Emergency management, Opuha Dam collapse, Waitangi Day 1997

Philip Lees[1] and David Thomson[2]

The partially completed Opuha Dam near Fairlie in South Canterbury failed at about 1.00 am on 6 February 1997, releasing about 13 million cubic metres of water into the Opuha Riverbed. The developing Civil Defence emergency is described, showing how rapidly a situation could change to one of high hazard.

This experience has reinforced views that: effective emergency management plans must be in place for large dams, both during and after construction; emergency procedures need to be activated early and when there are several hours of daylight left; dam-site staff must give an honest appraisal of a potential emergency situation, and in turn must provide accurate information to emergency management organisations.

Recommendations are given for the scope of emergency management plans for the now-completed Opuha Dam and for other dams during their construction.

Keywords: *Opuha Dam, dam breach, river capacity, volume of water, impounded.*

Introduction

Waitangi Day, 6 February, 1997 is a day that will remain on the minds of flood warning staff of Environment Canterbury (ECan) probably for the rest of their lives. The partially completed Opuha Dam near Fