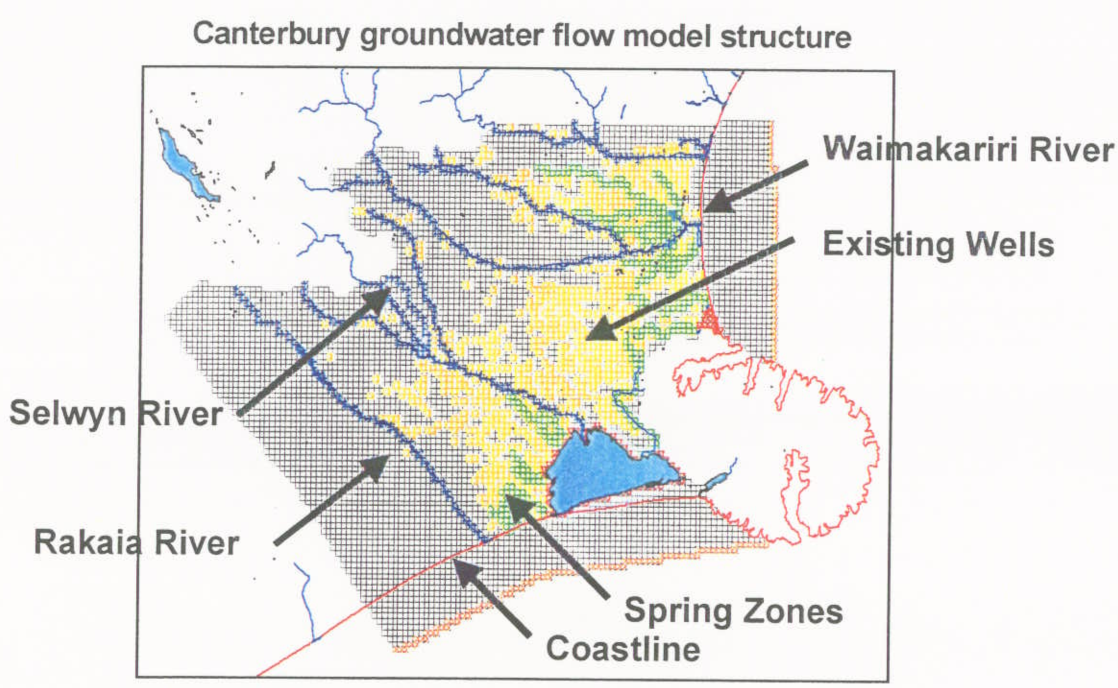

Figure 6-13: Model of Irrigated Area

Therefore, the results are the anticipated effects on the groundwater system during the period July 1994 to June 1999 as if the CPWE irrigation scheme had been in full operation.

Anticipated drainage data for the CPWE area modal, following implementation of the proposed scheme has been provided by Lincoln Environmental. The data has been calculated as daily drainage rates for the period 1994 to 1999 and allows for variations across the CPWE area in rainfall, evapotransporation, soil types and potential land use.

Additional drainage has been allowed for from the headrace canal and the irrigation distribution system. Long term drainage rates or losses from the headrace have been calculated to be 1 m^3/s and from the distribution system 3.4 m^3/s during the 6 month period of operation. The headrace is expected to be continuously full. Estimates of drainage are based on the calculations and assumptions presented in Section 2 of this report.

The results of the model have been presented in terms of the anticipated difference between the irrigated and non-irrigated model simulations. Therefore, the results are the anticipated incremental change that would have occurred in the groundwater system during the 1994 to 1999 period if the CPWE scheme had been in operation.

The results should be considered very much as a "worst case" scenario. They do not take into account any additional abstraction wells that have been installed since 1999 or any wells that are likely to be installed in the future prior to, or following, scheme implementation. These additional wells may abstract a significant portion of the additional drainage simulated in this model and mitigate, or reduce, the predicted effects. It also should be noted that the impacts from the land that may be irrigated by this future groundwater take are not included in this assessment.

Furthermore, it should also be noted that the model has been formulated to simulate effects as if the CPWE scheme has been in operation for an unlimited period of time prior to the commencement of the simulated period in 1994. Therefore, these are maximum predicted results for the simulated period. In reality, a "ramping-up" period would be anticipated following the implementation of the scheme before these scale of effects are observed, possibly in the order of 10 to 20 years.

It should be noted that in the first few years of scheme operation, drainage from the headrace and distribution system is likely to be at the levels predicted, and these will decrease over time as the headrace and canals seal from the fine silt and clay carried in the water from the rivers.

6.6.2 Results

Groundwater Levels

Figure 6-14 is an example of the output generated by the MODFLOW model and presents simulated groundwater level differences (head difference) between CPWE-irrigated and non-irrigated scenarios for February 1997. The largest predicted increase in groundwater levels is approximately 18m in the south eastern corner of the CPWE area where the soils are lightest and where groundwater recharge is likely to be greatest. This effect reduces towards the coast. Further inland the increased groundwater levels will have little impact. However at the edge of the confined zone increased groundwater levels of about 2 m will have an impact on drainage of periodically wet land with land staying wet for longer periods more frequently. The areas in and around Tai Tapu are not likely to be significantly affected, as the increase in the regional groundwater pressure in the confined aquifers will increase by less than 1m and this will not be translated into a similar increase in the shallow groundwater table that is influence to a greater degree by other surface drainage mechanisms.

Figure 6-15 shows eight locations selected in the model to present effects as time series for the simulated period. The results are shown on Figure 6-16. The results show how the anticipated difference in groundwater levels will vary during the simulated period. Of note is Location 4, which predicts the greatest fluctuation in effects. This location is on the boundary between the confined and unconfined groundwater systems and the simulated fluctuations appear to be associated with the back and forth change between a confined and unconfined system. The results also show that with increasing distance from the CPWE area the magnitude of the effect becomes smaller and the seasonal fluctuations are more subdued.

Spring Flows

Figure 6-18 present the difference in simulated spring flow time series between CPW-irrigated and non-irrigated scenarios for the simulated period. Figure 6-17 shows the locations of the springs in the model. Simulated differences in spring flows generally vary from zero to several hundred litres/second with the largest changes occurring in late summer, autumn and early winter.

Larger changes in flow are predicted for the Irwell River, with "spikes" in flow difference of up to 5,000 litres/second. This reflects the relatively close proximity of the Irwell springs to the CPWE area (see Figure 6-13.

Flow Direction

Predictions of flow paths from the eastern boundary of the irrigated area indicate that groundwater from underneath this area is travelling (broadly) in the direction of Lake Ellesmere. This is consistent with studies completed by others for the Canterbury Plains. It also shows that while the pressure effects may extend into Christchurch City, none of the actual water from beneath the scheme will flow into the city zone.

Water Balance

The MODFLOW model predicts that under the existing non–irrigated situation the average soil drainage rate from the CPWE area to the groundwater system for the simulated period was 5.1 m^3/s. This is simulated to mix beneath the CPWE area with an average seepage rate of 7.2 m^3/s from other sources such as river bed seepage. With irrigation and associated seepage from the canal system, the anticipated average soil drainage rate is simulated to be 12.1 m^3/s, an incremental increase of 5.2 m^3/s due to CPWE irrigation, while the contribution from rivers and streams reduces slightly to 5.5 m^3/s. This reduction reflects the general rise in groundwater levels beneath the CPWE area and the reduction in groundwater gradients between the rivers such as the Selwyn and the groundwater system.

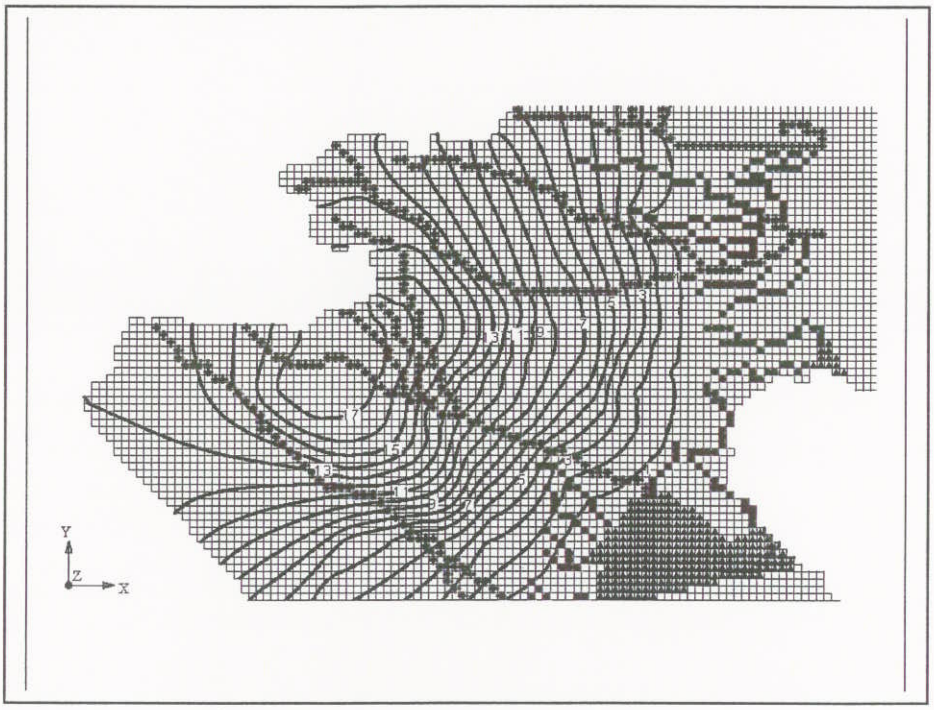

Figure 6-14: Head Difference February 1997

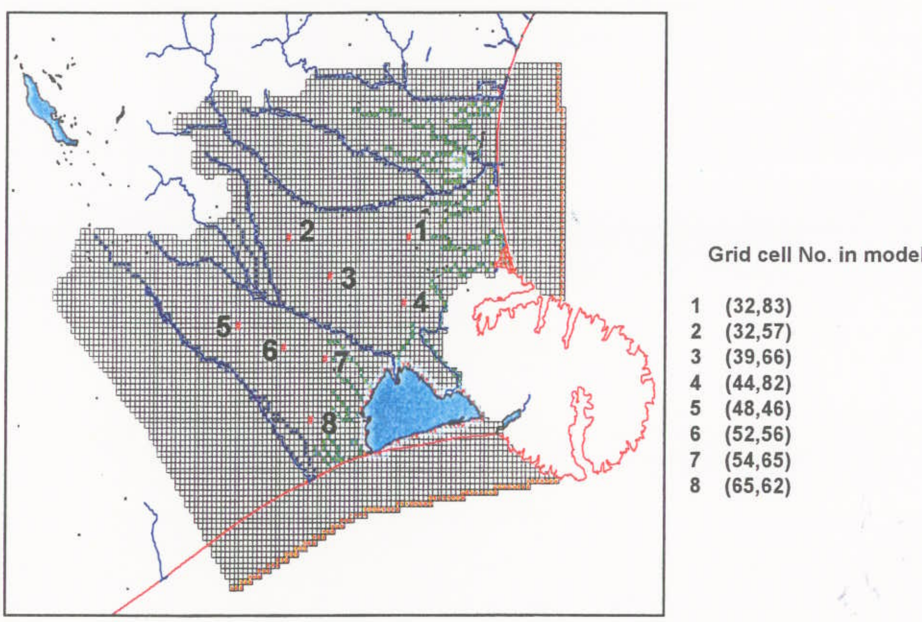

Figure 6-15: Location of Cells Chosen for Time Series Head Difference Calculation

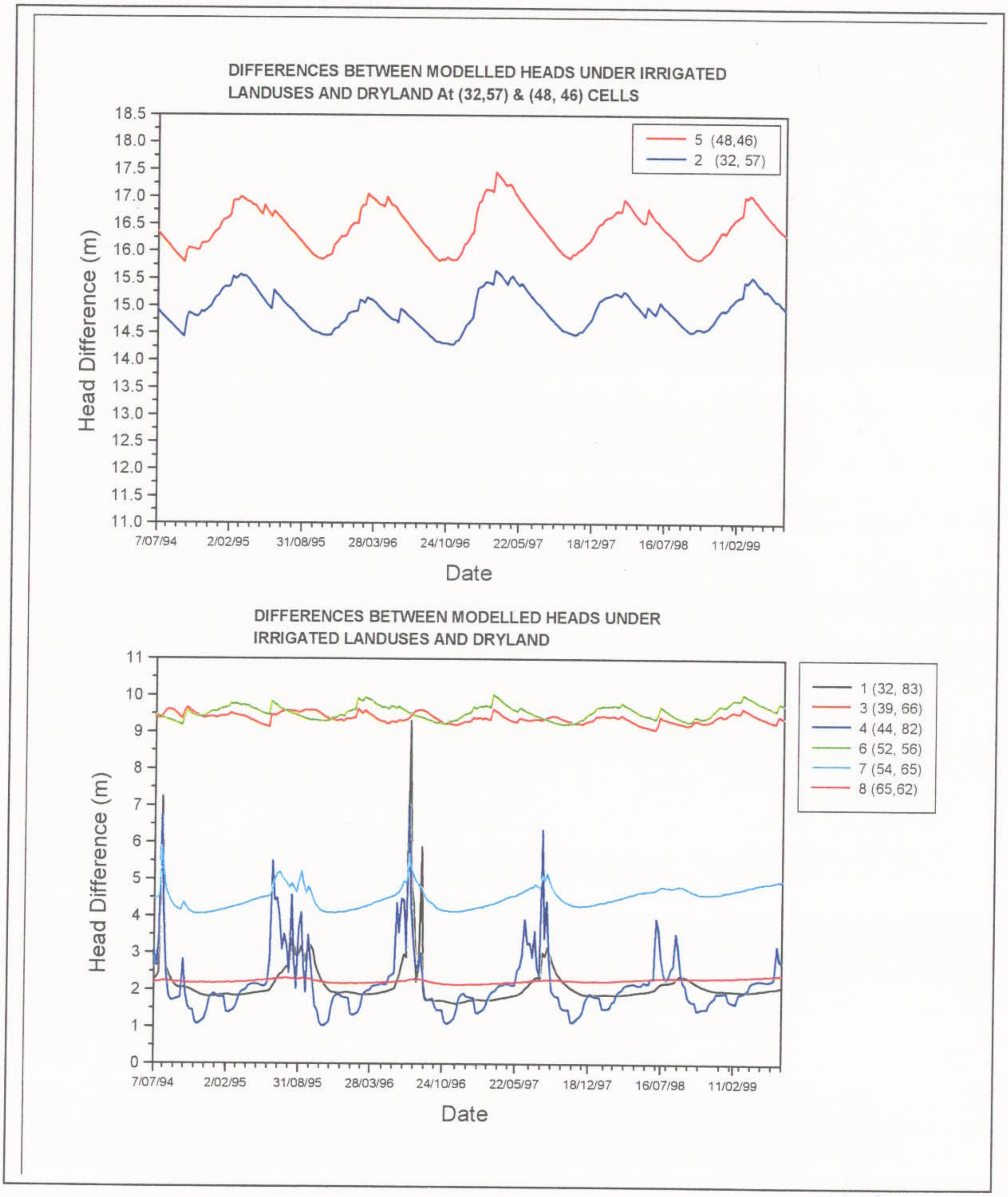

Figure 6-16: Modeled Time series of Head Difference at Selected Locations

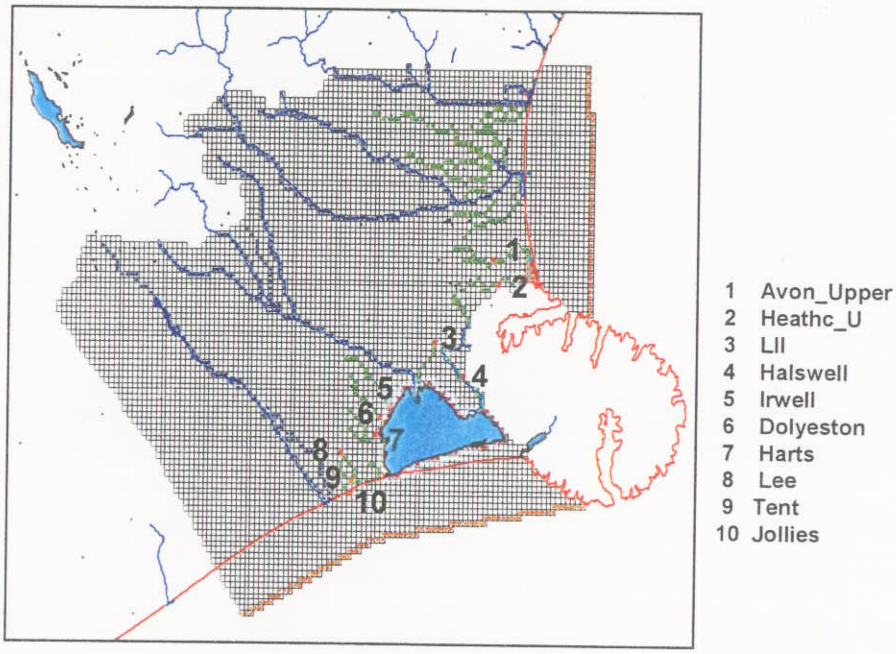

Figure 6-17: Location of Cells Chosen for Time Series Flow Difference Calculation

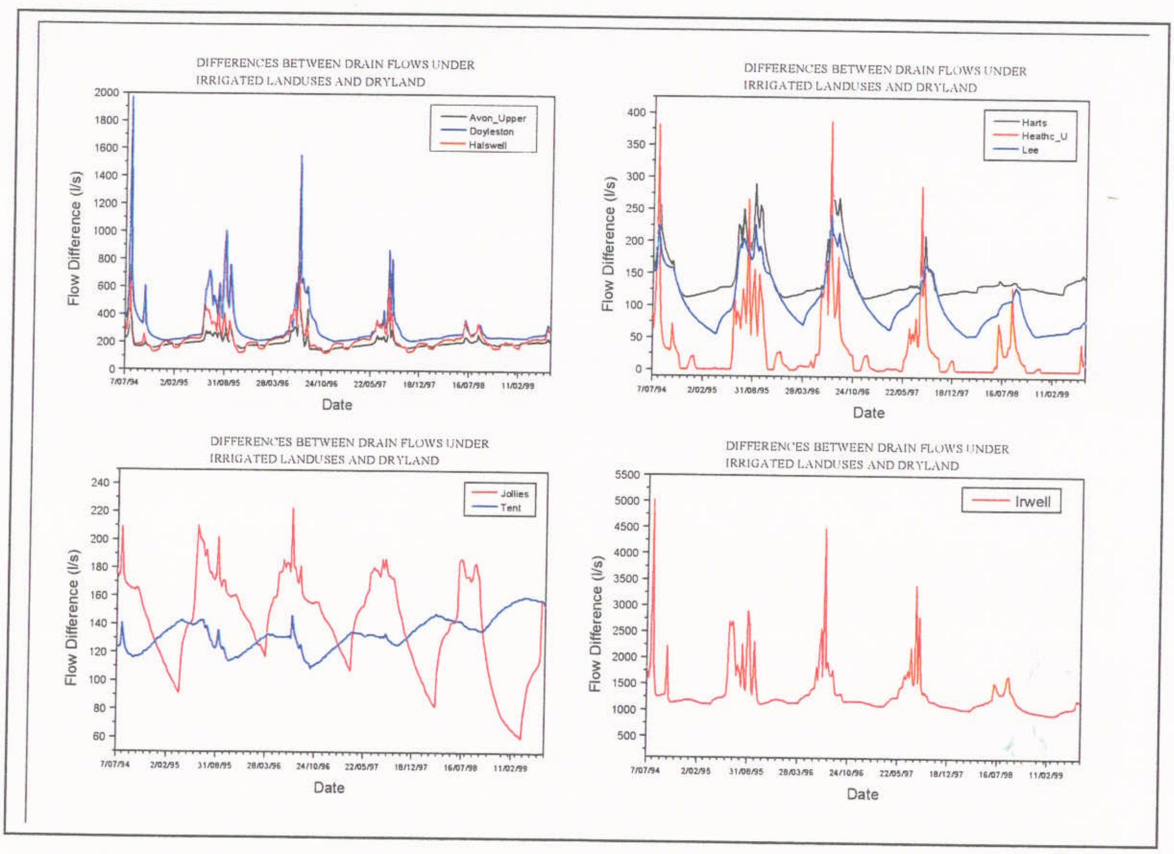

Figure 6-18: Modelled Time series of Flow Difference at Selected Locations

Lake Ellesmere inputs and outlet opening frequency.

Horrell (1992) used a water balance model to simulate fluctuations in Lake Ellesmere water level. This model successfully predicted the number of openings over the period January 1970 – March 1991 however, the timing of the openings differed. This model has also been used to predict the outlet opening frequency with an increase in inflows of 5.3 cumecs. The result suggests an average increase from 3.6 openings per year to 5.4 openings per year.

6.6.3 Water Quality Issues

Existing Groundwater Quality : Nitrate-N

Dryland sheep farming is the predominant existing land use in the CPWE area. A range of studies have been completed and published by others both in New Zealand and overseas on the typical contribution of nitrates to the groundwater system via seepage through the spoil profile. Results indicate that the concentration of nitrate-N in drainage from sheep farms typically varies from 6 to 8 g/m^3. For the existing groundwater system, it has been assumed that this is the average concentration of nitrate-N in all seepage through the soil profile in the CPWE area. If it is also assumed that seepage from rivers does not contribute any nitrate-N to the groundwater system, complete mixing of the two contributing sources should reflect existing groundwater quality. Based on the seepage rates provided in Section 6.7 of this report, this mass balance model indicates that groundwater beneath the CPWE area should have an existing nitrate-N concentration in the order of 2.5 to 3.5 g/m^3.

Figure 6-19 shows typical current concentrations of nitrate-N in groundwater measured across the CPWE area. This is based on groundwater samples collected and analysed by Ecan's groundwater quality section. The results are generally similar to those anticipated from the above mixing model. However, some local variation does occur and is expected given the relative complexity of the groundwater system compared to the mixing model described above. Issues such as localised nitrate-N contributions from sources such as septic tanks affect individual results. In addition, lower concentrations tend to occur close to the rivers where locally a greater proportion of groundwater seepage is sourced from the rivers. Nonetheless, the above mixing model gives a reasonable prediction of average nitrate-N concentrations across, and immediately downgradient of the CPWE area.

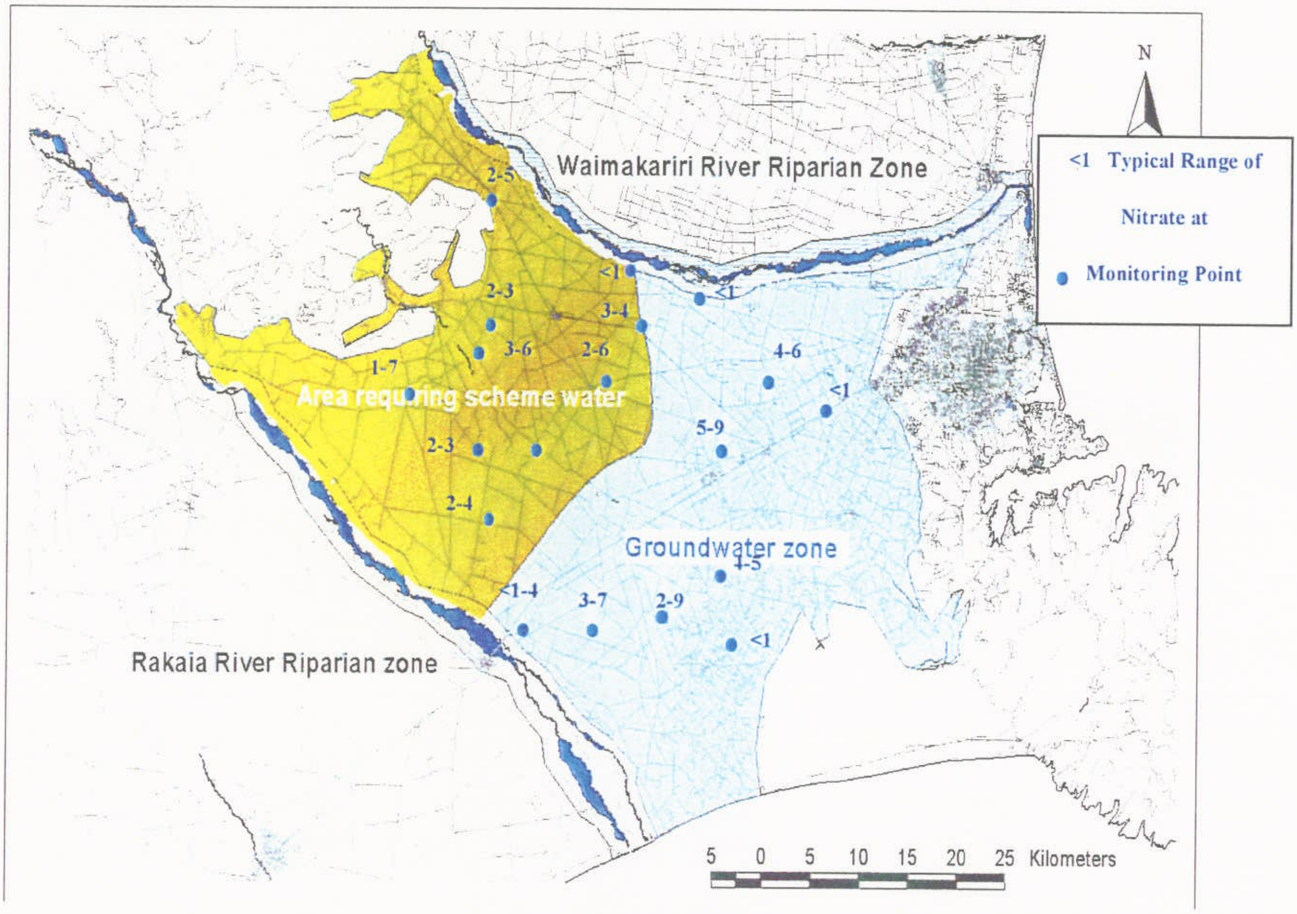

Figure 6-19: Typical Ranges of Existing Nitrate-N Concentrations

Predicted Changes to Groundwater Quality : Nitrate-N

The most likely change in land use is the conversion of sheep farms to intensive pastural farming (i.e., dairy farms). Numerous studies have been undertaken in New Zealand investigating the concentration of nitrate-N in drainage from pasture and they consistently find that the average concentration of nitrate-N in seepage to groundwater is in the order of 12 g/m^3, regardless of the rate at which drainage occurs. Arable farming may also occur over parts of the study area. Studies indicate that the average contribution of nitrate-N from arable farms is 50kg/ha/year (an average of about 13 g/m^3 for the simulated drainage rate from the CPWE scheme).

If it is assumed that 75 % of the CPWE area will convert to intensive pastural farming and 25% will be mixed cropping, the predicted average nitrate-N concentration in the groundwater system is 7.0 g/m^3, an average incremental increase of between 3.5 and 4.5 g/m^3.

For comparison purposes, the Drinking Water Standards for New Zealand 2000 has a maximum nitrate-N concentration of 11.3 g/m^3. The results indicate that groundwater is generally likely to remain below this standard.

However, as discussed above, agricultural land use is not the only contributor of nitrate-N to the groundwater system and in localised areas the combination of this increase with nitrate-N from other sources may be sufficient to increase nitrate-N concentrations above the drinking water standards. Furthermore, similar increases can be anticipated to occur in groundwater contributions to spring fed streams and rivers. Potential effects associated with these discharges will also need investigation further.

Other Groundwater Quality Issues

Other potential parameters of concern with respect to groundwater quality include pathogens (faecal coliforms and other organisms), phosphate and agricultural herbicides and pesticides. While groundwater issues associated with these parameters will require more detailed study, the following provides a summary of the likely issues.

- Animals excrete faecal pathogens and these may pass through the soil profile and enter the groundwater system. Faecal coliforms are a representative indicator of these pathogens and they have a relatively short half life (approximately 1.6 days). Therefore the travel distance for faecal coliforms in the groundwater system is generally relatively short (typically a few hundred metres) and this is likely to be a local rather than a regional issue. Less data is available on other pathogens such as viruses and further research is required in this area. It should be noted that viruses do not generally transfer from animals to humans.
- Within the Central Plains area, the predominant method of sewage treatment and disposal is by septic tanks. The Regional Plan requires that where septic tanks are within 30 m of the highest groundwater level, then the discharge is required to meet standards for pathogen control. This requires a treatment system that either includes a disinfection stage or a specifically designed ground filtration system. In areas where the groundwater is in excess of 30 m, the discharge via a soakage trench is permitted. There will be areas that are currently greater than 30 m from the groundwater table that will become closer than 30 m, thereby coming under the control of a differing rule in the Regional Plan. It is worthy of note that the Draft Natural Resources Regional Plan 2001 seeks to preserve this distinction between sites closer and further away than 30m from the highest groundwater level. The increased groundwater levels will result in higher treatment and disposal costs for those affected by this change.
- Phosphate is typically very immobile in soils and little passes through the soil profile into the groundwater system in solution. The more typical pathway is for phosphate to enter the surface water system is via animals excreting directly into waterways, or soil particles on which phosphate is attached being washed into waterways.
- Land use changes are likely to have associated changes in farming practices, including the use of agricultural sprays. This issue will require further investigation and study.

6.6.4 Potential Mitigation Options

Groundwater Levels and Pressures

Various interested parties may perceive many of the potential effects discussed in this document as being positive. Other effects may be perceived by some as being positive and by others as being negative. For example, increased groundwater levels and pressures near the coastline will benefit spring flows and groundwater abstractors but may impact upon farming practices in these areas. Therefore, any mitigation measures must be mindful of these types of competing issues.

It should also be noted that the effects reported here have been assessed for the period 1994 to 1999. Since 1999 additional abstraction wells have been installed and consented. Furthermore, it is almost certain that additional wells will continue to be installed in the area downgradient of the CPWE area over the next few years in response to changing farming practices in areas where groundwater is a viable abstraction resource.

Abstraction from these additional wells will offset at least some of the effects discussed in this report. The number and location of new wells (since 1999) and potential wells will need to be investigated in more detail as part of a future groundwater study.

It is worth noting that Ecan estimate the current average abstraction rate from irrigation wells in the Central Plain area varies from 3 to 5 m^3/s.

In addition to wells that either have been or are likely to be installed in the future, abstraction wells may also be used to specifically offset anticipated effects. Various methods are available, including:

- Promoting further groundwater use in specific areas to offset localised effects.
- Installation of a coordinated series of wells to mitigate effects across larger areas. Abstracted groundwater could either be utilised or diverted to surface water bodies.

Other available mitigation measures include improvement of drainage in selected areas.

It is very difficult to be specific about the scale of effects in specific locations, in terms of the magnitude of the effect and the time until such effect becomes noticeable. It will therefore necessary to address some of these effects at a later stage, once they have been identified and appropriate action can be taken.

Groundwater Quality

Mitigation options for groundwater quality issues are likely to focus on improving farming practice and wastewater disposal in the CPWE area. The possibility of an environmental "warrant of fitness" for farms involved in the CPWE scheme has been suggested. This may include measures such as:

- Ensuring that stock are prevented from entering open water ways. It is a perceived issue that dairy cows are responsible for the degradation of riparian areas, disturbance of stream beds (through crossing) and direct discharges of waste into them. This need not be the case, an in the CPWE situation as the majority of the land to be developed under irrigation is away from existing surface water ways, this is thought to be a minor and controllable issue.

- utilising best practice with respect to farm management of nitrate loadings. This will require control over the application of nitrogenous fertilisers, dairy shed effluent and some stock grazing and pasture renewal practices; and
- ensuring septic tanks and dairy effluent ponds are managed so that discharges to groundwater are minimised.

6.6.5 Further Studies

The following key issues have been identified as those requiring further study as part of any future Resource Consent Application:

- Assessment of effects on groundwater levels and spring flows allowing for predicted future increases in groundwater use.
- Identification of areas where changes in groundwater levels and pressures are perceived as having a significant negative effect and identification of mitigation options.
- Further studies on land use changes and potential groundwater quality issues.
- Further studies on the potential effects on the receiving environment (including spring fed streams) of changes in groundwater quality.
- Specific studies on the effects of both increased flows and water quality changes on Lake Ellesmere (Te Waihora).

6.7 Environmental Enhancement Opportunities

As part of this feasibility study, enhancement opportunities were given a high priority as the CPWE has objectives relating to:

- Executing *"feasibility studies into the viability and practicality of water enhancement schemes in the Central Plains area"*, and that this shall include consideration of
- *"benefits to downstream users including aquifer recharge, stream flow enhancement and provision of a source for potable water supply"*.

The previous sections highlighted that the operation of the scheme will result in some beneficial environmental effects, including the enhancement of spring flows and aquifer pressures. However, as discussed, not all parties may view these effects as beneficial and some associated effects such as increased nitrate concentrations in groundwater are negative.

The following sections provide a discussion on a number of enhancement opportunities that have been considered with the specific objective of enhancement. It should be noted that some of these opportunities have similar outcomes to the effects described previously.

6.7.1 Options for Christchurch Groundwater Enhancement

The CCC are predicting significant population growth in parts of the city, particularly the south and south-western margins, and need to look at ways to meet this predicted demand while minimising environmental impacts. While the existing CCC reticulation network could arguably cope with the projected demand in terms of groundwater availability within the City, stream depletive impacts, particularly on the headwaters of the Heathcote River, could be a limiting factor. To address this issue, selected options for enhancement of the City's potable water supplies using a portion of the CPWE water were discussed in a URS report "Options for Water Supply to Christchurch City Council (2001). This approach assumes that 1 m^3/s could be made available from the CPWE scheme for 365 days/yr, and it could be made available within the next 5 – 10 year time frame.

The options for any potential use of water are very diverse. For reporting purposes the options have been grouped into three main categories in this report:

- Potable water supplies,
- Groundwater augmentation, and
- Enhancement of spring fed stream flows.

Potable Water Supply for Christchurch City

Three principal options to enhance the City's potable water supplies directly from the scheme have been considered in this report:

- Treated distribution;
- The use of injection wells, and
- Enhance irrigation supplies to reduce dependence on groundwater near spring-fed streams.

Treated Distribution

This concept would take approximately 1 m^3/s of surface water from the scheme, via canals and/or pipelines, and use it to directly supplement drinking water supplies. The water would need to be treated and provided for distribution to the CCC reticulated system.

The benefits of treated distribution are significant since additional well fields would not be necessary for the CCC to accommodate the increasing demand for water.

Injection Wells

This concept would use injection wells to pump surface water derived from CPWE directly into a confined aquifer system. Surface water would need to be distributed to the well network and pumped under pressure into wells screened in the confined system. The well screen acts as the discharge zone into the aquifer, essentially working in reverse to a normal extraction well. As currently envisaged, this scheme would operate continuously to inject 1 m^3/s from CPWE.

Enhance Irrigation Supplies

Conceptually, additional surface water could be directed to augment irrigation in selected rural areas (the unconfined aquifer west of the City). Irrigation augmentation by surface water would reduce the need for irrigation water derived from abstraction wells. It is anticipated that this would have a downstream 'follow-on' effect in terms of improving spring-fed stream flows.

Surface water could be directed to either existing or upgraded stockwater systems. Additional means of conveyance may be required where systems are not available for use/upgrade. Transfer of water use from well abstraction(s) to surface water at individual farms may require significant equipment and piping changes.

Surface water would only be supplied during the growing season, therefore it is anticipated that the demand from CPWE would be 1 m^3/s for approximately 3 months in summer (Dec-Feb) . It is anticipated that no distribution would be carried out during the winter months.

Augmentation of Christchurch West Melton Aquifers

Groundwater augmentation is the process whereby surface water is induced to percolate through the soil and subsurface to recharge groundwater levels. While this process occurs naturally (e.g. infiltration from rainfall, or seepage through the base of rivers such as the Waimakariri), this can be achieved by design (also commonly referred to as 'artificial recharge').

There is the potential for CPWE scheme water to be directly used to recharge the unconfined aquifers in specific areas (e.g., West Melton-Yaldhurst) to raise groundwater levels in the vicinity of Christchurch City. The elevation of groundwater levels in certain areas can improve the performance of marginal wells.

In addition, the increase in groundwater levels in some areas, has the potential to have downstream benefits in terms of increasing the groundwater contribution to spring-fed stream flows e.g. the Avon River. Groundwater augmentation can also provide an additional 'buffer' against seawater intrusion near the coast.

Two options were considered in the URS 2001 report, spreading basins near Halkett and addition to the existing water race systems and soak holes. Each of these options tended to increase groundwater levels beneath the western fringe of the City by approximately 1m.

Enhancement of Christchurch Spring-fed Streams

The existing spring-fed streams within Christchurch City (the rivers Avon, Heathcote, Styx and Halswell, and all associated tributaries) are susceptible to depletive effects associated with groundwater pumping. As a result, stream flows can be lower than desired for ecological and amenity values. The introduction of water to the headwaters of some of these streams is likely to produce measurable benefits.

While a 'direct connection' to these streams (pipes and/or canals feeding 'new' water directly into the headwaters of these streams) is the most obvious method, the URS 2001 report also considers 'indirect' methods of improving stream flows (such as groundwater augmentation and/or creating new wetland environments immediately upgradient of the headwaters of these streams). In summary the two main options are:

- Direct Connection - Link the stockwater races to the channels of the streams, and
- Indirect Connection (Upgradient Infiltration) - Increase flows in the races to encourage more infiltration at the termination points (soak holes). A variation on this option is to 'convert; the soak holes to wetland environments.

Costs for CCC Enhancement Options

The cost associated with CPWE providing the water to the CCC has been estimated based on the cost of supply for the base case scheme scenario. However the scheme has been designed to meet a maximum demand of 0.6 l/s/ha. To achieve this a design peak flow of 60 m^3/s is provided. A simple basis to assign a cost to this augmentation water is to assume that a demand of 1 m^3/s would be the equivalent of supplying 1,670 ha. While this assumption is not strictly correct, it does provides a useful indication of the cost of supply of water from the scheme. This will under charge for the water as farmers will not be receiving the full allocation of 0.6 l/s/ha continuously, as would be required for these enhancement options. Based on this, the costs of CPWE supplying the CCC with 1 m^3/s is estimated to be:

- A capital contribution of $2,458,000
- An annual charge of $341,000

At this preliminary stage, accurate cost estimation of each option is difficult until the CCC have defined their need for water (how much, where, timing etc). The CCC may also have competing demands (or uses) of the water and therefore some prioritisation may be required. In addition, the CCC may need to consider water enhancement options using water from 'suppliers' other than CPWE e.g., increasing the take associated with the existing water races.

It should be noted that many of the beneficial effects from the CPWE scheme are likely to occur as by-products of the scheme operation without the need to purchase water directly from the scheme.

Enhancement of Christchurch Aquifers by base scheme

The preceding sections considered the taking of water from the CPWE scheme for specific use to enhance the water resources in and around Christchurch City. It should be noted from the hydrogeological investigations that there will be an effect on the groundwater in the Christchurch-West Melton area. This will result in elevated groundwater levels and increased spring flows, all of which are seen as positive benefits for Christchurch. This has been reported on in the groundwater impacts section of this report and is not repeated here. It should be noted that the benefits from the main scheme irrigation activities will be at no direct cost to the City Council.

Due to the groundwater flow direction from the CPWE towards Lake Ellesmere, there is unlikely to be any increase in nitrate-nitrogen of significance in the drinking water supplies of the City.

Summary of Christchurch City Groundwater Enhancement Options

The City Council has been furnished with information (URS 2001) that will allow it to assess CPWE options as it considers all options for long term water supply. Because CPWE water is expensive compared to water obtained directly from other sources, such as the Waimakariri River, the options discussed in the URS report are unlikely to be favoured. The City Council has decided to continue to source its drinking water from untreated groundwater if possible and to that end is prepared to apply for resource consents to source confined aquifers outside its district e.g. to the south west.

Modelling is predicting a significant improvement in low flows in the Avon and Heathcote Rivers at no cost to City Council and without additional nutrient loading. Under the water sharing regime proposed by Ecan's NRRP (2001) this will in fact increase the water that can be pumped from the aquifers below Christchurch.

6.7.2 Enhancement of Selwyn River Flows

The Selwyn River flows could be augmented in a number of ways. These include:

- Discharge from the Wairiri Reservoir
- Discharge from the headrace canal
- Replacement of riparian takes with scheme water.

Recommended minimum flow for Selwyn River

The Selwyn River invariably goes dry in summer, downstream of Coalgate to below the SH1 bridge. A continuous flow in this reach during the dry season would provide passage and additional rearing habitat for trout and other fish and improve their fisheries.

Habitat surveys were conducted in the Selwyn River at Whitecliffs and Coes Ford during summer low flows (~1m^3/s) in the late 1980s. In the reach between these two locations, there were occasional holding pools suitable for adult trout. From computations by NIWA, it is estimated that a suitable minimum flow for trout in the Selwyn River would be in the vicinity of 2.5 to 4 m^3/s (I Jowett, NIWA, pers. comm.). It is believed that this range would cater for the needs of both juvenile and adult trout, although the upper range would be more appropriate for adult trout. However, the benefits to trout from such increased flows would only accrue if invertebrate food production increased appreciably.

Alternatively, if the emphasis is to create an improved day-time fishery in the Selwyn River, then higher minimum flows of say 6-8 m^3/s may be needed to encourage trout to emerge from day-time cover and become more diurnally active and readily available to anglers. Typically, during low flows, trout remain hidden in cover during the day and become more nocturnally active. The advantages of higher flows in the Selwyn River would have to be adequately addressed against possible disadvantages (e.g., greater bank erosion, less suitable flows for bathers, etc.).

Discharge from the Wairiri Reservoir

It is estimated that a flow of 2-3 m^3/s would be needed to sustain the life-supporting capacities of this river during the dry season. To provide 2-3 m^3/s in the Selwyn River would almost certainly take a considerably greater inflow than 2-3 m^3/s from the CPWE scheme, as the water table is quite low during summer and losses from the river would be substantial. Water from the Wairiri Reservoir would be of suitable quality for augmentation of flows in the Selwyn River, because a considerable proportion of the incoming sediments would settle out in the reservoir.

Augmentation of flows in the Selwyn River might raise the water level and improve water quality conditions slightly in Lake Ellesmere during the dry season when inflows to the lake are naturally low. To assess these possibilities, modelling of inflows to and losses from the lake during the critical period would be required.

As discussed previously, hypolimnetic oxygen-depression and possible anoxia are predicted to occur in the reservoir at least during the first few years of operation. Oxygen depletion is unfavourable for most aquatic organisms and can have significant effects on water chemistry. Any possible build-up of hydrogen sulphide, ammonia, metals and nutrients in the reservoir would largely depend on the extent of stratification during the summer months, and consequently the extent of anoxia. However, there is considerable uncertainty regarding this, and it would be prudent to assume that anoxia would occur in at least the early years of the dam and possibly longer. Water from the reservoir should be not considered available for direct augmentation for at least 5 years.

A major disadvantage of the direct discharge to the Selwyn River arises from the mixing of waters from the Rakaia, Waimakariri and Selwyn rivers. As discussed in the Cultural Impacts section, this offends the traditions and culture of the tangata whenua. Discharge to the river for augmentation would require passing through land prior to entry to the surface water system. Given the high cost associated with providing augmentation water directly to the Selwyn River, it is unlikely that this option would proceed in any event.

Discharge from Headrace Canal

Water taken directly from the Rakaia or Waimakariri Rivers for flow augmentation in the Selwyn River is likely to be unsuitable much of the time because of their much greater sediment concentrations. This is not considered to be a practical nor consentable option.

Replacement of existing takes

Some enhancement of low flows in the Selwyn River would be possible by removing the existing takes from the river. Currently, there are three takes from the river sited upstream of the RL 235 contour that amount to a total of 188 l/s. These takes are for both public water and rural water supplies. However, substituting these takes with water from the CPWE scheme has the drawback that their intakes are sited upstream of RL 235 and water from the main race would have to be pumped, or taken from the reservoir which is water that already has been pumped. Moreover, water quality of the CPWE scheme may be an issue, as the existing Selwyn River takes include provision for public water supply – water from the Selwyn is usually considerably less turbid than water from the Rakaia River.

The current allocation of flow from the Selwyn river above the gauging site at Coes Ford is summarised as follows:

Table 6-5. Consented Takes from Selwyn River

Consented irrigation takes	
Total maximum rate of take	188 ℓ/s
Total maximum volumetric take per week, expressed as an average flow	138 ℓ/s
Consented stock water takes	
Total maximum rate of take	680.2 ℓ/s
Total maximum volumetric take per week, expressed as an average flow	361 ℓ/s
All consented takes from Selwyn above Coes Ford	
Total maximum rate of take	868.2 ℓ/s
Total maximum volumetric take per week, expressed as an average flow	499 ℓ/s

Environment Canterbury investigations of actual irrigation takes show that they are typically about 40% of the maximum consented rate of take. Assuming all irrigation takes are removed from the Selwyn (and supplied with Scheme water), the recovery instream flow is estimated to be 40% × 188 ≅ 75 l/s, compared to recent stream flow records from the Coes Ford site. If stock water was also removed, the recovery would be about 361 + 75 = 436 l/s.

The extent to which this changed would be reflected in the measured flow record is uncertain, because the relationship between stream flow and groundwater gains and losses is unknown. The absence of this relationship precludes an analysis of the effects on the daily stream flow time series of removing takes, in the manner that was undertaken for the Ashburton River.

An indication of the effects of removing the takes can be gained by considering potential changes in flow statistics over the period 1990 to 2000 as contained in Table 6-6. This period was chosen because most of the takes were probably active during this period, and the period is long enough to give meaningful statistics. The lack of date information in the consents database precludes proper ageing of the consents.

Table 6-6. Flow statistics for period 1 Sep 1990 to 30 Jun 2000

	Oct	Nov	Dec	Jan	Feb	Mar
Min	749	483	276	206	152	229
10%	943	732	386	270	210	442
20%	1198	1050	638	758	523	569
30%	1423	1164	819	810	704	634
40%	1708	1250	932	871	755	788
50%	2445	1474	1036	981	821	872

The lowest flows in the Selwyn at Coes Ford clearly occur in February. If it assumed that irrigation demand in February is typically 75 l/s, removal of the irrigation takes would potentially have the effects as described in Table 6-7 following.

Table 6-7 Effects of irrigation flows on Selwyn River at Coes Ford

Flow Condition	Expected Change
Minimum recorded flow	No change, because all irrigation takes must stop when the flow reduces below 600 l/s
10 percentile	No change
20 percentile	No change
30 percentile	11 % increase, to 779 l/s
Median (50 percentile)	9% increase, to 896 l/s

If the stock water take occur at 361 l/s all year round, removing these takes and the irrigation takes from the Selwyn would potentially have a very substantial, positive, effect on the flow at Coes Ford.

Table 6-8 Effects of irrigation and stockwater flows on Selwyn River at Coes Ford

Flow Condition	Expected Change
Minimum recorded flow	240% increase
10 percentile	172 % increase
20 percentile	69% increase
30 percentile	62% increase
Median (50 percentile)	53% increase

Cost of augmentation water for the Selwyn River

In the preceding sections concerning enhancement opportunities for the water resources of Christchurch City, the cost of 1 m^3/s of water was estimated to be:

- A capital contribution of $2,458,000
- An annual charge of $341,000

Therefore to supply 2.5 m^3/s of water from storage the approximate cost would be a capital contribution of $6.15M plus annual charges of $852,000/yr. Similarly to supply water for fishing values, the cost would be in the order of $14.8M in capital plus annual charges of $2.0M/yr. Ultimately it will be a community decision as to the value this represents, compared to other methods for improving flows in the river.

The assessment of the impacts on the groundwater resources has not provided much reliable information in the potential to raise the flows in the lower Selwyn. This is due to the complex nature of the Selwyn River with its water losing and water gaining reaches which are difficult to accurately model using current techniques. It is logical however to expect there to be an increase in base flow of the lower Selwyn, as a consequence of the irrigation of 84,000 ha of the Central Plains.

6.7.3 Enhancement of Tributaries to Selwyn River

Major tributaries of the Selwyn such as the Hawkins, Hororata and Waianiwaniwa usually go dry in the middle reaches during summer. Augmenting their summer flows with water from the scheme is not recommended as each stream would require some 2-3 m^3/s to provide habitat suitable for invertebrates and fish. However as discussed previously, enhancement of flows may occur as a by-product of the scheme operation.

6.7.4 Enhancement of Lowland Streams and Springs

The hydrogeological assessment has provided data on the impacts of the extra drainage that would result from the irrigation of 84,000 ha would have on the lowland streams. Simulated differences in spring flows varied between zero and several hundred litres/second with the largest changes occurring in the late summer to early winter. The Irwell River would be more directly affected due to its closer proximity to the irrigated area, which spike increases of up to 5 m^3/s possible.

It should be noted that these increases in spring flows assume there is no increasing demand on the groundwater resources for irrigation. Given the long term nature of this assessment, this is unlikely to be the case and much of benefit from the increased CWPE drainage would be lost to the lowland streams.

There will be a water quality issue to consider in relation to these recharged flows. The irrigation scheme will result in increased nitrate-nitrogen in the groundwater that feeds these springs. This will require detailed assessment. It is worthy to note however that ANZECC 1992 guidelines suggest that the growth limiting concentrations for phytoplankton of Dissolved Inorganic Nitrogen (DIN) (of which Nitrate will be the major portion) is in the range 0.040 – 0.100 g/m^3, which is considerably less than the drinking water standard of 11.3 g/m^3. Typically the lowland streams have DIN concentrations well in excess of the guideline value for phytoplankton growth, within the range 1 – 2 g/m^3. For this reason, nitrate is not a growth limiting nutrient and control of phytoplankton growth therefore is focussed on phosphorus as this is the growth limiting nutrient. It is therefore likely that increased nitrate levels in the groundwater will not have significant adverse effects on the instream values of the lowland streams. This requires further investigation.

Social Effects

7.1 Introduction

The social assessment of the Central Plains Irrigation proposals has so far been conducted in two phases. In the first phase, in late 2000, a general review was conducted of the social impacts of land use change associated with irrigation. This review was reported in the study of Regional Benefits of Water Enhancement in Canterbury by Butcher Partners (2000).

The next phase of work, the assessment reported here, has its primary focus on the social character of the local communities in and around the potential irrigation area, and impacts on the people who live there.

This social assessment was conducted after the consultation report (URS 2001) was released in August 2001. It is part of the feasibility study investigating Option A - Wairiri Pumped from Headrace - which was the base option recommended for consultation. As the Springfield-Sheffield area was incorporated within Option A, this area has been included in the social assessment.

It should be noted that there has been a parallel process of consultation undertaken by the Steering Committee and its consultants. While some material from this consultation was drawn on for the social assessment, the consultation process was conducted independently of the social assessment.

7.2 Social Profiles

7.2.1 Profiles of the communities

Four geographical areas, based on area units established by Statistics New Zealand, are likely to experience the effects of the proposed irrigation scheme. They are Malvern, Rural Darfield (the Kirwee area unit), Darfield Township and Te Pirita (part of the Ellesmere area unit) and are identified in the map on Figure 7-1.

The Malvern area has several communities including Hororata, Whitecliffs, Glentunnel, Coalgate, Sheffield, and Springfield, which are likely to experience the effects of the proposed irrigation scheme. Malvern had a small increase in population between 1986 and 1996. It had relatively more 'couple only' families and one person households than did Selwyn District as a whole in 1996. Household incomes were generally lower than the district pattern, with 64 % of the area's households reporting that their annual incomes were $50,000 or under (cf. 54 % for Selwyn District). A considerable number of Malvern's residents are employed at workplaces outside the area, reflecting the attraction of settlement there for lifestyle reasons. Malvern's workforce comprised relatively higher proportions of self-employed persons, employers, and unpaid workers in family businesses than did Selwyn District's workforce in 1996. The agriculture, forestry and fishing sector provided more than half the jobs (53 %) for people whose workplace was in the Malvern area. Each of the townships in the Malvern area has only a few business enterprises, although bentonite, a clay with many specialised industrial uses is processed at Coalgate, and there is a sawmill and a salmon processing plant at Hororata. Golf, skiing, ice skating, salmon fishing, and jet boating, are popular recreational activities which attract visitors to the area.

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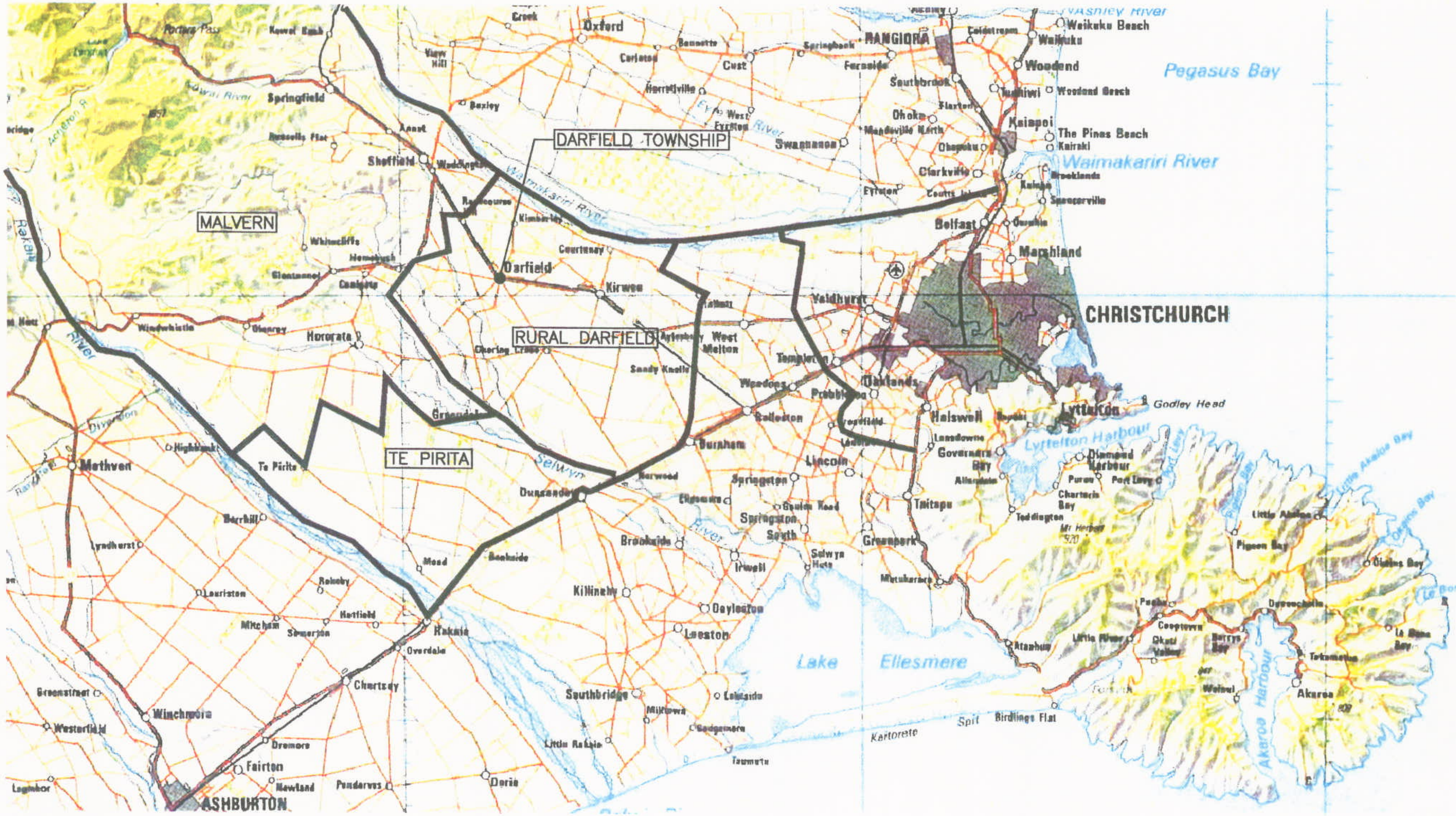

URS
Woodward Clyde
Dames & Moore

Title
GEOGRAPHICAL AREAS FOR COMMUNITY PROFILES

Figure No. **FIGURE 7-1**

Population growth in Rural Darfield was very strong between 1986 and 1996, when the number of residents rose from 1,452 to 2,253 due to rural subdivision. Rural Darfield's population in 1996 was relatively young when compared with the district's population as there was a higher proportion of children (26 % cf. 23 % for Selwyn District) among its residents. Households in Rural Darfield had relatively high annual incomes compared with the district's households. A third of them reported that their incomes were $50,001 or over in 1996 (cf. 30 % for Selwyn District), and only 10 % of them indicated their income was $20,000 or under (cf. 17 % for Selwyn District). There were relatively higher proportions of wage and salary earners, self-employed persons, employers, and unpaid workers in family businesses in Rural Darfield's workforce compared with the district's workforce. The agriculture, forestry and fishing sector provided two-thirds of the jobs (68 %) for people whose workplace was at Rural Darfield in 1996, while a third of workers resident in Rural Darfield were employed in that sector. The township of Kirwee, which acts as a dormitory settlement for people working in Christchurch, is also likely to experience effects from the proposed irrigation scheme. It has several sports clubs and community organisations, and a small number of business firms.

Darfield Township had a moderate increase in population from 1,122 to 1,296 between 1986 and 1996. The age structure of the township's population in 1996 was relatively older than the district's population as there was a higher proportion of elderly people aged 65 years and over (19 % cf. 8 % for Selwyn District) among its residents. It also had higher proportions of 'one parent' families and one person households, and relatively less one family households than Selwyn District. Just under a quarter of households in Darfield Township reported that their incomes were under $20,000 or under in 1996 (cf. 17 % for Selwyn District), and the income distribution among the township's households indicates they were economically disadvantaged compared with the district's households. The workforce of Darfield Township had lower proportions of self-employed persons, employers, and unpaid workers in family businesses than did the district's workforce. The community/social/personal sector provided 27 % of the jobs for workers resident in Darfield Township in 1996. A further 23 % of its workers were employed in the wholesale/retail/hospitality sector, and 14 % in manufacturing. A wide range of community organisations are based at Darfield. While the township has a broad range of business activities, its economy is closely linked to the agricultural sector. Darfield is also the gateway to outdoor recreational activities in the district including fishing, boating and skiing, and visitors passing through the township make purchases from local businesses. There are some signs that the township's economy is becoming more diversified (from its agricultural base), with the recent opening of four eating establishments and a block of motels.

Te Pirita is a lightly populated area bounded by the Selwyn and Rakaia Rivers and SH 1, where farming is the major economic activity. Several dairy units have recently been established in the area on land formerly used for sheep and dry land farming. The population of Te Pirita increased by 30 % from 318 to 414 between 1986 and 1996, while the district's population grew by about 20 % over the same period. The age structure of Te Pirita's population in 1996 was relatively younger than the district's population as there was a higher proportion of children aged 14 years and under (26 % cf. 23 % for Selwyn District) among its residents. Te Pirita had higher proportions of one family and one person households, and a lower proportion 'one parent' families than the district as a whole. Twenty-three % of households in the area reported that their incomes were less than $20,000 or under in 1996 (cf. 17 % for Selwyn District).

The income distribution among the area's households indicates they were economically disadvantaged compared with the district's households. The workforce of Te Pirita had higher proportions of self-employed persons, employers, and unpaid workers in family businesses than did the district's workforce. The agriculture, forestry and fishing sector provided 55 % of the jobs held by the residents of the area in 1996.

7.2.2 Profiles of farmers

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

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

Interviews with farmers within the scheme area revealed that many were currently irrigating part of their properties from deep bore wells, and most of them had contingency plans to extend irrigation from that source.

The research indicated that farmers whose properties will be required for the reservoir in the Wairiri Valley want compensation measures not only to address issues concerning the farm business, but also other factors such as changes of lifestyle and future plans. Farmers with properties outside the area of the proposed irrigation scheme have concerns about its impact on water quality and quantity in their localities.

7.3 The Social Impacts

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

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

In addition to the social and economic effects of land use changes arising from accessing water from the proposed irrigation scheme, there are a number of other direct and indirect effects that are anticipated and discussed below.

7.3.1 Four scenarios of land use change

Recent studies of the irrigation potential of Mid Canterbury and the Central Canterbury Plains indicate that there is a total area of 192,427 ha in these regions which would benefit from the provision of water through community irrigation schemes. The area on the Central Canterbury Plains estimated to benefit from irrigation was estimated to be 84,279 ha, with 71,885 ha identified as suitable for intensive livestock production, and 12,394 for arable or intensive cropping production (Butcher Partners Ltd, 2000: 6).

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

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

Butcher Partners Ltd then projected the patterns of land use associated with each of these four scenarios. The projections of land use patterns they developed are presented in Table 7-1. Butcher Partners Ltd point out that the "Likely Short Term" scenario is the "most likely mix" based on the economics of different land uses, and realistic expectations of ownership change that is likely to occur over the short term. The other three scenarios are illustrative rather than predictive.

Table 7-1: Land Use (ha) by four scenarios arising from irrigation development

Land Use	Present	Likely Short Term	Dairy	Fruit & Vegetable Bowl	Biological Enterprises
Dairy	0	76,089	148,939	76,089	76,089
Dairy Support	0	0	37,235	0	0
Sheep	118,126	41,218	0	41,218	41,218
Beef	17,908	15,638	0	15,638	15,638
Deer	7,093	19,232	0	19,232	19,232
Arable	45,086	32,819	0	0	15,083
Process Crop	4,214	6,253	6,253	14,087	12,583
Horticulture	0	1,177	0	26,161	12,583
TOTAL	192,427	192,427	192,427	192,427	192,427

Source: Butcher Partners Ltd (2000: 21).

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

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

7.3.2 Previous experience with land use change following irrigation

Case studies of other irrigation areas show that irrigation can transform the land and landscape. It can also transform society. Nevertheless, several generations of New Zealand farmers viewed irrigation primarily as an 'insurance' against a perverse climate rather than as a tool to manage their production. It was not until a sophisticated irrigation technology developed with spray and sprinkler systems that the full potential of water application was realised. Previous research[10] compiled and reviewed as a background study for this social assessment has traced the development and social impacts of community irrigation schemes, attitudes and adaptations of farm families and subsequent ownership changes.

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

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

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

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

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10 This research includes community case studies of the Waitaki Plains, Otautau and Clandeboye undertaken by Taylor Baines and Associates as part of the FRST funded project "Resource Community Formation and Change" (Contracts TBA801 and TBAX0001), and a review report, "Social Impact of Irrigation", Appendix 4 in Butcher Partners (2000).

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

7.3.3 A general model of land-use and ownership change

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

First wave

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

Second wave

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

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

Third wave

Here widespread changes in land use and farm ownership take place. Newcomers buy into converted farms or directly convert them on change of ownership. They are usually dairy farmers by choice and experience and they frequently come into the district from an established dairying district, often in the North Island. As the third 'wave' of irrigation farmers they create the 'new' dairy economy in the host district.

7.3.4 Likely scenario of social impacts of land-use and ownership change

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

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

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

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

Communities undergoing irrigation development undergo considerable social change as the 'old' families move out and are replaced by 'new' families. Potential social divisions are created as the first dairy families move in from outside. Dairy farming is often regarded as a lower status occupation than traditional sheep and beef farming, one with very different work patterns and with a comparatively high number of farm workers. The continual movement of dairy workers and any seasonal workers in and out of the district can create feelings of dislocation among members of the old community who remain. Established farmers can also find the philosophy of the sharemilker contract and attitudes to stock and land are different from their values.

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

Another issue is the ability of the district to take full advantage of the flow-on effects from the new land use activity and changes in population. Opportunities will be created for irrigation contractors and suppliers, building contractors and suppliers, dairy equipment, veterinary services, transport operators, etc. Increased horticultural production will bring a demand for seasonal workers.

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

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

Overall, based on the "Likely Short Term" scenario of land use change devised by Butcher Partners Ltd (2000) the following can be predicted as likely changes for the Central Plains area:

- there will be a transfer of land ownership to newcomers, although some established farmers will adapt by converting their properties to other forms of production;
- local businesses will need to expand their base of skills to take advantage of the new opportunities offered by dairying and other forms of agricultural activity;
- there will be increases in the rolls of schools arising from the arrival of young families attracted by the expansion of dairying; and
- demand for social services will increase due to the population growth associated with changes in land use.

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

The social effects arising this scenario are identified and discussed below in a number of themes: the local business sector, employment, the local economy, cost, community organisations, services and schools. Under each theme there is a list of specific points that describes the nature of these anticipated effects.

7.3.5 The local business sector

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

Those additional sales will allow local firms to expand their activities and employ more staff. A recent study of the intra-regional expenditure of Canterbury farmers (Agriculture New Zealand Ltd, 2001) found that about half of overall farm expenditure (working, capital and personal) in Central Canterbury[11] is disbursed in small towns in the region. Farmers commonly purchase the majority of direct inputs as close to the farm as possible, while services (both professional and semi-skilled) and capital items are purchased in Christchurch and Ashburton. Although dairy farmers incur a lower proportion of their expenditure in small towns than both arable and livestock farmers, they still have a major throughput on the local economy as their expenditure per hectare is much greater than their arable and livestock counterparts.

The specific points raised about the impact on the local business sector include:

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

7.3.6 Employment

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

The specific points raised about impacts on employment include:

- people resident in the area may lack the skills required by employers and may need to receive appropriate training;
- the type of employment provided to local residents may change from casual to permanent;
- on farm jobs such as maintenance, fencing, spraying etc will provide employment for local contractors;

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

- the creation of jobs through the establishment of any additional plants to process the expansion in farm production; and
- people attracted by employment opportunities in the area may choose to reside in Darfield and other rural townships.

7.3.7 The local economy

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

A specific negative impact could arise from the closure of the road through the Wairiri Valley which will reduce the traffic through Glentunnel, and may decrease the custom which local businesses derive from visitors passing through the township. There are already impacts on local real estate markets in the area around the Wairiri Valley as a result of this scheme being investigated.

The specific points raised about the impact on the local economy include:

- a consistent supply of water to more of the area's farmers will enable them to achieve consistent levels of production and allow them to diversify into horticulture, different types of crops and seeds, and dairying;
- consistent levels of agriculture production will stabilise the turnover of other rural businesses and enable them to create more jobs;
- the more intensive use of irrigated land will increase the value of farm properties and reduce the amount of land available for subdivision into lifestyle blocks;
- real estate sales in Glentunnel, Whitecliffs and the Wairiri Valley have come to a halt because of uncertainties associated with the siting of the reservoir and the route of the discharge canal;
- an expansion of dairy production in the area may drive up wage rates in other parts of the local economy (e.g. truck drivers);
- dairy farms require winter feed (e.g. barley) and dairy grazing which can be supplied by arable farms allowing them to diversity;
- the scheme could lead to an "imbalance" of dairy farms in the area;
- an inflow of sharemilkers and workers on dairy farms will generate extra expenditure in the rural townships of the area; and
- the loss of through traffic visitors to Glentunnel from the closure of the Wairiri Valley Rd and its effects on the custom of the camping ground, motel and local store.

7.3.8 Community organisations

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

The specific points raised about community impacts on organisations include:

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

7.3.9 Services and schools

This theme is closely related to community organisations. It addresses the effects of the proposed irrigation scheme of the delivery on community and health services to people in the area, and the impacts on school rolls and other aspects of educational activities. Recent changes in rolls (1996-2001) for schools in the vicinity of the proposed irrigation scheme show that while several schools have had increases in the number of their pupils, others have experienced declining rolls.

The specific points raised about impacts on services and schools include:

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

7.3.10 Scheme costs

This theme addresses issues concerning the affordability of the irrigation scheme (including the cost at the farm gate) and funding, management and shareholding arrangements.

The specific points raised about costs include:

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

7.3.11 Management of change

The introduction of irrigation into farming systems creates distinct social impacts through changed and new farming systems and wider demographic and community changes. Irrigation technology and routines are seen to be 'hard work' and therefore most effective in the hands of 'youth and enthusiasm' resulting in a demographic change towards younger farm families.

New land uses, such as dairying, bring newcomers with different skills who replace families holding traditional skills. As a result the community can initially be destabilised. The leadership role of those families who remain, changing their own skills base and upgrading their existing production to effectively utilise irrigation, is critical during this interim period. They help both to validate the new land use and maintain some sense of stability in the community. They become 'social anchors' for the emerging community. Furthermore, a stabilised or even increased population can have a positive impact on local schools, sports and recreation facilities, and social services, thereby strengthening rural communities.

Irrigation and associated land uses demand a wider skills base among farmers, farm workers, farming service providers and contractors, rural service providers and small business people. Often local skills and resources are not congruent with the new production systems and the community and rural towns can miss out on the full economic and social potential of the new irrigation-based production system.

The wider community of Central Canterbury will need to take specific steps to maximise the benefits of irrigation. These include:

- establishing where and how new labour demands will be met;
- considering where and how accessible training and technological expertise are available to farmers, contractors and farm workers to adapt to the skill demands of new technologies and land use changes;
- ensuring businesses such as building and irrigation contracting industries are prepared to take part in the on-farm construction stages of irrigation and dairy conversion, to maximise local employment and expenditure;
- considering the wider entrepreneurial and business opportunities offered by irrigation;
- establishing mechanisms for managing social change, such as a community trust.

7.4 Other effects

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

7.4.1 Flooded Residences

Within the Wairiri Valley there are approximately 13 residences that will be inundated by water. These are shown on Figure 7-2. The impact on these people will be large, as there is no suitable alternate storage scenario for storage in the valley that will not result in their places being flooded. All such residences will need to be relocated. Of these 13 residences, 3 are owned by the New Zealand Defence Forces.

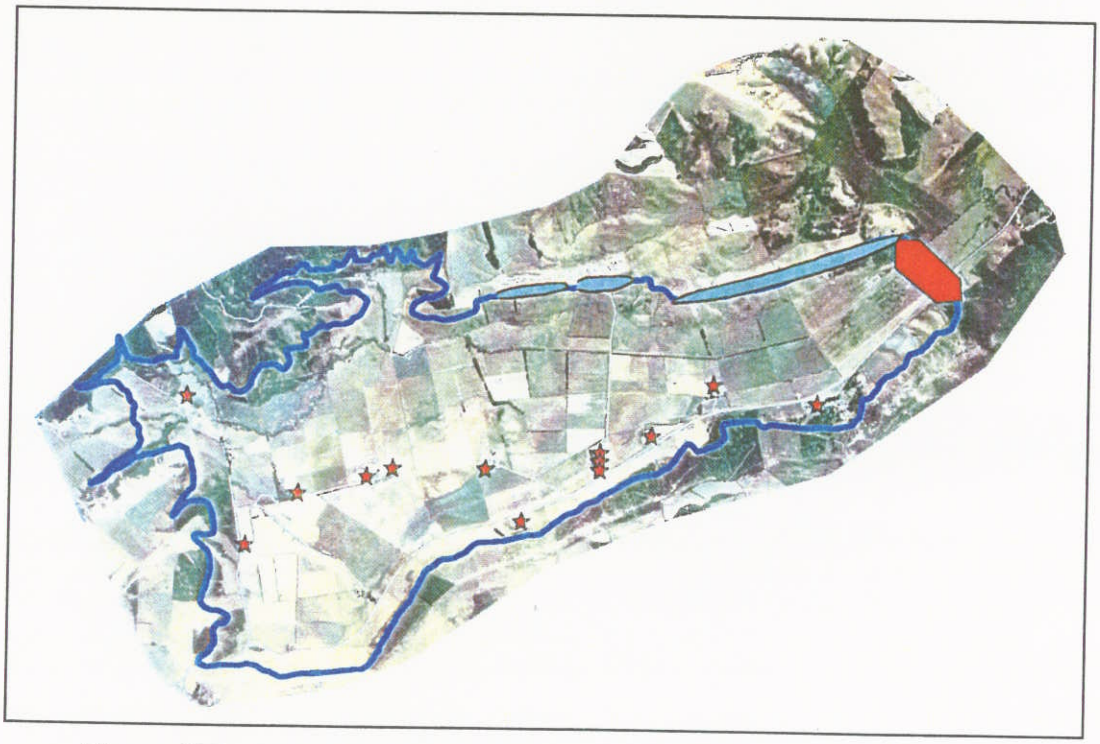


Figure 7-2: Location of Residence to be flooded in Wairiri Valley

7.4.2 Loss of productive land

With the flooding of the Wairiri Valley, there will be the loss of approximately 800 – 900 ha of agricultural land. This will be offset by the increased productivity from the land to be irrigated.

7.4.3 QEII Covenants

In addition to flooding the residence, within Wairiri Valley there are two pieces of land protected by a QEII covenant. These are for a raised peat wetland and for a stand of native bush. The water in the reservoir would completely flood the raised peat wetland, and partially intrude into the native bush area. How these issues are to be resolved remains unclear at this time, although this has been identified as a major issue for residents within the valley.

7.4.4 Roading Re-routing

State Highway 77 runs through the Wairiri Valley and provides access to Windwhistle and the Rakaia Gorge through Glentunnel. If this road is relocated around the south side of the Harper Hills, then Glentunnel will not longer be on the State Highway. This potentially could have adverse impacts on the store and camping facilities in Glentunnel, but also may be seen as having a positive effect in relation to businesses in Coalgate and Hororata. The relocation of this road has been identified by the local residents at Glentunnel as a major issue.

7.4.5 Canal Systems

The irrigation system will involve a large number of canals crossing the plains. In particular there is little scope to relocate the main headrace canal, feeder canal into Wairiri Valley and the outlet canal. It may be practicable to move the alignment east and west by up to 100 m to avoid significant features, but this will not be sufficient for some properties to become divided by the canal. Allowances have been made in the cost estimates for bridge and culvert crossing of these canals.

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

The locations of the distribution canals below the headrace are more flexible. It would be likely that the existing routes of stock water races could be utilised in an expanded form. Some distribution races may be able to be located within the road reserve.

There will be a significant safety issue with these canals, i.e. in particular the outlet canal from the reservoir. At times this canal will have no water in it, and may therefore appear safe. Shortly thereafter there could be 60 m^3/s flowing down it, which would be extremely dangerous to be caught in. Fencing of the canals around the Selwyn River at Glentunnel will be essential, given the proximity to the camping ground, swimming holes and golf course.

7.4.6 Works in River Beds

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

7.4.7 Archaeological sites

It is possible that during the construction phases, archaeological sites may be discovered. It will be essential to have in place protocols to deal with such finds. This is particularly so with Mäori cultural sites. Tangata whenua have separately identified the need for protocols to be established in advance of any physical works being undertaken (see Section 8).

7.4.8 Construction

There impacts will be from construction activities at the dam site and along the routes of the irrigation scheme 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.

The specific points raised about construction activities include:

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

7.4.9 Risks to residents

There are actual and perceived risks from natural phenomenon to the operation of the irrigation scheme, and the safety of the dam residents in the local area.

The specific points raised about risk include:

- the options of tunnels through the Harper Hills, or culverts past the townships of Glentunnel, Coalgate and Whitecliffs, provide an opportunity to balance the reduced risk of canals failing against the cost increased cost of these alternatives;
- the risk of an earthquake breaching the reservoir in the Wairiri Valley, or main outlet, and flooding the townships;
- the risk of an explosion at New Zealand Defence Force's ammunition facility breeching the reservoir and flooding the townships;
- the low incidence of dam collapse in New Zealand; and
- the low risk of natural flooding in the limited Wairiri catchment.

7.4.10 Site

There are concerns about the irrigation scheme and its operations, and its impact on local ecology (wildlife, vegetation etc) near the storage dam or distribution channels.

The specific points raised about the site include:

- the merits (or otherwise) of High Peak Valley, Lake Coleridge and other alternative sites for the reservoir;

- the establishment of a reservoir at the proposed site in the Wairiri Valley will flood a peat swamp and other natural features;
- dust blown by Northwest winds from the mudflats of the reservoir when it is drawn down in summer could affect residents of Whitecliffs, Glentunnel and Coalgate; and
- the route of the discharge canal and its effects on properties and reserve land such as the Holiday Park, domain and golf course at Glentunnel.

7.4.11 Visual

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

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

7.4.12 Disadvantaged groups

Some groups of people in the area may be disadvantaged by the proposed irrigation scheme, and there are possible effects on their welfare.

The specific points raised about disadvantaged groups include:

- the loss of amenity values for residents of the townships of Glentunnel and Coalgate who have chosen to live there for lifestyle reasons;
- business operators in Glentunnel whose turnover may be reduced by the closure of the road through the Wairiri Valley; and
- the farm families occupying properties that will be inundated by the reservoir in the Wairiri Valley.

7.4.13 Compensation

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

The specific points raised about compensation include:

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

7.4.14 Recreation

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

The specific points raised about recreational activities include:

- the opportunities for recreational use (e.g. windsurfing) of the reservoir in the Wairiri Valley;
- the limitations of the reservoir as a recreational space due to the seasonal fluctuations in water levels;
- the impact of water extraction from the Rakaia and Waimakariri Rivers and the nitrification of surface water on the fish population;
- the concern of anglers that their recreational use of these rivers will be restricted by further reductions in water levels;
- the need to better manage the multiple use of surface water; and
- the restrictions on recreational use of the Selwyn River when the discharge canal is being constructed.

Recreational Opportunities

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 this access 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. This will require a greater area of land but is indicative of the type of community projects that could be initiated with forethought.

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

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

7.4.15 Water

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

The specific points raised about water include:

- the effect of large scale extraction of water for dairy farms on the quality and quantity of the ground water source of the Kirwee township supply;
- the pollution of waterways and ground water through increased nitrate levels associated with dairying;
- the potential effects on the quality (i.e. nutrients) and quantity of ground water available for farms near Lake Ellesmere;
- the extent that nitrate leaching will be manageable;

- future environmental controls over pollution could limit the expansion of dairying;
- the possibility that greater flows of water in the Selwyn River and other streams on the level of Lake Ellesmere may require more frequent openings to the sea which would impose an additional rate burden on about 50 lakeside properties;
- concern that continued reliance on wells for irrigation may deplete the resource of ground water;
- the proposed scheme will recharge the existing deep wells in the area;
- the use of Lake Coleridge to provide an additional reserve of water for the proposed scheme; and
- debate about whether Christchurch's water supply should be an issue for the proposed irrigation scheme.

7.5 Conclusions

A major water enhancement and irrigation project such as proposed for the Central Plains involves several strands of social change. The nature of these social changes will vary over the life cycle of the project, including the planning, construction and operational phases.

Monitoring the outcomes of the scheme from the point of view of farmers and their families, communities and other affected parties, will require the development of a more detailed profile of farmers and families in the area as part of the final resource consent applications. Additional information about water based recreation and effects may also be required once the water sources and scheme configuration to be put forward for consent applications have been confirmed. Further work is needed on mitigation strategies, and local input should be sought to develop them. It would be useful to establish early on a system to manage the social impacts of the scheme. One option to investigate in this regard is a community trust fund.

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

8.1 Mäori Cultural Values

Te Taumutu Rünanga and Te Ngäi Tüähuriri Rünanga are the kaitiaki Rünanga for the Waikirikiri/Selwyn District. These Rünanga are the collective voice of all persons who have whakapapa (genealogical) links to the district being descendants of the iwi (tribes) of Te Rapuwai, Häwea, Waitaha, Ngäti Mämoe and Ngäi Tahu.

8.1.1 Mäori Occupation of the Malvern Hills Area

Mäori have occupied Käkäpötahi or the Malvern Foothills for many generations. Nowadays, although the historical information is limited, we do know that this area was valued for the microclimate that existed within the valleys of the area. As well as being a prized area for gathering many bird, plant and fish species, this microclimate supported cultivation of various staple foods, in particular the kümara. Hapü and whänau travelled to the area from their coastal villages as the winter snows retreated to prepare their gardens. These gardens were generally located on the north facing slopes of the foothills and in close proximity to spring holes or streams.

Whilst the majority of nohoanga (campsites) were occupied seasonally, Käkäpötahi did support at least one permanent pä (stockade) called Whakaepa. Whakaepa is situated on the banks of the Waikirikiri/Selwyn River near the present day township of Coalgate and was an outpost of the Ngäi Tüähuriri people situated at Kaiapoi.

8.1.2 Overview of Mäori Cultural Issues

The following values have been identified as relevant and necessary for consideration within this assessment of the Central Plains Water Enhancement proposal. Each value is explained in such terms so that all parties involved in the proposal may understand them. Following the values identification, this section identifies in depth how a particular value will be impacted upon and suggests possible options to avoid, remedy or mitigate these impacts.

8.1.3 Mauri

Papatuanuku (Earth Mother) supports life including all people, flora and fauna. Waterways represent the blood vessels that supply nourishment to her, through her, and to all living things.

The primary management principle for Ngäi Tahu is the maintenance and enhancement of the mauri or life-giving essence of a resource. Mauri can be tangibly represented in terms of elements of the physical health of the land, a river, or surrounding biodiversity. While there are also many intangible qualities associated with the spiritual presence of a resource, elements of physical health which Ngäi Tahu use to reflect the status of mauri and to identify the enhancements needed include:

- Aesthetic qualities e.g. clarity, natural character and indigenous flora and fauna;

- Life supporting capacity and ecosystem robustness;
- For rivers, the continuity of flow from the mountain source of a river to the sea;
- Fitness for cultural usage; and
- Productive capacity.

Manmade activities have the potential to degrade or extinguish the mauri of a resource and as a result may offend the mana of Papatipu Runanga who hold traditional rights and responsibilities with respect to that resource. The mauri of the land or river is degraded if it no longer has the capacity to support traditional uses and values. Across the rohe, one of the principle indicators by which Ngäi Tahu assesses the mauri of a resource is its productivity and the food and other materials sourced from it, hence Ngäi Tahu use of mahinga kai as an environmental indicator.

8.1.4 Wairua

Mauri, the essence of life is imparted by wairua, is a bonding element that interrelates water to every other element of the natural order.

Wairua is the spirit, or source of existence, being and life. It is upholding, sustaining, replenishing, and regenerating to all things by its *hau* or *mauri*. Wai, or water, is the medium in which dead travel to and from this world, hence the practise of Waiwhakaheketüpäpaku, the practise of water burials. Wai is the lifeblood of Papatuanuku (Earth Mother) that falls upon her from the heavens of Rakinui (Sky Father).

Thus water maintains two specific roles within Ngäi Tahu cultural values; firstly to provide the sustenance of life, and secondly the medium in which our spirit moves freely from one world to the next.

8.1.5 Kaitiaki

Preservation of the integrity of valued waterways is an important aspect of the responsibilities of those members of Ngäi Tahu whanui that are identified as Kaitiaki. Values (both tangible and intangible) associated with specific resources include:

- The role of particular resources in unique ancient tribal creation stories;
- The role of those resources in historical accounts;
- The proximity of important wähi tapu, settlement or other historical sites in or adjacent to specific resources;
- The use of resources, such as rivers, as access routes or transport courses;
- The value of resources as traditional sources of mahinga kai, food and other cultural materials; and
- The continued capacity for future generations to access, use and protect the resource.

8.1.6 Maunga

Maunga (Mountains) play an important role in the spiritual and cultural beliefs of Ngai Tahu. Foremost, maunga are the gateways to the atua (gods) and heavens, hence the story of Aoraki and the creation of Te Wai Pounamu. Maunga are also the gatherers of the tears of Rakinui (Sky Father), whose valleys collect the waters and in turn supply the lifeblood of Papatuanuku (Earth Mother).

Maunga of the Waikirikiri/Selwyn Catchment:

- Motukiore – Woolshed Hill
- Tarauri – Mount Misery
- Ruruahine – Cairn Hill
- Pukeähua – Abners Head
- Pukemärama – Racecourse Hill
- Käkäpötahi – Malvern Hills

8.1.7 Ngä Wai / Awa

Wai, or water, is the lifeblood of Papatuanuku. Without water no living thing, plant, fish or animal can survive. Water is taonga and this taonga value refers to values associated with the water itself, the resources living in the water and the resources in the wider environs that are sustained by the water. Further, water is a holistic resource. The complexity and interdependency of different parts of the hydrological system should be considered when carrying out activities that have known effects to water. This includes groundwater systems that provide the continuous flows of rivers that may retreat beneath the surface and appear again in valued waipuna (springs). The following sub-values are also pertinent to the understanding of the value of Wai.

Awa of the Waikirikiri/Selwyn Catchment:

- Hororata – Hororata River
- Waikirikiri – Selwyn River
- Waianiwaniwa – Waianiwaniwa/Waireka River
- Pauri – Hawkins River
- Te Mimi o Taua – Glendore Creek
- Otäneäkau – Tributary of Upper Waikirikiri/Selwyn River

- Te Awatutu – Tributary of Upper Hawkins River
- Waikohuwai – Blacks Stream
- Te Awaakeake – Tributary of Hawkins River (near Waddington)

Waiora

This water is the purest form of water and has the potential to give life, sustain well-being and to counteract evil. Waiora is used in sacred rituals to purify and sanctify. Tohunga (priests) used these waters for healing.

Waitohi

These waters were used by tohunga during initiation and baptismal ceremonies. The function was to remove the tapu from people, that is, to whakanoa. For this reason restrictions were imposed on these waters in order to ensure their continued purity.

Waihapua

These waters refer to coastal estuaries and lagoons where salt and fresh water mix. The water quality of these swampy areas was formally good enough to sustain food and so was important mahinga kai (food gathering) for Ngäi Tahu. Te Waihora (Lake Ellesmere) is a perfect example of a waihapua.

Waipuna

Waipuna, or springs, play an integral part in the natural environment as well as the cultural practises of Ngäi Tahu. These water bodies had various uses including Mahinga kai (food gathering) sites, tüähu (alters), waiwhakaheketüpäpaku (water burial sites).

Waikino

This is water that is polluted, debased and spoilt. Water in this polluted form has the potential to cause harm in particular humans.

Repo Raupö

Repo Raupö is the general term applied to wetlands. These areas were important sources of mahinga kai or were rich in biodiversity that supported species that were considered important mahinga kai. These areas were also valued for such things as paru (mud for dye).

8.1.8 Kainga Noho/Pa Tawhito

The extremely harsh environment Ngäi Tahu lived in made them a nomadic type of people who constantly moved within their areas following the seasonal variances of their mahinga kai. During the warmer months, a larger amount of time was spent in the higher altitudes, and during winter they generally retreated to their permanent coastal villages.

Urupä

Urupä are the burial sites associated with the Mäori occupation of an area. Generally the larger urupä are associated with the more permanent living settlements in the area. The burial sites of tupuna are wähi tapu and the modification or destruction of these is prohibited.

Known Urupä of the Waikirikiri/Selwyn Catchment

- Whakaepa Pa – Coalgate
- Ohinekakaraiti – Junction of Köwai & Waimakariri Rivers

It is likely that there are other urupa at other sites within the Central Plains.

Tüähu

Tüähu, or sacred altars, were important sites of significance. Tüähu played an important role in traditional Ngäi Tahu tikanga (customs) including matakite (foretelling the future), waitohi (blessings/baptisms), karakia (incantations), whakanoa (cleansing), as well as being a medium that connected with ngä atua (the gods).

The tüähu were the tools of the tohunga to aid them in the task they had before them.

Known Tüähu of the Waikirikiri/Selwyn Catchment

- Taramata (3)
- Whakaepa (30)
- Ohinekakaraiti (29)
- Pukeähua (13)

Umu

These ovens were used in the preservation of foods such as kiore and weka caught on these foothills.

Cultural Effects

Tuhituhi Neherä

Given the nomadic lifestyle of southern Mäori due to the mahinga kai gathering cycles, natural caves and land formations were used as shelters. Whänau groups often lived in these places for long periods and used the walls of these shelters to express myths, stories and tribal lore.

8.1.9 Wähi Pakanga

Wähi pakanga are places where historical battles took place between iwi, hapü or whänau. The sites automatically inherit a wähi tapu (sacred site) status given the blood that has been shed upon it. Equally, those killed on the battle field were often buried in close proximity to the site and thus wähi pakanga also have associated urupä. The site of the Whakaepa Pa remains a wähi pakanga and holds special significance for Ngäi Tahu whänau whose tupuna (ancestors) were killed there.

8.1.10 Mahinga Kai

The South Island was recognised as a land of abundance, a land rich in water resources and a diversity of plant, fish and bird species. The rich water and terrestrial resources were geographically dispersed and their availability varied seasonally. To survive, Ngäi Tahu people developed patterned movements throughout their traditional territories. These seasonal cycles enabled the people to harvest available resources, store them for periods of scarcity, and to integrate these subsistence pursuits with cultural activities.

8.1.11 Wähi Raranga

This site is similar to a mahinga kai but differs in that it is specifically valued for the weaving resources that are found there. A wähi raranga is more often a stand of harakeke (flax) but can also include species such as taramea (spaniard), ti kouka (cabbage tree), neinei (shrub), raupö (bulrush), and toetoe.

8.1.12 Huarahi

Te Wai Pounamu was covered with a complex system of trail and access routes. These linked the various Ngäi Tahu settlements to the social and economic life of the tribe and tied them into networks of trade that extended well beyond the South Island.

8.1.13 Wähi Köhatu

Köhatu, or rock formations, were often attributed with stories from the past and therefore often carry the names of eponymous ancestors associated with the area. With this spiritual personification, these köhatu become kaitiaki (guardians) that watch over the surrounding area and bind the whakapapa (genealogy) of the tangata whenua to the land.

8.1.14 Wähi Mahi Köhatu

As a stone age people, tangata whenua had intimate knowledge of all places throughout the country where they could source the various stones and minerals from which they manufactured their implements. Wähi mahi köhatu are the areas from where these resources were mined.

8.1.15 Wähi Ingoa

Ngäi Tahu knew their homeland intimately. They moved, on an annual basis, across the width and breadth of the island following the seasonal characteristics of their food supplies; the birds, the fish and plants. The preferred or abundant places for particular foods were identified through specific names that described a feature, such as a mountain, or a personality who claimed the area. These places and their names formed vast oral maps that were an integral part of the culture of Ngäi Tahu. Any Ngäi Tahu person who knew the traditions, whakapapa (genealogy) and histories, would have been able to navigate their way throughout the rohe.

8.1.16 Wähi Taonga

For Ngäi Tahu, the term wähi taonga refers to places that hold the respect of the people in accordance to kawa and tikanga. Some sites are of tribal significance while others are important to the hapü and whänau who visited, lived at, or had special affiliations to that area. Mountains and hills, landforms, springs, remaining areas of indigenous vegetation and archaeological sites are examples of physical taonga. Other taonga can include the püräkau (stories), place names or associations those living today have with the tupuna (ancestors) that have gone before.

8.1.17 Wähi Täpuke

During times of siege or anticipated attack people within a pä would ensure that treasured resources were removed from the site and placed within the surrounding environment for safe keeping. These taonga often included whakairo (carvings), waka (vessels) or treasures made from valuable resources such as pounamu (greenstone).

8.1.18 Wähi Tapu

Wähi tapu is a term applied to all sacred sites associated with tapu (sacredness) or areas held in reverence according to tribal custom and history. Some wähi tapu sites are important to Ngäi Tahu as a whole, while others are important to individual hapü or whänau. Of all wähi tapu, urupä (burial sites) are the most significant.

8.2 Mäori Cultural Impacts

8.2.1 Mauri and Wairua

The mauri of the land is intrinsically linked to the mauri of water. Mountains and foothills are the first to receive the teardrops of Rakinui (Sky Father) as he laments for Papatuanuku (Earth Mother). These waters gather together in a network of veins that are the life-giving force to Papatuanuku. These waters continuously flow ki uta ki tai (from the mountains to the sea) linking all resources, flora and fauna of the area to one another. The continuity of this journey is essential for ensuring the wellbeing of the mauri of the waterway and the land and all things they support.

Options that create a waterway potentially sourced from water types that do not occur naturally within the Waikirikiri/Selwyn Catchment, that is, where there is potential for artificial mixing of waters, include the following:

- Wairiri Storage Reservoir;
- Enhancement flows to the Waikirikiri/Selwyn River;
- Failure of the storage dam in a catastrophic event;
- The Low Flow Replacement Option for the Waimakariri (Kowai) take;
- And during times of extremely large flows within the Selwyn River, the discharge from Wairiri Reservoir to Headrace Canal via Waikirikiri/Selwyn River route.

The creation of an artificial canal to transport a large body of water over an area that has never supported a natural water body in the past, will occur in the following options:

- Rakaia to Wairiri Pumped Canal
- Reservoir Outlet Canal
- Central Headrace Canal
- Springfield Canal Route

These options are designed to transport water with minimal loss to the surrounding environment and thus the life supporting capacity of the water is not utilised in the process. Tangata whenua have a concern that the water within the canal will not provide the maximum life giving potential it would have if it were left in the original river.

The creation of a surface discharge canal that runs in, but separate to, the Waikirikiri/Selwyn River (Discharge from Wairiri Reservoir to Headrace Canal via Waikirikiri/Selwyn River) will require a section of the natural river will need to be shifted. The creation of another water body with extremely different characteristics to that of the natural river, side be side would have a negative impact on the Wairua of the natural water body. The impact this would impose on cultural values is considered significant and therefore not supported. The option of a buried canal beneath the Waikirikiri/Selwyn River would also impose on cultural values in a similar manner.

Several options involve the abstraction of water. Surface water abstraction interferes with the continuity of the journey of water, and reduces the volume of water left in the river system to maintain the life sustaining capacity of the waterway. Water abstraction, if at all, should take place when flows in the river exceed those flows required to maintain the life supporting capacity of the river. Options which include abstraction of water are as follows:

- Waimakariri River to Springfield Canal Intake
- Rakaia River Abstractions
- Waimakariri River Abstractions

8.2.2 Kaitiaki

The kaitiaki role of Te Taumutu Rünanga and Te Ngäi Tüähuriri Rünanga must be respected and maintained throughout all aspects of work related to all proposals, including the ongoing construction and work until such time as the project is complete. Once complete this kaitiaki role will continue into the future and thus the owners of the scheme will need to maintain an on-going relationship with tangata whenua.

8.2.3 Maunga

The Wairiri Storage Reservoir option has the potential to modify the characteristics of the foothills and mountains that surround it. It is important to ensure that the proposed manmade lake is integrated as naturally as possible into the landscape of the area.

8.2.4 Ngä Wai

The following options involve the construction of canals:

- Rakaia to Wairiri Pumped Canal;
- Discharge form Wairiri Reservoir to Headrace Canal via Waikirikiri/Selwyn River;
- Buried Canal;
- Central Headrace Canal;
- Springfield Canal;

Particular concern is raised by tangata whenua with regard to the construction of canals and how these ensure:

- the canal waters are not artificially mixed with those of the natural water body;
- that the natural water body is not altered in course, flow volume or character;
- that canal mechanisms are constructed to withstand catastrophic events;
- that flow within the system can be stopped in the event of a catastrophic event.

The Wairiri Storage Reservoir option would involve inundation with the loss of a considerable sized valley and natural water bodies that form part of the wider Waikirikiri/Selwyn Catchment. Given the continued stresses placed on water resources within the wider catchment, this proposal adds a further link in the chain to the degradation of the Waikirikiri/Selwyn River that is not acceptable to tangata whenua.

Other options will have a negative impact on Ngä Wai values by the alteration of the natural landscape, and the creation of artificial waterways. These options include:

- Discharge form Wairiri Reservoir to Headrace Canal via Waikirikiri/Selwyn River; and
- Buried canal.

The effects of abnormal levels of sediment and/or glacial flour can have detrimental impacts on mahinga kai species, both aquatic and land based. The effects and disposal of these materials is of concern in the following options:

- Headrace Canal
- Rakaia River Intake System
- Waimakariri River Intake System

8.2.5 Kainga noho

The disturbance of archaeological sites is of great concern. Some options includes sites that are identified as significant, including the historic pä of Whakaepa. The options of the Discharge from Wairiri Reservoir to Headrace Canal via Waikirikiri/Selwyn River and the buried canal, are within very close proximity to, if not through, this site. It would be unquestionable that the canal would disturb wähi taonga and wähi tapu sites associated with the pä.

The construction of the canal in this location will also place a physical barrier between the pä site and the river that it is associated with. The separation of these two elements would not be acceptable to tangata whenua.

Additionally the Waimakariri River to Springfield Canal intake option is located at the historic pä site of Ohinekakaraiti at the junction of the Waimakariri and Kowai Rivers. This was a permanent settlement of reasonable size and population. Whilst there are some archaeological sites recorded for the area, the potential of further sites is high.

For the Wairiri Storage Reservoir option there is no direct evidence or documentation that identifies occupation sites within Wairiri Valley. It is though highly likely, given the scale of food gathering that was conducted in the area, that seasonal living sites were constructed in many of the valley within the Waikirikiri/Selwyn catchment. These sites would potentially have wähi taonga and wähi tapu sites associated with them.

8.2.6 Mahinga Kai

Any options which included the creation of canals void of biodiversity are of concern. Some options (Rakaia River Intake System and Waimakariri River Intake System) include locked systems and therefore no opportunity for fish to escape. Mechanisms to prevent fish entering canals or reservoirs would be required. Reservoir options may require mechanisms to allow adult fish to migrate to the sea,

The continued support of mahinga kai of concern. The inundation of the Wairiri Valley for the Reservoir option will destroy the numerous mahinga kai values it currently supports. Tangata whenua would require that no net loss of mahinga kai values occur in the Waikirikiri/Selwyn Catchment if the proposal is to proceed. Important wetlands and vegetation in the area will need to be created in other areas of the catchment.

8.2.7 Huarahi

The concern with several options proposed is the continued access to the network of trails that exist throughout the proposed areas. There should not be a barrier to tangata whenua accessing and using historic trails should they wish. Options which potentially create this barrier include:

- Wairiri Storage Reservoir
- Rakaia to Wairiri Pumped Canal
- the Discharge from Wairiri Reservoir to Headrace Canal via Waikirikiri/Selwyn River
- Buried Canal
- Central Headrace Canal Route

8.2.8 Wähi Ingoa

Some options will have an impact on place names of the area. Where impacts are identified, the naming of new features created from the proposal uphold, where agreed by tangata whenua, the historic place names of the area.

8.2.9 Wähi Taonga and Wähi Tapu

The likely presence of cultivation areas on the north facing slopes of the Harper Hills is a wähi taonga. The options of the Wairiri Storage Reservoir and the Rakaia to Wairiri Pumped Canal, would affect this area. Although there is no archaeological documentation of these at present, sources have suggested that these do in fact exist.

By virtue of the presence of historic sites, place names, or landforms several options already listed above have potential to also impact on Wähi Taonga.

Given the extent of the Central Headrace Canal system it is highly likely that both wähi tapu and wähi taonga will be impacted upon by the construction of this canal system. In particular, the proposed contour of the head canal moves through an area north of Homebush that already contains a number of archaeological sites. These sites generally contain evidence of seasonal occupation such as umu (ovens) and artefacts associated with food gathering and preparation. Further sites including kainga noho (settlements) and urupä may also be located in this, and other areas of the proposed headrace canal.

From information available at this time, sources have not identified any located wähi tapu within the Wairiri Valley, which would be affected by the Wairiri Storage Reservoir option. This aside, and given the higher level of historical occupation in the area, it is highly likely that there are burial sites in the valley. Equally, those sites that are not unearthed during construction of the reservoir can potentially be uncovered through wave action of the lake and its fluctuating level.

The Springfield Canal Route includes the pä site of Ohinekakaraiti, which has associated urupä and tüähu that should not be disturbed.

8.2.10 Wähi Pakanga

The option for a discharge from the Wairiri Reservoir to Headrace Canal Via Waikirikiri/Selwyn River has an identified impact on the Whakaepa historic pä site, which would equally be a disturbance of a wähi pakanga. Given the blood that has been shed upon this land, the pä holds the status of that of an urupä. Any impact on this site would be unacceptable. The same applies to the buried canal option.

8.2.11 Summary of Cultural Issues and Impacts

In conclusion, the proposed options for a reservoir and canal network within the Malvern Hills area is currently located in an area that contains a generally high density of sites and areas of significance to Ngäi Tahu, Ngäti Mämoe and Waitaha.

Given the abundance of food resources, the suited climate for cultivation and the fact that this area was on-route to mountain passes, all contributed to the fact that historical occupation in, and use of, Waikirikiri/Selwyn River was generally of a larger scale than other foothill areas in the Canterbury region.

With this occupation, Ngäi Tahu applied their tikanga and kawa (cultural rites and customs) to the environment in order to protect and sustain the resources within the area that they harvested. These values remain today, having been passed down from generation to generation in the role of kaitiaki (guardianship).

With regard to the various options that this report has assessed, particular options have been assessed as having a have high impact on Ngäi Tahu cultural values are therefore it is recommended that the following options do not progress in their current form:

- Discharge from the Wairiri Reservoir to Headrace Canal via the Selwyn River
- Discharge from the Wairiri Reservoir to Headrace Canal via Buried Canal in the Selwyn River
- Waimakariri River to Springfield Canal Scheme
- Waimakariri River to Springfield Canal Scheme – Low Flow Replacement Option

At the point at which a final combination of options has been decided upon, it will be necessary to have further research and identification carried out on the area, in particular archaeological surveys. Once this level of detail has been established, it will be necessary to revisit this report and re- analyse the options against this new or more detailed information.

Scheme Feasibility

9.1 Introduction

The feasibility of a project such as the CPWE scheme involves many aspects. It is not sufficient to provide a concept that technically can be built and paid for. It is also necessary to provide the balance between environmental, social, and cultural issues. This balance will ultimately provide the basis for a successful path through the resource consent process and uptake by the potential beneficiaries. This scheme, as well as providing opportunities for irrigation, provides the opportunities for environmental enhancement. This section overviews all these aspects and considers the question; Is the scheme feasible?

9.2 Technical Feasibility

9.2.1 Reservoir Risks

Overtopping

One of the major risks normally associated with reservoirs is overtopping of the dam wall due to high flood flows. In the case of the Wairiri Reservoir the total catchment draining into the reservoir is very small relative to the size of the dam (about twice the dam surface area) and the outlet capacity (60 m^3/s) is large. Therefore the risk of the dam being overtopped by floodwaters is assessed to be very low.

Earthquake

The dam and reservoir would be located in an area of significant earthquake hazard. However, the preliminary geotechnical investigations have not indicated the presence of an active fault within the Wairiri Valley. Properly designed earth dams have demonstrated their ability to successfully resist strong earthquake shaking even when situated close to the fault source. These design techniques will be incorporated into the Wairiri dam design.

Seepage and Piping

Seepage and piping induced failures of earth dam embankments occur as the result of uncontrolled water flowing through or under the dam eroding part of the soil itself. If this becomes excessive then the process can accelerate to the stage where large volumes of water can flow from the reservoir to the downstream face resulting in increased erosion and eventually collapse of the dam. Modern dam design practice recognises this possibility in all earth dams. Specially designed earth filters incorporated into the dam body act to control seepage and prevent internal erosion of the dam's soil structure.

The preliminary geotechnical investigations have identified the potential for erosion of the weak sandstones in the dam foundation if they are not properly protected. Further, a layer of relatively permeable sand and gravel has been identified at the base of the valley fill sediments. The extent and continuity of this layer will need to be checked to ascertain its impact upon the dam design. Removal and replacement of part or the entire layer may prove to be the best solution.

Foundation Failure

Foundation failure could occur when weak soil or rock layers permit the overlying dam wall to move. A shear surface will often form along them. During preliminary dam design subsurface drilling investigations will be used to determine whether such weak layers exist in the dams foundations. If they are found then there is a variety of proven methods for dealing with them including removal by excavation or strengthening by grouting or similar technique. The weak Eyre Group sandstone found at the base of the valley fill sediments will be investigated further during the preliminary design.

Another potential form of foundation failure, which has been identified, is liquefaction of the saturated valley silts and sands. Liquefaction is a form of severe weakening of soils induced by strong earthquake shaking. Again more detailed analysis of this issue will be carried out during preliminary design. Modern treatment techniques include removal of the at-risk soils or insitu treatment by one of a variety of methods. It has been assumed that all such material will be excavated from beneath the dam footprint and the cost estimates have provided for this.

Siltation

The issue of the reservoir filling up with silt has been addressed in Section 6 and the annual accumulated sediment volume calculated to be approximately 0.02% of the reservoir volume. On this basis it would take 50 years for 1 % of the reservoir volume to be lost. Siltation of the reservoir is therefore not a significant risk.

NZDF

The NZDF facilities require protection from a number of risks including encroachment of recreational activities into their controlled space and seepage from the ridge dams. The control of public access will be important and it is likely that the water surface area near their facilities will have to be buoyed as a non-encroachment zone. Seepage and drainage through the ridge dams will be one of the major design aspects for this reservoir.

Valley Slope Instability

Large scale and rapid failure of the slopes adjacent to the reservoir could cause a wave within the reservoir, which overtops the dam. For this to occur the slope failure volume must be very large compared to the volume of water it displaces when it enters the reservoir. The preliminary geotechnical investigations have not identified any existing slope failures along the lake shoreline, which would be capable to generating a wave, which overtops the dam. A full investigation of existing landslide areas will be carried out during the preliminary design phase to further examine the potential for slope instability.

Well established treatment techniques such as; buttressing the slope toe, unloading the top of a potentially unstable area and slope drainage, are available to stabilise potential landslide areas.

There will be other minor surficial instability along the north side of the Harper Hills, but this will be of no significance.

9.2.2 Construction Difficulties

This section outlines the construction issues to be resolved during preliminary design.

Sources of Dam Embankment Materials

Construction of the Wairiri Valley dam will require sources of low permeability materials to construct the dam core, coarse grained well graded materials for the dam shoulders, sands to construct intermediate filter zones, and rock riprap for erosion protection. The preliminary geotechnical investigations have established that suitable material types for the dam construction are likely to exist within the Wairiri Valley. It is anticipated that with the exception of clean sands there will be sufficient volumes of the required material types available within the Wairiri Valley. The preliminary design stage investigations will examine these materials in detail to assess the available volume and their compaction characteristics. One potential construction consideration will be the need to dry out some of the valley fill soils to reduce their water content prior placing in the dam embankment. For this reason construction of the dam embankment should be programmed for the drier summer months, to avoid the likely material handling problems and additional costs that would arise from construction during winter.

Outlet Canal Construction

It is expected that the outlet canal will only encounter Eyre Group rocks and the overlying colluvium and loess. The preliminary investigations will need to establish the variation in geology along the canal length. Design of the canal will consider the effect on the adjacent slope stability of excavating into the slope toe. These are unlikely to be major design issues.

Canal Seepage Losses

An allowance has been made in the preliminary design of the reservoir outlet canal to line 50% of its length. This canal is particularly susceptible to leakage losses, as it will be alternating between periods of use and non-use. When the canal is not in use the water will drain from the canal exposing the base lining material. While the lining for seepage control will not be at the surface, it will still be subject to some drying out, that could lead to cracking and increased leakage potential when the water first flows down the canal again. Once wet, these materials have the tendency to swell and reseal, provided the leakage has not been sufficiently great to lead to a piping failure. This is a matter to be resolved during the canal design.

Losses along the main headrace canal also pose a risk that in the early years of operation before sediment, entering from the rivers has contributed to sealing. It should be noted that construction of the RDR canals made no special effort to provide a lining and leakage from these is limited. It is necessary, however, to undertake site investigations along the alignment of the headrace canal to assess the geotechnical properties of the soils and to determine how these relate to canal design and cost. Design criteria can be established for the canals and suitable material to be compacted as a insitu lining are expected to be available along the canal route.

It will also be important during construction to pay attention to the interface between structures and the canal earthworks, as these locations have a greater potential to leak. Construction supervision will be extremely important to maintain the integrity of the scheme.

9.2.3 Operational Risks

Adverse weather conditions

The water budget for the scheme has been based on the period of record from 1967 to 2001. While this period of record includes the very dry period experienced in the late 60's and early 70's there is a possibility that a even dryer period could be experienced that would result in a the scheme running out of water. The climate change could also impact on the reliability of the scheme.

Management of seepage and bywash

The assessment of the water demand on the scheme have made certain assumptions as to the losses in the distribution system due to seepage and bywash. While we believe these estimates to be realistic, if these estimates prove to have underestimated the losses the area able to be served by the scheme would have to be reduced. This could impact on the cost per hectare viability of the scheme.

9.2.4 Can it be built?

The preliminary examination of the various technical issues affecting the feasibility of the dam construction has not found any technical issues, which would prevent the design and construction of a water storage reservoir in the Wairiri valley. The technical uncertainties, which have been identified, will be more fully considered during the preliminary design phase. Contingency sums have been allowed in the cost estimates to cover the financial risks associated with these uncertainties. Therefore at the feasibility level of project detail the cost estimates are considered a realistic reflection of the costs of building the scheme.

9.3 Economic Feasibility

The final assessment of affordability/bankability must be made by considering all of the perspectives involved. These include:

- Affordability at the farm gate to the farmers;
- Strong regional economics to ensure down stream processing and marketing support;
- Sufficiently robust structures to provide confidence from the financiers; and
- Community value in terms of jobs and wealth creation.

The price of water has been estimated to be within the range of an up-front capital contribution of $1,450 - $1,600/ha, plus annual charges of between $189 - $229/ha/yr. At the farm gate, there are sufficient cash farm surpluses from a range of farming activities including dairy, high end arable, above average beef and deer, and dairy support, which are sufficient to pay for the cost of the community supplied water.

At the regional level, this scheme could boost the total annual regional output of Canterbury by $647 million and increase the total regional value added by $241 million.

The financial structures that must be put in place have yet to be determined, and will depend upon the collective stakeholder's priorities. It would be safe to assume at this stage of the study that there is a sufficient range of structural options available for all stakeholders needs to be met. It is premature at this stage to be specific on the guarantees that may be required by the funders of the scheme. These may include underwriting of debt by either local or national government.

It is anticipated that the scheme will increase the total regional employment by 2,630 full time equivalent jobs. This will significantly distribute wealth throughout the community. The creation of jobs would be across the whole spectrum of employment, including unskilled, skilled, trades and professional. It would be likely that this development would create a shortage of skilled workers within the rural communities.

On the basis of the above assessments, a community irrigation scheme is financially viable and will be economically beneficial to the whole Central Plains area and is therefore both affordable and bankable, remembering that this does require significant changes in land use practices.

9.4 Environmental Feasibility

9.4.1 Environmental Risks

While there are many environmental issues associated with the CRWE project only a few have the potential to affect the feasibility of the scheme. These key issues have been discussed in section 6 and an assessment of the risk they pose to the feasibility of the scheme is outlined below.

Consents required.

There are a number of consents required in relation to this project including: permits for the use and discharge of water, permits for the construction and operation of the scheme components and land use consents for the occupation and use of land from Environment Canterbury and the Selwyn District Council.

These include:

- Take water from Rakaia River
- Divert and discharge water from the Rakaia River
- Discharge sediment into the Rakaia River
- Take from Waimakariri River
- Divert and discharge from the Waimakariri River
- Discharge sediment into the Waimakariri River
- Use water for irrigation
- Discharge of bywash water
- Land use permits for the intake works, reservoir, pump stations, pipelines, and all canals and associated works
- Works in the bed of the Rakaia and Waimakariri River
- Consents to construct the dam
- Consents for any enhancement works
- Consents associated with the road re-routing

Water quality in reservoir

During the initial years it is anticipated that water quality problems will be experienced in the Wairiri Reservoir with anoxic conditions developing in the lower levels of the reservoir. This is not an unusual condition in a new reservoir. The design of the outlet will be such that water can be drawn off at different levels so only the well oxygenated near surface water is discharged for irrigation. Clearing of the basin of vegetation prior to flooding can also help alleviate this potential problem.

Take from Rakaia River

As the take from the Rakaia river is within the NWCO and no more than minor impacts on the Rakaia River are anticipated there is a low risk that this take will not be granted.

Take from Waimakariri River

The taking of 40 m^3/s from the Waimakariri River is a relatively large take from the Waimakariri River. While this take is within the rules of the PWRRP some detrimental environmental effects will be experienced in the river. These impacts primarily relate to the ideal conditions for salmon fishing being reduced from 11 to 7 days per year on average and the removal of the stimulus for salmon to move upstream during prolonged periods of low flow. The low and stable flow conditions that may affect the migration of salmon are infrequent occurrences, however this will have little effect on the overall sustainability of the salmon resource. This is likely to attract opposition to the take and there is a risk that the full 40 m^3/s may not be granted.

Impacts on Groundwater

The irrigation of 84,000 ha of the Central Plains will result in increases in groundwater level under the scheme area of up to 18 m. This effects reduces towards the coast. Further inland the increased groundwater levels will have little impact. However at the edge of the confined zone increased groundwater levels of about 2 m will have an impact on drainage of periodically wet land with land staying wet for longer periods more frequently.

The increased groundwater levels will result in increased flow in the spring fed streams.

Increased drainage from irrigated land will result in increased leaching of nitrate to groundwater. Based on the modelled drainage and groundwater flows it is estimated that groundwater nitrate-N levels could increase on average by between 3.5 and 4.5 g/m^3 to about 7.0 g/m^3. This is below the Drinking Water Standards for New Zealand 2000. However, other contributions to nitrate in groundwater exist and the increase could result in local or periodic increases of nitrate-N concentration to above the maximum drinking water concentration of 11.3 g/m^3.

The increased nitrate-N levels in groundwater will also result in increased Nitrate-N levels in the spring fed streams flowing into Lake Ellesmere. However as the lowland streams typically have DIN concentrations well in excess of the guideline value for phytoplankton growth, nitrate is not a growth limiting nutrient and control of phytoplankton growth therefore is focussed on phosphorus as this is the growth limiting nutrient. It is therefore likely that increased nitrate levels in the groundwater will not have significant adverse effects on the instream values of the lowland streams.

9.4.2 Mitigation Options

Water quality in reservoir

To mitigate the possible development of anoxic conditions in the reservoir the design of the outlet will be such that water can be drawn off at different levels so only the well-oxygenated near surface water is discharged for irrigation. Clearing of the basin of vegetation prior to flooding can also help alleviate this potential problem.

Take from Rakaia River

Keeping the take within the NWCO conditions and providing fish screens will mitigate against potential adverse effects of the Rakaia take.

Take from Waimakariri River

The impacts on salmon fishability and salmon passage during low flows cannot be easily mitigated without compromising the reliability of the scheme during critical periods. These impacts could be reduced if the size of the scheme were reduced.

Impacts on Groundwater

Various interested parties may perceive many of the potential effects relating to groundwater as being positive and by others as being negative. For example, increased groundwater levels and pressures near the coastline will benefit spring flows and groundwater abstractors but may impact upon farming practices in these areas. Therefore, any mitigation measures must be mindful of these types of competing issues.

It should also be noted that the effects reported here have been assessed for the period 1994 to 1999. Since 1999 additional abstraction wells have been installed and consented. Furthermore, it is almost certain that additional wells will continue to be installed in the area downgradient of the community supply zone over the next few years in response to changing farming practices in areas where groundwater is a viable abstraction resource.

Abstraction from these additional wells will offset at least some of the effects discussed in this report. The number and location of new wells (since 1999) and potential wells will need to be investigated in more detail as part of a future groundwater study.

It is worth noting that Ecan estimate the current average abstraction rate from irrigation wells in the Central Plain area varies from 3 to 5 m^3/s.

In addition to wells that either have been or are likely to be installed in the future, abstraction wells may also be used to specifically offset anticipated effects. Various methods are available, including:

- Promoting further groundwater use in specific areas to offset localised effects.
- Installation of a coordinated series of wells to mitigate effects across larger areas. Abstracted groundwater could either be utilised or diverted to surface water bodies.

Other available mitigation measures include improvement of drainage in selected areas.

Mitigation options for groundwater quality issues are likely to focus on improving farming practice and wastewater disposal in the Central Plains area. The possibility of an environmental "warrant of fitness" for farms involved in the CPWE scheme has been suggested. This may include measures such as:

- ensuring stock are prevented from entering open water ways;
- utilising best practice with respect to farm management of nitrate loadings; and
- ensuring septic tanks and dairy effluent ponds are managed so that discharges to groundwater are minimised.

The mitigation effects for groundwater quality will also be effective in reducing nutrient quality in the spring fed streams.

9.4.3 Is it Consentable

Of the issues discussed above the two that pose the greatest risk in terms of obtaining consents are the take of up to 40 m^3/s from the Waimakariri River and the use of water resulting in increased groundwater nitrate concentrations and groundwater levels.

The taking of up to 40 m^3/s from the Waimakariri River is seen as a large take for a river the size of the Waimakariri River and would be the largest take granted from any river in Canterbury. While the maximum take is large it needs to be seen that the take is for flows up to 40 m^3/s within the allocation rules proposed in the PWRRP. It is therefore considered that the consent to take up to 40 m^3/s has a reasonable probability of being granted. Sensitivity analyses undertaken indicate that it is possible to reduce the size of the take from the Waimakariri River if a lower level of reliability is accepted.

Obtaining consents to use water for irrigation and the associated discharge of nitrate to groundwater will not be easy, as there are significant impacts on people downstream. The issues of nitrate levels in groundwater and reduced drainage due to increased groundwater levels will need to be worked through with potentially affected parties to identify if appropriate mitigation measures can be identified.

9.4.4 Draft Natural Resources Regional Plan

The Discussion Draft Canterbury Natural Resources Regional Plan was released in October 2001 and is available for public comment until 29 March 2002. The draft document is extensive and a review of its provisions is outside the scope of this feasibility study. While at present, the draft document has not statutory significance, it does outline the thinking of Ecan in relation to many of the consenting issues outlined in this section.

By way of example, the draft Chapter 7: Water Quality, contains proposed rules for activities such as the use of water for irrigation purposes which range from permitted, for irrigation where the groundwater concentrations of nitrate are less than 50% of the maximum acceptable value (MAV = 11.3 g/m^3) and the area is less than 50 ha, discretionary where the groundwater nitrate concentrations are between 50 – 100 % of MAV and non-complying where the groundwater concentrations exceed MAV.

There are draft rules relating to stock access to waterways, pesticide and fertiliser use, discharges of wastewater from a variety of sources, bores, excavations and intake galleries, and many more.

There is a need to review this document and make comment on it, as this will ultimately have a direct impact on the consentability of the scheme.

9.5 Social Feasibility

9.5.1 Social Risks

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

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

In addition to the social and economic effects of land use changes arising from accessing water from the proposed irrigation scheme, there are a number of other direct and indirect effects that are anticipated. The effects this assessment has identified have been organised into a number of themes: the local business sector, employment, the local economy, cost, community organisations, services and schools, disadvantaged groups, compensation, construction, recreational activities, risks to residents, site, visual and water. Under each theme there is a list of specific points that describes the nature of these anticipated effects.

A major irrigation project such as proposed for the Central Plains involves several strands of social change. The nature of these social changes will vary over the life cycle of the project, including the planning, construction and operational phases.

9.5.2 Mitigation Measures

Monitoring the outcomes of the scheme from the point of view of farmers and their families, and other affected parties, will require the development of a detailed profile of farmers and families in the area. Additional information about water based recreation and effects may also be required once the water sources and scheme configuration to be put forward for consent applications have been confirmed. Further work is needed on mitigation strategies, and local input should be sought to develop them. It would be useful to establish a system to manage the social impacts of the scheme. One option to investigate in this regard is a community trust fund.

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

9.6 Cultural Feasibility

The proposed options for a reservoir and canal network within the Malvern Hills area is currently located in an area that contains a generally high density of sites and areas of significance to Ngäi Tahu, Ngäti Mämoe and Waitaha.

Given the abundance of food resources, the suited climate for cultivation and the fact that this area was on-route to mountain passes, all contributed to the fact that historical occupation in, and use of, Waikirikiri/Selwyn River was generally of a larger scale than other foothill areas in the Canterbury region.

With this occupation, Ngäi Tahu applied their tikanga and kawa (cultural rites and customs) to the environment in order to protect and sustain the resources within the area that they harvested. These values remain today, having been passed down from generation to generation in the role of kaitiaki (guardianship).

With regard to the various options that this report has assessed, particular options have been assessed as having a have high impact on Ngäi Tahu cultural values are therefore it is recommended that the following options do not progress in their current form:

- Discharge from the Wairiri Reservoir to Headrace Canal via the Selwyn River
- Discharge from the Wairiri Reservoir to Headrace Canal via Buried Canal in the Selwyn River
- Waimakariri River to Springfield Canal Scheme
- Waimakariri River to Springfield Canal Scheme – Low Flow Replacement Option

At the point at which a final combination of options has been decided upon, it will be necessary to have further research and identification carried out on the area, in particular archaeological surveys. Once this level of detail has been established, it will be necessary to revisit this report and re-analyse the options against this new or more detailed information.

9.6.1 Mitigation Measures

The following proposed options have a common set of recommendations to address cultural impacts in relation to the Wairiri Valley Reservoir, Rakaia to Wairiri Pumped Canal, Canal for Reservoir Via Homebush Road to Main canal, Central Headrace Canal, Rakaia River Take, Waimakariri River Take, Rakaia Intake, and the Waimakariri Intake.

The recommendations are as follows:

- That a memorandum be signed between the owners of the scheme and kaitiaki Rünanga and that the agreement apply to all work related to the project and the ongoing future management and operation of the water scheme;
- That an Archaeological Survey be undertaken by persons agreed to by kaitiaki Rünanga of all areas to be affected in any way by the proposed projects;
- That an Accidental Discovery Protocol be entered into with the kaitiaki Rünanga to manage the potential unearthing of any historical site;
- That access to all sites prior to and during construction be permitted for kaitiaki Rünanga, and that this ongoing access be permitted after work is completed pending practical accessibility issues. In particular, this access will allow ongoing monitoring and assessment of impacts on cultural sites;
- That no barrier be made to tangata whenua accessing to traditional trail routes.

The following proposed options have a common set of recommendations to address cultural impacts in relation to Rakaia to Wairiri Pumped Canal, Canal for Reservoir via Homebush Road to Main canal, and the Central Headrace Canal.

The recommendations are as follows:

- Given the size and volume of the proposed canal, this is used to support a vegetation corridor that encourages the rejuvenation of native plant species on the plains and provides a corridor for the movement of native bird species;
- That the canal system be constructed in such a way to ensure the following concerns are met:
  - the canal waters are not artificially mixed with those of the natural water body;
  - that the natural water body is not altered in course, flow volume or character;

- that canal mechanisms are constructed to withstand catastrophic events;
- that flow within the system can be stopped in the event of a catastrophic event.

In conjunction with those recommendations already listed above, the following lists options with recommendations specific to that option.

Wairiri Valley Reservoir

- Ensure no impediments, including damming, interferes with the main flow of the Waikirikiri/Selwyn River;
- That any proposed supplementary enhancement flows to the Waikirikiri/Selwyn Catchment are integrated via a wetland of sufficient size to address tangata whenua concerns regarding mixing of waters;
- Ensure all necessary testing and measures are taken to identify risks related to the on-going safety of a dam structure;
- That design of all works reflect the surrounding landscape and that the reservoir be integrated into the surrounding landscape through use of vegetation enhancement etc.;
- Those other valleys within the Waikirikiri/Selwyn Catchment are enhanced to supplement the natural water flows that would have naturally gathered within the Wairiri valley i.e. no net loss of water yield;
- Areas of repo raupö within Wairiri valley lost through inundation are created/enhanced within other areas of the catchment;
- All resident fish populations are caught and transferred from the valley to alternative locations within the area;
- All vegetation with cultural/landscape value lost through inundation are planted throughout alternative areas of the catchment;
- Should fish already resident within the Wairiri Valley that can adapt to greater water volumes be left resident within the reservoir, a fish pass mechanism must be integrated into the dam design to provide for adult migration;
- Where place names are directly impacted through proposed works, tangata whenua have an opportunity to uphold and reflect those names in those names applied to the modified environment i.e. the proposed reservoir upholds the name Wairiri;

Central Headrace Canal

- That glacial flour/sediment removed from the canal during periodic cleaning are disposed of or used so as to not adversely impact on the landscape of the area;

Rakaia Take/Waimakariri Take

- That all abstractions from the Rakaia River/Waimakariri River be at a level that ensures the river continues to flow at a rate that sustains the life supporting capacity and quality of the river;
- Abstraction shall not reduce the flow of the Rakaia River/Waimakariri River to a point that causes adverse effects within that environment including that the river is able to maintain a diverse braid network and inundation of weeds does not increase.

Rakaia Intake/Waimakariri Intake

- That sediment from stilling basins and dredged from the headrace canal are disposed of, or used, to ensure this sediment does not impose adverse impacts on the river or surrounding landscape;
- To ensure fish do not enter the system, a fish screen is installed at the intake from the Rakaia River/Waimakariri River to the canal system.

The following options are identified as having considerable cultural impacts and it is recommended that they be not progressed:

- Discharge to the Selwyn River
- Buried Canal
- Springfield canal and take swap

9.7 Scheme Feasibility

9.7.1 Overall Feasibility

Considering the technical, economic, social, cultural and environmental factors raised through out this study has lead to the conclusion that a water enhancement scheme for the Central Plains:

- Can be built
- Is affordable
- Will have effects that can be mitigated

And is therefore feasible.

10.1 Introduction

This section provides recommendations as to the work required to progress this project through to the resource consenting stage. The Steering Committee has developed a strategy, which in the first phase includes the resource consent investigations. No recommendations are made in relation to land acquisition strategies, financial structures, or marketing and uptake assessment, although these activities are all essential to the ultimate success of the project.

10.2 Programme

A programme has been developed in conjunction with the CPWE steering committee, which outlines the four phase staged progression of this water enhancement project. This programme is contained in Figure 10-1.

10.3 Geotechnical Investigations

Geotechnical investigations are required for the following:

10.3.1 Canal Lining Materials

The location of suitable lining materials and their characteristics need to be established. This includes a survey along the line of the proposed headrace canal and the identification of suitable borrow pits enroute. Testing of the material should include physical properties including grain size distribution, density, and permeability, both insitu and recompacted.

10.3.2 Waianiwaniwa Valley

The Waianiwaniwa Valley is still an option for a reservoir, however the geotechnical understanding of this valley system is not equivalent to the understanding of the Wairiri Valley. Geotechnical investigations as outlined in Section 4 for the Wairiri Valley are required to make an informed evaluation of the potential of this valley as an alternate to the Wairiri Valley.

10.3.3 Mining Activity

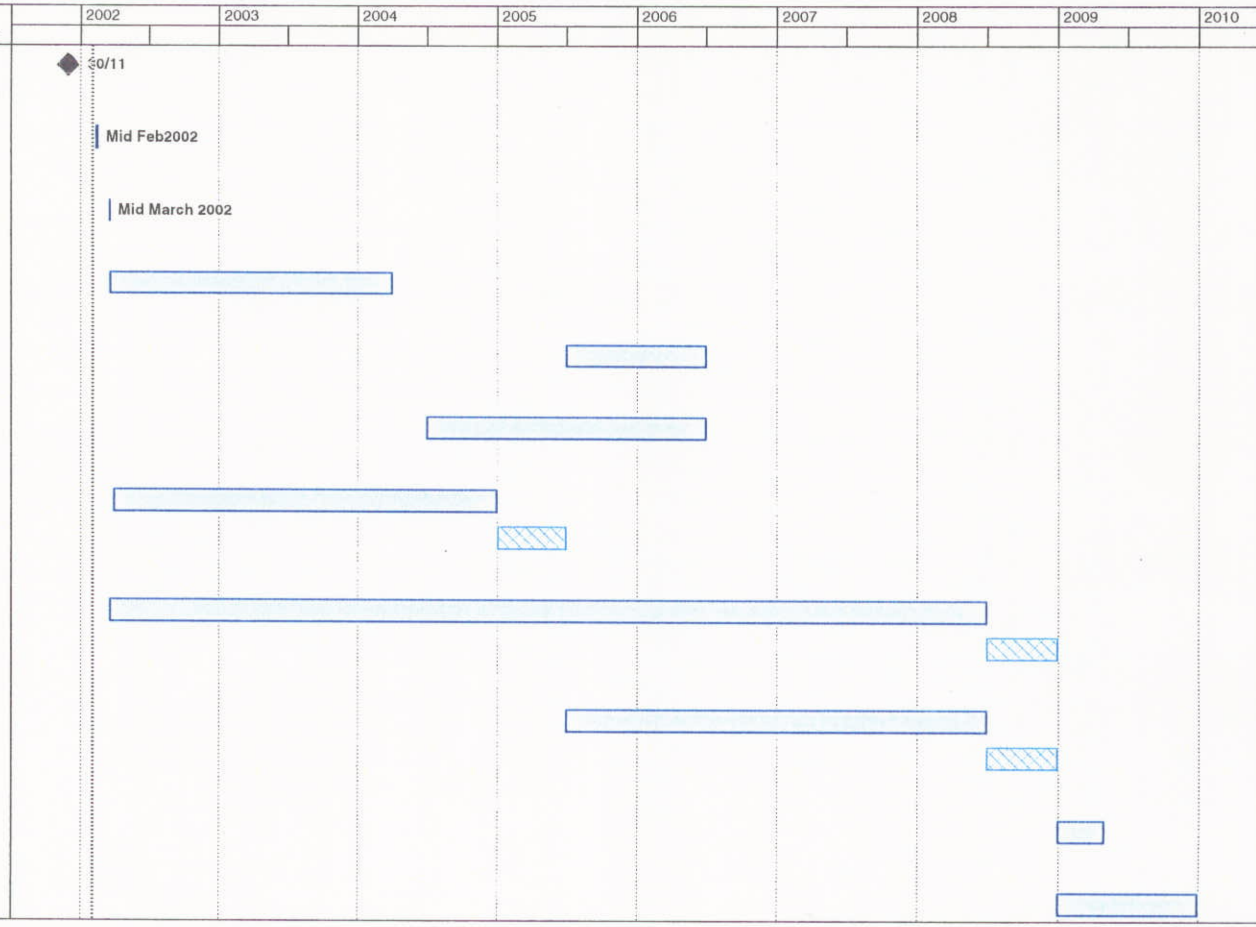
Design investigations for the dams will necessitate further exploratory drilling within the foundation footprint, including the saddle dams, and these should confirm that coal is not present in the near surface geology. While this drilling is not recommended for the next phase, an in-depth assessment of the mining activities in the Wairiri/Coalgate area is warranted, to fully assess the potential impact on any proposed structures. This should include engaging with past and present coal miners in the area.

CENTRAL PLAINS WATER ENHANCEMENT - PRELIMINARY PROGRAMME

NOTE : This programme is based on the assumption that the Councils will decide to proceed with irrigation and enhancement.

29 January 2002

ID	ID	Task Name	Duration Mths
1	1	Complete Feasibility Study	–
2			
3	2	Report to Councils	-
4			
5	3	Council Decision to Proceed	-
6			
7	4	Survey, Geotech, Preliminary Design	24
8			
9	5	Establish Company Structure	12
10			
11	6	Land Acquisition	48
12			
13	7a	Resource Consents/Land Use Consents, Designations	33 +
14	7b	Appeal/ Contingency	(6)
15			
16	8a	Consultation Process - Consents, Gaining Commitment/UpTake	75 +
17	8b	Contingency	(6)
18			
19	9a	Design and Construction	36
20	9b	Design and Construction Contingency	6
21			
22	10	Commission	5
23			
24	11	Maintenance	12



Project: PrelimProgProject1c.mpp
Date: Wed 30/01/02

Task	Milestone	Rolled Up Split	External Tasks
Split	Summary	Rolled Up Milestone	Project Summary
Progress	Rolled Up Task	Rolled Up Progress	

Figure 10 -1: Programme

10.3.4 Wairiri Valley Sediments

This feasibility study has assumed that all of the sediments beneath the proposed dam would be removed to found the dam on stronger material overlying the weak sandstone base. An assessment of the engineering properties of this material should be considered, to identify the potential to found the dam at a shallower depth.

10.4 Survey

10.4.1 Headrace Canal

A line survey with limited cross sections of the main headrace canal and the main outlet canal should be undertaken. This should also include more detailed topographical survey of the intake sites and the terraces where the canals would pass out onto the upper plains. This will entail a combination of GPS and aerial survey techniques.

10.4.2 Waianiwaniwa Valley

A topographical survey should be undertaken for the Waianiwaniwa Valley to determine the stage/storage (height/volume) relationship and to accurately define the top water surface shoreline. This will predominantly be from aerial surveys with ground-truthing provided by GPS survey.

10.4.3 Distribution Canals

The route of the distribution canals cannot be defined at present. There is limited survey data from previous investigative work, however much of the Community Supply Zone has no survey data available. Limited survey, confined to main roads to infill existing survey information should be undertaken.

10.5 Environmental Studies

10.5.1 Groundwater

The following topics are recommended for further study.

- Assessment of effects on groundwater levels and spring flows allowing for predicted future increases in groundwater use, including an assessment of the number and location of new wells (since 1999) and potential wells will need to be investigated in more detail.

- Identification of areas where changes in groundwater levels and pressures are perceived as having a significant negative effect and identification of mitigation options.
- Further studies on land use changes and potential groundwater quality issues, including an evaluation of the effects of increased water and fertiliser application and stock densities to the Central Plains irrigated area on flows and enrichment of lowland streams.
- Further studies on the potential effects on the receiving environment (including spring fed streams) of changes in groundwater quality, with specific studies on the effects of both increased flows and water quality changes on Lake Ellesmere (Te Waihora).
- Mitigation options for groundwater quality issues are likely to focus on improving farming practice and wastewater disposal in the CPWE area. The possibility of an environmental "warrant of fitness" for farms involved in the CPWE scheme should be investigated.

10.5.2 Surface Waters

The following studies are recommended for the surface waters of the Central Plains.

- Obtain habitat information in a representative, braided reach of the Waimakariri River below the gorge during summer low flows and model the effects of the 40 m^3/s take on downstream habitats and bedload transport.
- Ratify the recommended flow (2.5-4 m^3/s) for trout in the Selwyn River by conducting IFIM habitat surveys in a braided reach downstream of the main race for the CPWE scheme and at Coes Ford at a moderate flow (suggested range 3-8 m^3/s).
- Conduct soil and vegetation analysis in the Wairiri and Waianiwaniwa Valleys for use in obtaining estimates of BOD in the reservoir.
- Establish meteorological stations at strategic locations in the Wairiri and Waianiwaniwa Valleys to monitor wind data for use in modelling mixing of the water column in the reservoir using an existing dynamic reservoir simulation model. This will allow for planning and design of mitigation options for water quality.
- Conduct a more detailed assessment of the possible alleviation of hypolimnetic anoxia over time in the reservoir.
- Upon completion of further studies, if water quality of the reservoir is likely to be favourable for fish life, then conduct desktop study considering options for establishing a recreational fishery.
- Determine habitat requirements for breeding Wrybilled plover, plus feeding habitat of black-fronted tern and black-billed gull on braided river floodplains.

- Model the effects of the CPWE takes on dilution of PPCS effluent and discharges from the proposed Waimakariri District Sewerage Project in the lower Waimakariri River.
- Model inflows and water losses of Lake Ellesmere during the dry season and use the results in a desktop assessment of the effects of flow augmentation in the lower Selwyn River on lake levels and water quality in Lake Ellesmere.
- Confirm a strategy for the relocation of the Canterbury mudfish to a reserve specifically designed for them, possibly in the Glendore catchment.
- Assess the potential impact the Draft Natural Resources Regional Plan may have on the proposed scheme.

10.6 Social

Consultation with the communities of interest is recommended to continue. Further work is needed on:

- Mitigation strategies, with local input to develop them.
- Establish a system to manage the social impacts of the scheme. One option to investigate in this regard is a community trust fund.
- Development of a more detailed profile of farmers and families, communities and other affected parties in the area for monitoring the outcomes of the scheme from their point of view.
- Establish the community of interest impacted by possible reservoirs within the Waianiwaniwa Valley, and engage in consultation with them.

10.7 Cultural Mitigation Measures

Kaitiaki Rūnanga should be engaged at a deeper level specifically to agree on protocols for the advancement of this project. From this process, agreements can be reached that apply to all work related to the project and the ongoing future management and operation of the water scheme. This may include:

- Archaeological Surveys.
- Accidental Discovery Protocols.
- Site access during construction.
- Barriers to tangata whenua accessing to traditional trail routes.
- Supplementary enhancement flows via wetlands to address tangata whenua concerns regarding mixing of waters;
- Ensure the on-going safety of a dam structure;

- That the life supporting capacity and quality of the rivers are maintained.
- To ensure fish do not enter the system.
- Other matters of specific detail as outlined in Section 8.

10.8 Enhancement Opportunities

Many enhancement opportunities have been identified in this study, including:

- Recreational opportunities for use of the reservoir as a contact recreation venue, (sailing, windsurfing, power boating, skiing, jet skiing, swimming etc.) and possibly fishing.
- Creation of new recreational water bodies that are constantly full of water for the above activities through the careful consideration of other construction activities.
- Opportunities for areas adjacent to existing streams to be developed as wetlands where bypass flows from the scheme could be discharged.
- Use of canals for swimming, canoeing, kayaking and multi-sports events and wild fowl shooting.
- Non water based recreational activities include tramping along the canal banks, picnicking and photography.
- Use of canals as an important rural water source for fire fighting purposes.

It is recommended that community based focus groups further develop the range of ways in which community values may be enhanced by the provision of the infrastructure required for this scheme.

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Appendix A – Farm Budgets

Dairy			
REVENUE		per kg MS	Total
Milksolids	1110 Price	4.59	5095
Cattle net of Purchases		0.49	544
Other		0.03	
GROSS FARM REVENUE			**5639**
FARM WORKING EXPENSES			
Livestock Purchases		0.01	11.1
Wages		0.41	455.1
Animal Health		0.15	166.5
Breeding		0.08	88.8
Shed Expenses		0.06	66.6
Electricity		0.13	144.3
Feed		0.51	566.1
Fertiliser		0.34	377.4
Freight		0.03	33.3
Seeds		0.03	33.3
Shearing		0	0
Weed and Pest		0.02	22.2
Fuel		0.06	66.6
Vehicle		0.06	66.6
Repairs & Maint		0.16	177.6
Rates		0.04	44.4
Communication		0.02	22.2
Insurance		0.03	33.3
Acct, Legal,Cons		0.02	22.2
Administration		0.01	11.1
Other		0.02	22.2
Packing		0	0
Irrigation			80
Drawings			
CASH FARM EXPENDITURE			**2511**
CASH FARM SURPLUS			**3128**

REVENUE	SHEEP		Total
Lamb Trading	38	63.75	2422.5
Ewe Breeding /	8	125.15	1001.2
Wool	8	11.2	89.6
Other			
GROSS FARM REVENUE			**3513.3**
FARM WORKING			
16 SU/Ha		per SU	
Livestock Purchases			2074.72
Wages		3.67	58.72
Animal Health		3.41	54.56
Breeding		0.12	1.92
Shed Expenses		0	0
Electricity		0.53	8.48
Feed		2.88	46.08
Fertiliser		6.19	99.04
Freight		0.99	15.84
Seeds		1.76	28.16
Shearing		1.89	30.24
Weed and Pest		1.52	24.32
Fuel		1.73	27.68
Vehicle		1.33	21.28
Repairs & Maint		2.51	40.16
Rates		1.08	17.28
Communication		0.56	8.96
Insurance		0.74	11.84
Acct, Legal,Cons		1.08	17.28
Administration		0.11	1.76
Other		1.43	22.88
Packing			0
Irrigation			80
CASH FARM			**2691.2**
CASH FARM SURPLUS			**822.1**

BEEF FINISHING			
REVENUE			Total
Beef	211.02		3376.32
GROSS FARM REVENUE			**3376.32**
FARM WORKING EXPENSES			
16 SU/Ha		per SU	
Livestock Purchases		76.66	1226.56
Wages		2.75	44
Animal Health		4.75	76
Breeding		0	0
Shed Expenses		0	0
Electricity		0.45	7.2
Feed		11.75	188
Fertiliser		8.75	140
Freight		2.25	36
Seeds		3.76	60.16
Shearing		0	0
Weed and Pest		1.52	24.32
Fuel		1.73	27.68
Vehicle		1.33	21.28
Repairs & Maint		2.51	40.16
Rates		1.08	17.28
Communication		0.56	8.96
Insurance		0.74	11.84
Acct, Legal, Cons		1.08	17.28
Administration		0.11	1.76
Other		1.43	37
Packing			0
Irrigation			80
CASH FARM EXPENDITURE			**2065.48**
CASH FARM SURPLUS			**1310.84**

DEER FINISHING		
REVENUE		Total
Venison	284.2	4547.2
GROSS FARM REVENUE		**4547.2**
FARM WORKING EXPENSES		
16 SU/Ha	per SU	
Livestock Purchases	165	2640
Wages	2.04	32.64
Animal Health	4.08	65.28
Breeding	0	0
Shed Expenses	0	0
Electricity	0.45	7.2
Feed	5.43	86.88
Fertiliser	8.75	140
Freight	1.68	26.88
Seeds	3.76	60.16
Shearing	0	0
Weed and Pest	1.52	24.32
Fuel	1.73	27.68
Vehicle	1.33	21.28
Repairs & Maint	2.51	40.16
Rates	1.08	17.28
Communication	0.56	8.96
Insurance	0.74	11.84
Acct, Legal, Cons	1.08	17.28
Administration	0.11	1.76
Other	1.43	37
Packing		0
Irrigation		80
CASH FARM EXPENDITURE		**3346.6**
CASH FARM SURPLUS		**1200.6**

DAIRY SUPPORT			
REVENUE	15000		Total
Heifer Grazing	0.25	0.12	450
Silage	0.3	0.18	810
Cow wintering	0.45	0.19	1282.5
GROSS FARM REVENUE			**2542.5**
FARM WORKING EXPENSES			
	SU/Ha	per SU	
Livestock Purchases			
Wages		16	16
Animal Health		0	0
Breeding		0	0
Shed Expenses		0	0
Electricity		9	9
Feed		540	540
Fertiliser		340	340
Freight		35	35
Seeds		50	50
Shearing		0	0
Weed and Pest		25	25
Fuel		27	27
Vehicle		21	21
Repairs & Maint		40	40
Rates		17.28	17.28
Communication		8.96	8.96
Insurance		11.84	11.84
Acct, Legal, Cons		17.28	17.28
Administration		1.76	1.76
Other		22.88	43
Packing		0	0
Irrigation		0	80
CASH FARM EXPENDITURE			**1283.12**
CASH FARM SURPLUS			**1259.38**

WATER AFFORDABILITY MODEL

CASH FARM SURPLUS /Ha			DAIRY 3610.8		ARABLE 1492.8		SHEEP 1240.14		BEEF 1911.8		DEER 1761.32		DAIRY 1841.4
Model Property	200 Ha		722160		298560		248028		382360		352264		368280
Servicing Existing Debt 300000 @	8 %		24000		24000		24000		24000		24000		24000
Drawings			30000		30000		30000		30000		30000		30000
Interest on Development		Cost /	Total	Cost /	Total	Cost /	Total	Cost /	Total	Cost /	Total	Cost /	Total
Irrigation	0.08	2000	32000	2000	32000	1500	24000	1500	24000	1500	24000	1500	24000
Other	0.08	8760	140160	100	1600		0	100	1600	520	8320	50	800
Stock, plant	0.08	3260	52160	650	10400		0	1350	21600	2100	33600	200	3200
Total		14020	224320	2750	44000	1500	24000	2950	47200	4120	65920	1750	28000
Capital Contribution		1422	22752		22752		22752		22752		22752		22752
Total Interest and Drawings			301072		120752		100752		123952		142672		104752
Surplus Total			421088		177808		147276		258408		209592		263528
Per Ha			2105.44		889.04		736.38		1292.04		1047.96		1317.64
Capital Repayment 20			169420		56720		44220		58720		70420		46720
Tax			58032		52668		51008.4		75648		53983.2		84384
Surplus Available for Water Charges			193636		68420		52047.6		124040		85188.8		132424
per Ha			**968.18**		**342.1**		**260.238**		**620.2**		**425.944**		**662.12**

Appendix B1

No Springfield/Sheffield

Stated in 2001 Nominal $

Base Case		
Scheme size	100%	(84000 ha)
Debt	50%	
Finance rate	7.00%	
Repayment term	20	years
Equity	50%	
Return on equity	0%	
Inflation rate	2.00%	
Depreciation type	DV	

		No inflation
Upfront capitial cost	$	123,650,575
	Ha	1,472
Annual operating cost Y_9 - Y_{28}	$	17,136,000
	Ha	204
	$	5,460,000
Annual operating cost Y_{29} - Y_{43}	Ha	65

Debt/Equity		Base Case 50/50	60% Debt 40% Equity	40% Debt 60% Equity
Upfront capitial cost	Ha	1,472	1,200	1,732
Annual operating cost Y_9 - Y_{28}	Ha	204	235	174
Annual operating cost Y_{29} - Y_{43}	Ha	65	65	65

Scheme size		Base Case 100%	90%	80%	70%	60%	50%
Upfront capitial cost	Ha	1,472	1,473	1,482	1,511	1,578	1,715
Annual operating cost Y_9 - Y_{28}	Ha	204	195	189	191	192	206
Annual operating cost Y_{29} - Y_{43}	Ha	65	55	49	48	43	43

Reliability		Base case 290	250	220
Upfront capitial cost	Ha	1,472	1,398	1,343
Annual operating cost Y_9 - Y_{28}	Ha	204	197	191
Annual operating cost Y_{29} - Y_{43}	Ha	65	65	65

Finance Rate		Base Case 7.0%	4%	8%
Upfront capitial cost	Ha	1,472	1,407	1,495
Annual operating cost Y_9 - Y_{28}	Ha	204	168	217
Annual operating cost Y_{29} - Y_{43}	Ha	65	65	65

Finance Term		Base Case 20 years	25 Years	30 Years	35 Years
Upfront capitial cost	Ha	1,472	1,472	1,472	1,472
Annual operating cost until debt repaid	Ha	204	191	184	179
Annual operating cost after loan repaid	Ha	65	65	65	0

Equity Return		Base Case 0%	5%	15%
Upfront capitial cost	Ha	1,472	1,472	1,472
Annual operating cost Y_9 - Y_{28}	Ha	204	277	425
Annual operating cost Y_{29} - Y_{43}	Ha	65	139	286

Energy costs		Base Case 6.3 cents	5 cents	8 cents
Upfront capitial cost	Ha	1,472	1,472	1,472
Annual operating cost Y_9 - Y_{28}	Ha	204	195	216
Annual operating cost Y_{29} - Y_{43}	Ha	65	56	77

Appendix B1 (Cont')

Springfield/Sheffield - Equalised

Stated in 2001 Nominal $

Base Case	
Scheme size	100% (84000 ha)
Debt	50%
Finance rate	7.00%
Repayment term	20 years
Equity	50%
Return on equity	0%
Inflation rate	2.00%
Depreciation type	DV

		No inflation
Upfront capitial cost	$	132,347,062
	Ha	1,577
Annual operating cost Y_9 - Y_{28}	$	19,236,000
	Ha	229
Annual operating cost Y_{29} - Y_{43}	$	6,720,000
	Ha	80

Debt/Equity		Base Case 50/50	60% Debt 40% Equity	40% Debt 60% Equity
Upfront capitial cost	Ha	1,577	1,285	1,854
Annual operating cost Y_9 - Y_{28}	Ha	229	262	197
Annual operating cost Y_{29} - Y_{43}	Ha	80	80	80

Scheme size		Base Case 100%	90%	80%	70%	60%	50%
Upfront capitial cost	Ha	1,577	1,588	1,611	1,659	1,751	1,922
Annual operating cost Y_9 - Y_{28}	Ha	229	222	220	227	234	255
Annual operating cost Y_{29} - Y_{43}	Ha	80	72	68	70	68	74

Reliability		Base case 290	250	220
Upfront capitial cost	Ha	1,577	1,501	1,446
Annual operating cost Y_9 - Y_{28}	Ha	229	222	217
Annual operating cost Y_{29} - Y_{43}	Ha	80	80	80

Finance Rate		Base Case 7.0%	4%	8%
Upfront capitial cost	Ha	1,577	1,507	1,600
Annual operating cost Y_9 - Y_{28}	Ha	229	191	243
Annual operating cost Y_{29} - Y_{43}	Ha	80	80	80

Finance Term		Base Case 20 years	25 Years	30 Years	35 Years
Upfront capitial cost	Ha	1,577	1,577	1,577	1,577
Annual operating cost until debt repaid	Ha	229	215	207	202
Annual operating cost after loan repaid	Ha	80	80	80	0

Equity Return		Base Case 0%	5%	15%
Upfront capitial cost	Ha	1,577	1,577	1,577
Annual operating cost Y_9 - Y_{28}	Ha	229	307	465
Annual operating cost Y_{29} - Y_{43}	Ha	80	159	316

Energy costs		Base Case 6.3 cents	5 cents	8 cents
Upfront capitial cost	Ha	1,577	1,577	1,577
Annual operating cost Y_9 - Y_{28}	Ha	229	218	243
Annual operating cost Y_{29} - Y_{43}	Ha	80	69	94

Appendix B1 (Cont')

Springfield/Sheffield - User pays

Stated in 2001 Nominal $

Base Case		
Scheme size	100%	(84000 ha)
- Springfield/Sheffield		10,000 ha
- Other		74,000 ha
Debt	50%	
Finance rate	7.00%	
Repayment term	20	years
Equity	50%	
Return on equity	0%	
Inflation rate	2.00%	
Depreciation type	DV	

		No inflation
Upfront capitial cost	$	23,420,000
	Ha	2,342
Annual operating cost Y_9 - Y_{28}	$	4,120,000
	Ha	412
Annual operating cost Y_{29} - Y_{43}	$	1,910,000
	Ha	191

Debt/Equity		Base Case 50/50	60% Debt 40% Equity	40% Debt 60% Equity
Upfront capitial cost	Ha	2,342	1,908	2,757
Annual operating cost Y_9 - Y_{28}	Ha	412	462	365
Annual operating cost Y_{29} - Y_{43}	Ha	191	191	191

Scheme size		Base Case 100%	90%	80%	70%	60%	50%
Upfront capitial cost	Ha	2,342	2,343	2,352	2,381	2,448	2,584
Annual operating cost Y_9 - Y_{28}	Ha	412	403	398	400	401	414
Annual operating cost Y_{29} - Y_{43}	Ha	191	182	176	175	170	170

Reliability		Base case 290	250	220
Upfront capitial cost	Ha	2,342	2,268	2,212
Annual operating cost Y_9 - Y_{28}	Ha	412	405	400
Annual operating cost Y_{29} - Y_{43}	Ha	191	191	191

Finance Rate		Base Case 7.0%	4%	8%
Upfront capitial cost	Ha	2,342	2,242	2,377
Annual operating cost Y_9 - Y_{28}	Ha	412	356	434
Annual operating cost Y_{29} - Y_{43}	Ha	191	191	191

Finance Term		Base Case 20 years	25 Years	30 Years	35 Years
Upfront capitial cost	Ha	2,342	2,342	2,342	2,342
Annual operating cost until debt repaid	Ha	412	392	380	371
Annual operating cost after loan repaid	Ha	191	191	191	0

Equity Return		Base Case 0%	5%	15%
Upfront capitial cost	Ha	2,342	2,342	2,342
Annual operating cost Y_9 - Y_{28}	Ha	412	530	764
Annual operating cost Y_{29} - Y_{43}	Ha	191	308	543

Energy costs		Base Case 6.3 cents	5 cents	8 cents
Upfront capitial cost	Ha	2,342	2,342	2,342
Annual operating cost Y_9 - Y_{28}	Ha	412	402	427
Annual operating cost Y_{29} - Y_{43}	Ha	191	181	206

Appendix B2 – Model 1

No Springfield/Sheffield

Inflation Adjusted

Base Case		
Scheme size	100% (84000 ha)	
Debt	50%	
Finance rate	7.00%	
Repayment term	20 years	
Equity	50%	
Return on equity	0%	
Inflation rate	2.00%	
Depreciation type	DV	

		Inflation
Upfront capital cost	$	138,646,889
	Ha	1,650
Annual operating cost Y_9 - Y_{28}	Ha	218 - 253
Annual operating cost Y_{29} - Y_{43}	Ha	115 - 152

Debt/Equity		Base Case 50/50	60% Debt 40% Equity	40% Debt 60% Equity
Upfront capital cost	Ha	1,650	1,346	1,943
Annual operating cost Y_9 - Y_{28}	Ha	218 - 253	250 - 285	188 - 223
Annual operating cost Y_{29} - Y_{43}	Ha	115 - 152	115 - 152	115 - 152

Scheme size		Base Case 100%	90%	80%	70%	60%	50%
Upfront capital cost	Ha	1,650	1,652	1,661	1,693	1,768	1,920
Annual operating cost Y_9 - Y_{28}	Ha	218 - 253	207 - 237	200 - 227	202 - 228	202 - 226	216 - 240
Annual operating cost Y_{29} - Y_{43}	Ha	115 - 152	99 - 130	87 - 115	86 - 113	77 - 102	78 - 103

Reliability		Base case 290	250	220
Upfront capital cost	Ha	1,650	1,567	1,505
Annual operating cost Y_9 - Y_{28}	Ha	218 - 253	211 - 246	205 - 240
Annual operating cost Y_{29} - Y_{43}	Ha	115 - 152	115 - 152	115 - 152

Finance Rate		Base Case 7.0%	4%	8%
Upfront capital cost	Ha	1,650	1,579	1,676
Annual operating cost Y_9 - Y_{28}	Ha	218 - 253	182 - 217	232 - 267
Annual operating cost Y_{29} - Y_{43}	Ha	115 - 152	115 - 152	115 - 152

Finance Term		Base Case 20 years	25 Years	30 Years	35 Years
Upfront capital cost	Ha	1,650	1,650	1,650	1,650
Annual operating cost until debt repaid	Ha	218 - 253	205 - 252	197 - 258	192 - 267
Annual operating cost after loan repaid	Ha	115 - 152	127 - 152	141 - 152	0

Equity Return		Base Case 0%	5%	15%
Upfront capital cost	Ha	1,650	1,650	1,650
Annual operating cost Y_9 - Y_{28}	Ha	218 - 253	301 - 336	466 - 501
Annual operating cost Y_{29} - Y_{43}	Ha	115 - 152	198 - 235	363 - 400

Energy costs		Base Case 6.3 cents	5 cents	8 cents
Upfront capital cost	Ha	1,650	1,650	1,650
Annual operating cost Y_9 - Y_{28}	Ha	218 - 253	207 - 237	233 - 275
Annual operating cost Y_{29} - Y_{43}	Ha	115 - 152	99 - 130	137 - 181

Appendix B2 – Model 2

Springfield/Sheffield - Equalised

Inflation Adjusted

Base Case		
Scheme size	100% (84000 ha)	
Debt	50%	
Finance rate	7.00%	
Repayment term	20 years	
Equity	50%	
Return on equity	0%	
Inflation rate	2.00%	
Depreciation type	DV	

		Inflation
Upfront capitial cost	$	148,441,936
	Ha	1,767
Annual operating cost Y_9 - Y_{28}	Ha	262 - 306
Annual operating cost Y_{29} - Y_{43}	Ha	142 - 188

Debt/Equity		Base Case 50/50	60% Debt 40% Equity	40% Debt 60% Equity
Upfront capitial cost	Ha	1,767	1,441	2,080
Annual operating cost Y_9 - Y_{28}	Ha	262 - 306	300 - 343	227 - 270
Annual operating cost Y_{29} - Y_{43}	Ha	142 - 188	142 - 188	142 - 188

Scheme size		Base Case 100%	90%	80%	70%	60%	50%
Upfront capitial cost	Ha	1,767	1,781	1,807	1,860	1,962	2,154
Annual operating cost Y_9 - Y_{28}	Ha	262 - 306	254 - 294	252 - 289	259 - 297	267 - 304	292 - 332
Annual operating cost Y_{29} - Y_{43}	Ha	142 - 188	128 - 169	121 - 159	124 - 164	122 - 160	131 - 173

Reliability		Base case 290	250	220
Upfront capitial cost	Ha	1,767	1,684	1,622
Annual operating cost Y_9 - Y_{28}	Ha	262 - 306	255 - 298	249 - 292
Annual operating cost Y_{29} - Y_{43}	Ha	142 - 188	142 - 188	142 - 188

Finance Rate		Base Case 7.0%	4%	8%
Upfront capitial cost	Ha	1,767	1,691	1,794
Annual operating cost Y_9 - Y_{28}	Ha	262 - 306	220 - 264	278 - 322
Annual operating cost Y_{29} - Y_{43}	Ha	142 - 188	142 - 188	142 - 188

Finance Term		Base Case 20 years	25 Years	30 Years	35 Years
Upfront capitial cost	Ha	1,767	1,767	1,767	1,767
Annual operating cost until debt repaid	Ha	262 - 306	247 - 305	238 - 312	232 - 324
Annual operating cost after loan repaid	Ha	142 - 188	157 - 188	173 - 188	0

Equity Return		Base Case 0%	5%	15%
Upfront capitial cost	Ha	1,767	1,767	1,767
Annual operating cost Y_9 - Y_{28}	Ha	262 - 306	351 - 394	527 - 571
Annual operating cost Y_{29} - Y_{43}	Ha	142 - 188	230 - 276	407 - 453

Energy costs		Base Case 6.3 cents	5 cents	8 cents
Upfront capitial cost	Ha	1,767	1,767	1,767
Annual operating cost Y_9 - Y_{28}	Ha	262 - 306	249 - 287	279 - 331
Annual operating cost Y_{29} - Y_{43}	Ha	142 - 188	123 - 162	167 - 221

Appendix B2 – Model 3

Springfield/Sheffield - User pays

Inflation Adjusted

Base Case		
Scheme size	100%	(84000 ha)
- Springfield/Sheffield		10,000 ha
- Other		74,000 ha
Debt	50%	
Finance rate	7.00%	
Repayment term	20	years
Equity	50%	
Return on equity	0%	
Inflation rate	2.00%	
Depreciation type	DV	

		Inflation
Upfront capitial cost	$	25,330,000
	Ha	2,533
Annual operating cost Y_9 - Y_{28}	Ha	468 - 572
Annual operating cost Y_{29} - Y_{43}	Ha	340 - 448

Debt/Equity		Base Case 50/50	60% Debt 40% Equity	40% Debt 60% Equity
Upfront capitial cost	Ha	2,533	2,064	2,983
Annual operating cost Y_9 - Y_{28}	Ha	468 - 572	521 - 626	416 - 521
Annual operating cost Y_{29} - Y_{43}	Ha	340 - 448	340 - 448	340 - 448

Scheme size		Base Case 100%	90%	80%	70%	60%	50%
Upfront capitial cost	Ha	2,533	2,536	2,547	2,582	2,659	2,816
Annual operating cost Y_9 - Y_{28}	Ha	468 - 572	457 - 556	450 - 546	453 - 548	454 - 547	469 - 562
Annual operating cost Y_{29} - Y_{43}	Ha	340 - 448	323 - 426	312 - 412	311 - 410	302 - 398	302 - 399

Reliability		Base case 290	250	220
Upfront capitial cost	Ha	2,533	2,450	2,388
Annual operating cost Y_9 - Y_{28}	Ha	468 - 572	460 - 565	454 - 559
Annual operating cost Y_{29} - Y_{43}	Ha	340 - 448	340 - 448	340 - 448

Finance Rate		Base Case 7.0%	4%	8%
Upfront capitial cost	Ha	2,533	2,426	2,571
Annual operating cost Y_9 - Y_{28}	Ha	468 - 572	407 - 512	491 - 595
Annual operating cost Y_{29} - Y_{43}	Ha	340 - 448	340 - 448	340 - 448

Finance Term		Base Case 20 years	25 Years	30 Years	35 Years
Upfront capitial cost	Ha	2,533	2,533	2,533	2,533
Annual operating cost until debt repaid	Ha	468 - 572	446 - 585	433 - 610	424 - 644
Annual operating cost after loan repaid	Ha	340 - 448	375 - 448	414 - 448	0

Equity Return		Base Case 0%	5%	15%
Upfront capitial cost	Ha	2,533	2,533	2,533
Annual operating cost Y_9 - Y_{28}	Ha	468 - 572	595 - 699	848 - 952
Annual operating cost Y_{29} - Y_{43}	Ha	340 - 448	467 - 575	720 - 828

Energy costs		Base Case 6.3 cents	5 cents	8 cents
Upfront capitial cost	Ha	2,533	2,533	2,533
Annual operating cost Y_9 - Y_{28}	Ha	468 - 572	455 - 553	485 - 597
Annual operating cost Y_{29} - Y_{43}	Ha	340 - 448	321 - 423	365 - 482

Appendix B3 – Model 1 (inflation adjusted at 2%)

Taxation

Accummulated income tax benefit at year 43

Stated in 2001 Nominal $

Base Case	$000
Excluding Springfield/Sheffeid	15,781
Including Sprinfield/Sheffield	18,458

Debt/Equity	Base Case 50/50	60% Debt 40% Equity	40% Debt 60% Equity
Excluding Springfield/Sheffeid	15,781	8,250	22,997
Including Sprinfield/Sheffield	18,458	10,394	26,187

Scheme size	Base Case 100%	90%	80%	70%	60%	50%
Excluding Springfield/Sheffeid	15,781	14,177	12,641	11,370	9,926	8,924
Including Sprinfield/Sheffield	18,458	16,854	15,318	14,047	12,603	11,601

Reliability	Base case 290	250	220
Excluding Springfield/Sheffeid	15,781	15,443	15,191
Including Sprinfield/Sheffield	18,458	18,120	17,869

Finance Rate	Base Case 7.0%	4%	8%
Excluding Springfield/Sheffeid	15,781	13,983	16,422
Including Sprinfield/Sheffield	18,458	16,545	19,140

Finance Term	Base Case 20 years	25 Years	30 Years	35 Years
Excluding Springfield/Sheffeid	15,781	15,781	15,781	15,781
Including Sprinfield/Sheffield	18,458	18,458	18,458	18,458

Equity Return	Base Case 0%	5%	15%
Excluding Springfield/Sheffeid	15,781	15,781	15,781
Including Sprinfield/Sheffield	18,458	18,458	18,458

Energy costs	Base Case 6.3 cents	5 cents	8 cents
Excluding Springfield/Sheffeid	15,781	15,781	15,781
Including Sprinfield/Sheffield	18,458	18,458	18,458

Appendix B3 – Model 2 (inflation adjusted at 2%)

Central Plains Irrigation Scheme

Model Variables

No Springfield/Sheffield

Scheme size	
% of scheme	100% - 290
Hectares	84,000
Capital Expenditure	
Development and construction cost	223,438,147
Capitalised interest	23,863,002
Total Capital Expenditure	247,301,150
Capital cost per hectare	2,944
Annual Operating Expenditure	
Energy cost (cents/kWh)	6.3
Total energy cost p.a.	3,790,000
Operating and maintenance p.a.	1,665,136
Depreciation (SL,DV)	DV
Funding Variables	
Debt	
Debt % of Total Funding	50%
Finance Rate	7.0%
Loan repayment term	20
Equity	
Land owner	123,650,575
Equity cost per hectare	1,472
Government and other	
Rate of return	0%
Inflation	
Inflation rate	2.0%

Funding Summary

Capital cost	223,438,147
Capitalised interest	23,863,002
Total capital cost	**247,301,150**
Funded by	
Debt	123,650,575
Land owner equity	123,650,575
Government and other	0
Total	**247,301,150**

Land Owner Summary / **Taxation Summary**

Upfront capital cost per hectare $ **1,472.03**

Operating costs per hectare

	Real Cost (no inflation)	Tax $000	Tax - cummulative $000
Year 9	204	-1,919	-1,919
Year 10	204	-1,715	-3,635
Year 11	204	-1,515	-5,150
Year 12	204	-1,318	-6,468
Year 13	204	-1,123	-7,591
Year 14	204	-928	-8,519
Year 15	204	-733	-9,252
Year 16	204	-538	-9,790
Year 17	204	-340	-10,130
Year 18	204	-140	-10,270
Year 19	204	64	-10,206
Year 20	204	273	-9,933
Year 21	204	487	-9,446
Year 22	204	708	-8,738
Year 23	204	936	-7,803
Year 24	204	1,172	-6,630
Year 25	204	1,418	-5,212
Year 26	204	1,675	-3,537
Year 27	204	1,944	-1,593
Year 28	204	2,225	632
Year 29	65	-1,331	-700
Year 30	65	-1,290	-1,989
Year 31	65	-1,251	-3,240
Year 32	65	-1,213	-4,453
Year 33	65	-1,178	-5,631
Year 34	65	-1,144	-6,775
Year 35	65	-1,112	-7,887
Year 36	65	-1,081	-8,968
Year 37	65	-1,052	-10,019
Year 38	65	-1,024	-11,043
Year 39	65	-997	-12,039
Year 40	65	-971	-13,011
Year 41	65	-947	-13,957
Year 42	65	-923	-14,880
Year 43	65	-901	-15,781

Appendix B3 – Model 3 (inflation adjusted at 2%)

Central Plains Irrigation Scheme

Model Variables

Springfield/Sheffield - equalised

Scheme size	
% of scheme	100% - 290
Hectares	84,000
Capital Expenditure	
Development and construction cost	239,291,166
Capitalised interest	25,402,959
Total Capital Expenditure	264,694,124
Capital cost per hectare	3,151
Annual Operating Expenditure	
Energy cost (cents/kWh)	6.3
Total energy cost p.a.	4,425,000
Operating and maintenance p.a.	2,294,660
Depreciation (SL,DV)	DV
Funding Variables	
Debt	
Debt % of Total Funding	50%
Finance Rate	7.0%
Loan repayment term	20
Equity	
Land owner	132,347,062
Equity cost per hectare	1,576
Government and other	
Rate of return	0%
Inflation	
Inflation rate	2.0%

Funding Summary

Capital cost	239,291,166
Capitalised interest	25,402,959
Total capital cost	264,694,124
Funded by	
Debt	132,347,062
Land owner equity	132,347,062
Government and other	0
Total	**264,694,124**

Land Owner Summary / **Taxation Summary**

Upfront capital cost per hectare $ 1,575.56

Operating costs per hectare

	Real Cost (no inflation)	Tax $000	Tax - cummulative $000
Year 9	229	-2,334	-2,334
Year 10	229	-2,083	-4,418
Year 11	229	-1,840	-6,258
Year 12	229	-1,602	-7,859
Year 13	229	-1,368	-9,228
Year 14	229	-1,138	-10,366
Year 15	229	-910	-11,276
Year 16	229	-683	-11,959
Year 17	229	-456	-12,415
Year 18	229	-227	-12,642
Year 19	229	4	-12,638
Year 20	229	239	-12,399
Year 21	229	478	-11,921
Year 22	229	724	-11,197
Year 23	229	976	-10,221
Year 24	229	1,237	-8,985
Year 25	229	1,506	-7,479
Year 26	229	1,787	-5,692
Year 27	229	2,079	-3,612
Year 28	229	2,385	-1,227
Year 29	80	-1,417	-2,644
Year 30	80	-1,369	-4,014
Year 31	80	-1,324	-5,338
Year 32	80	-1,282	-6,620
Year 33	80	-1,241	-7,861
Year 34	80	-1,203	-9,064
Year 35	80	-1,167	-10,230
Year 36	80	-1,132	-11,363
Year 37	80	-1,100	-12,462
Year 38	80	-1,069	-13,531
Year 39	80	-1,039	-14,570
Year 40	80	-1,011	-15,581
Year 41	80	-984	-16,565
Year 42	80	-959	-17,524
Year 43	80	-934	-18,458

Appendix B4 – Accumulation Income Tax Benefits

Central Plains Irrigation Scheme
Model Variables
Springfield/Sheffield - User pays

Scheme size

% of scheme	100% - 290
Hectares	84,000
Capital Expenditure	
Development and construction cost	239,291,166
Capitalised interest	25,402,959
Total Capital Expenditure	264,694,124
Capital cost per hectare	3,151
Annual Operating Expenditure	
Energy cost (cents/kWh)	6.3
Total energy cost p.a.	4,425,000
Operating and maintenance p.a.	2,294,660
Depreciation (SL,DV)	DV
Funding Variables	
Debt	
Debt % of Total Funding	50%
Finance Rate	7.0%
Loan repayment term	20
Equity	
Land owner	132,347,062
Equity cost per hectare	1,576
Government and other	
Rate of return	0%
Inflation	
Inflation rate	2.0%

Funding Summary

Capital cost	239,291,166
Capitalised interest	25,402,959
Total capital cost	264,694,124
Funded by	
Debt	132,347,062
Land owner equity	132,347,062
Government and other	0
Total	**264,694,124**

Land Owner Summary / **Taxation Summary**

Upfront capital cost per hectare $ 2,342

Operating costs per hectare

	Sheffield Only (no inflation)	Tax $000	Tax - cummulative $000
Year 9	412	-2,334	-2,334
Year 10	412	-2,083	-4,418
Year 11	412	-1,840	-6,258
Year 12	412	-1,602	-7,859
Year 13	412	-1,368	-9,228
Year 14	412	-1,138	-10,366
Year 15	412	-910	-11,276
Year 16	412	-683	-11,959
Year 17	412	-456	-12,415
Year 18	412	-227	-12,642
Year 19	412	4	-12,638
Year 20	412	239	-12,399
Year 21	412	478	-11,921
Year 22	412	724	-11,197
Year 23	412	976	-10,221
Year 24	412	1,237	-8,985
Year 25	412	1,506	-7,479
Year 26	412	1,787	-5,692
Year 27	412	2,079	-3,612
Year 28	412	2,385	-1,227
Year 29	191	-1,417	-2,644
Year 30	191	-1,369	-4,014
Year 31	191	-1,324	-5,338
Year 32	191	-1,282	-6,620
Year 33	191	-1,241	-7,861
Year 34	191	-1,203	-9,064
Year 35	191	-1,167	-10,230
Year 36	191	-1,132	-11,363
Year 37	191	-1,100	-12,462
Year 38	191	-1,069	-13,531
Year 39	191	-1,039	-14,570
Year 40	191	-1,011	-15,581
Year 41	191	-984	-16,565
Year 42	191	-959	-17,524
Year 43	191	-934	-18,458

Appendix B5 – Base Model 1

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Operating Cost Per Hectare (in 2001 nominal $)

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Capital Cost Per Hectare (in 2001 nominal $)

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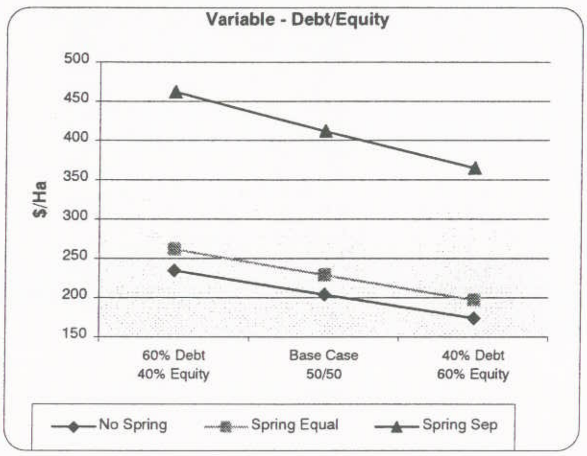
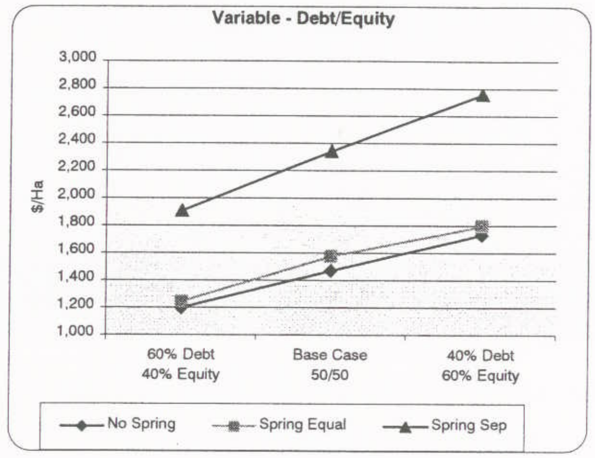
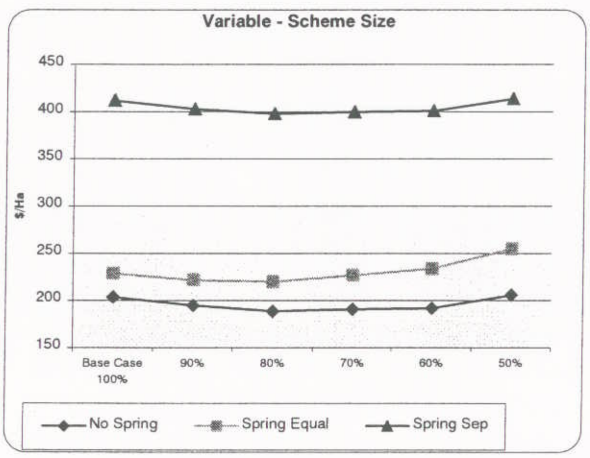
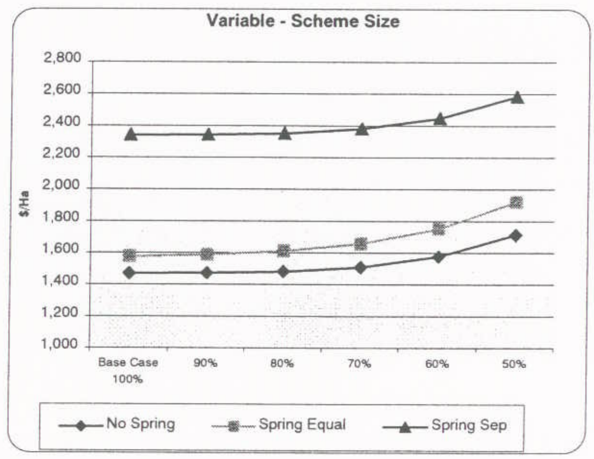
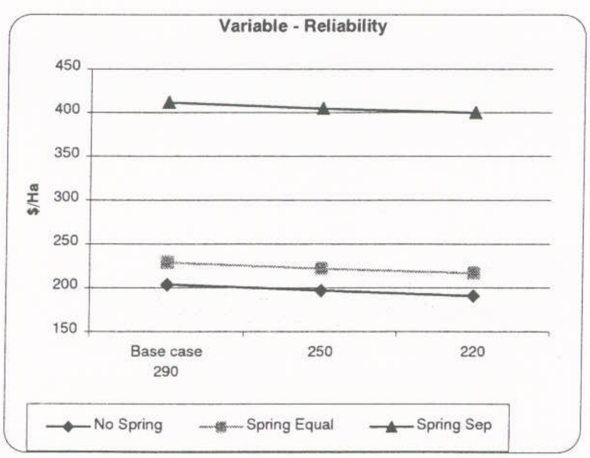
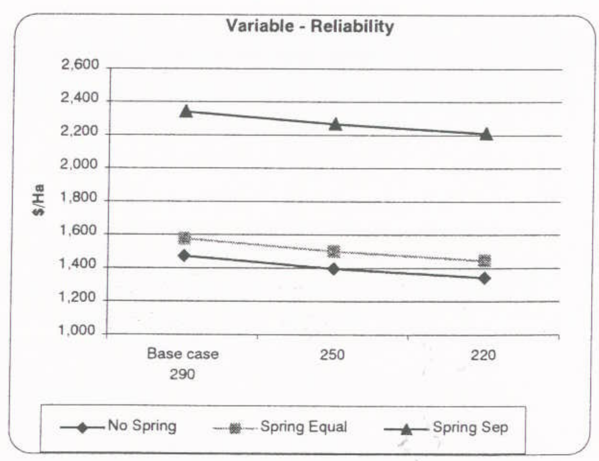






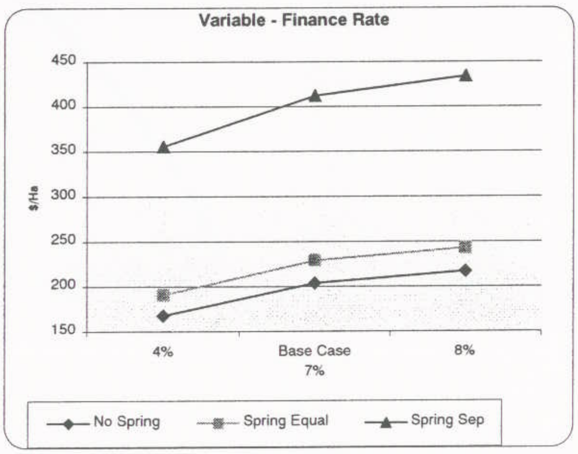


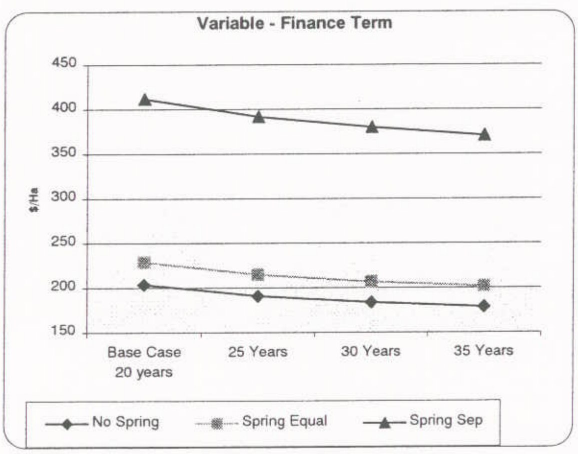


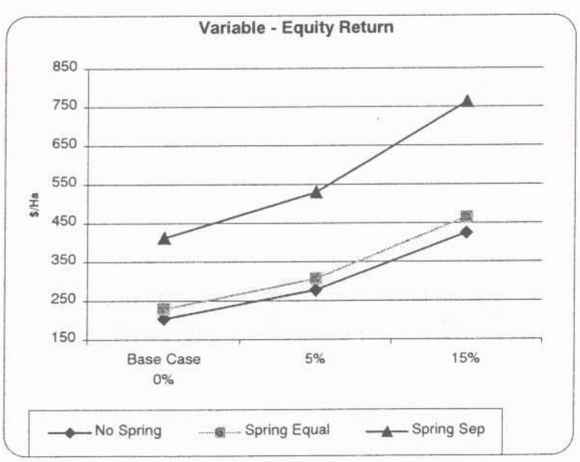


Appendix B5 – Base Model 2

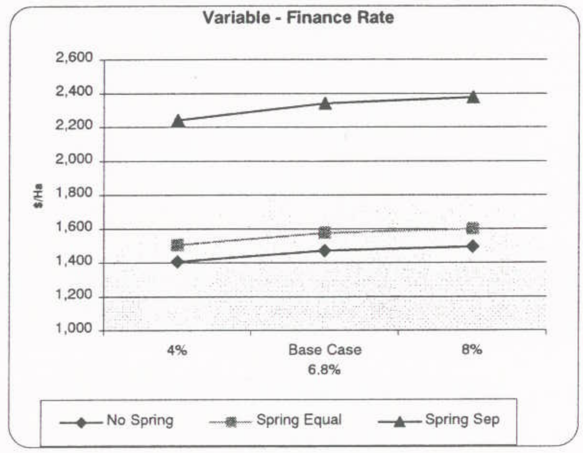
Operating Cost Per Hectare (in 2001 nominal $)

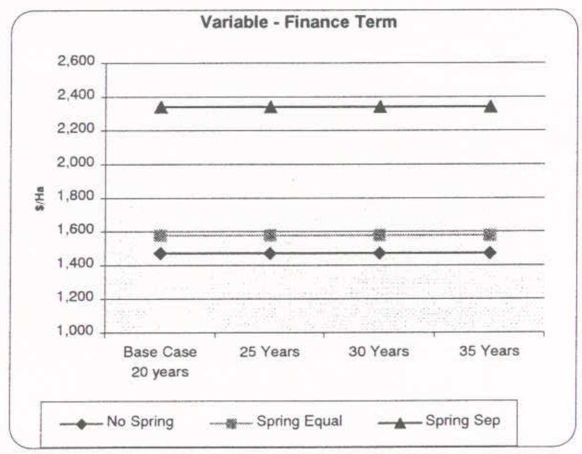


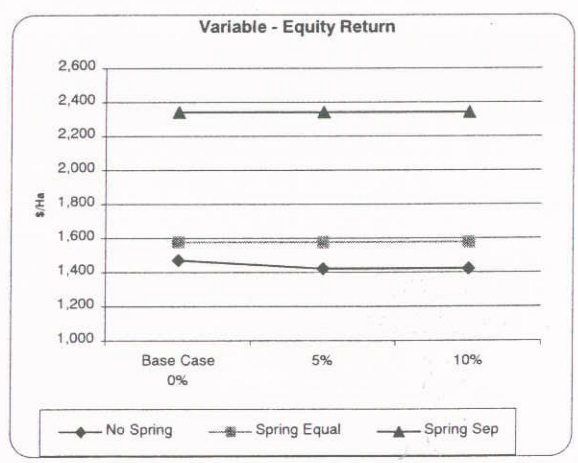




Capital Cost Per Hectare (in 2001 nominal $)

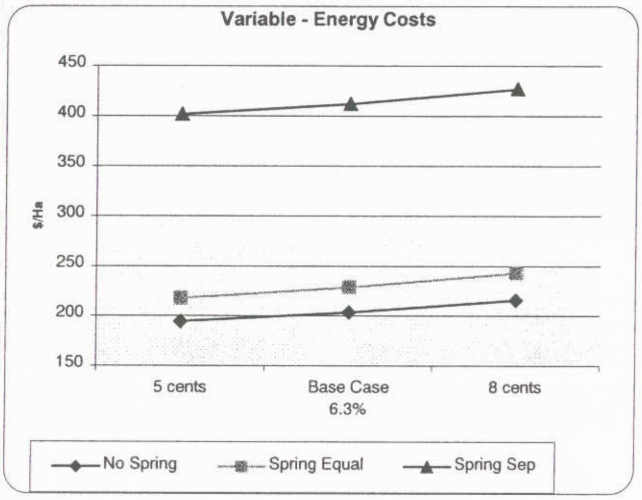




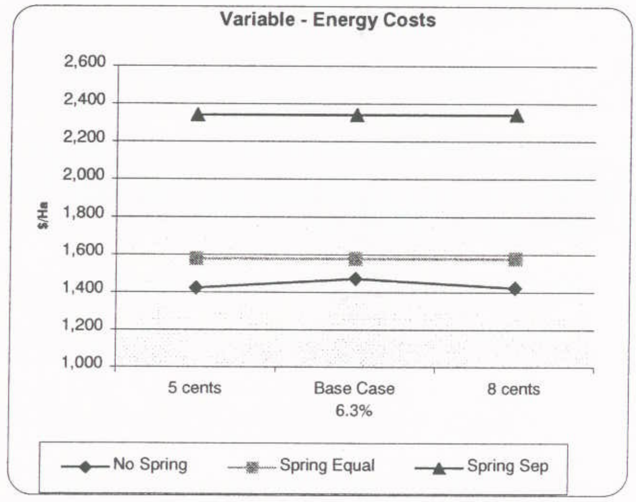


Appendix B5 – Base Model 3

Operating Cost Per Hectare (in 2001 nominal $)



Capital Cost Per Hectare (in 2001 nominal $)



Impact of Delayed Take-up

Impact for water users who delay takeup

- No Springfield

Year of user entry into scheme	One off cost per ha (if paid at inception)**	Cost per ha per year (if financed over 20 years)**
Year 9*	$170 /ha	$16 /ha
Year 10	$352 /ha	$33 /ha
Year 11	$546 /ha	$52 /ha
Year 12	$754 /ha	$71 /ha
Year 13	$977 /ha	$92 /ha
Year 14	$1,215 /ha	$115 /ha
Year 15	$1,470 /ha	$139 /ha
Year 16	$1,743 /ha	$165 /ha
Year 17	$2,034 /ha	$192 /ha

- Springfield Equal

Year of user entry into scheme	One off cost per ha (if paid at inception)**	Cost per ha per year (if financed over 20 years)**
Year 9*	$189 /ha	$18 /ha
Year 10	$391 /ha	$37 /ha
Year 11	$607 /ha	$57 /ha
Year 12	$838 /ha	$79 /ha
Year 13	$1,085 /ha	$102 /ha
Year 14	$1,350 /ha	$127 /ha
Year 15	$1,633 /ha	$154 /ha
Year 16	$1,935 /ha	$183 /ha
Year 17	$2,260 /ha	$213 /ha

- Springfield Userpays

Year of user entry into scheme	One off cost per ha (if paid at inception)**	Cost per ha per year (if financed over 20 years)**
Year 9*	$325 /ha	$31 /ha
Year 10	$673 /ha	$64 /ha
Year 11	$1,045 /ha	$99 /ha
Year 12	$1,445 /ha	$136 /ha
Year 13	$1,871 /ha	$177 /ha
Year 14	$2,327 /ha	$220 /ha
Year 15	$2,815 /ha	$266 /ha
Year 16	$3,337 /ha	$315 /ha
Year 17	$3,896 /ha	$368 /ha

Estimated Takeup for CPWE
(Per discussions with URS and Stu Ford)

Year 9 *	75%	taken up
Year 10	90%	taken up
Year 11	100%	taken up

Total cost of underwriting based on the above takeup assumptions
(i.e. no penalty for water users who delay entry to the scheme)

No Springfield	$6,522,000
Springfield Equalised	$7,242,000
Springfield - User pays	$12,486,000

** = Year 9 is the first year of operation based on an 8 year construction plan.*

** = These costs are in addition to ongoing operating costs to access water.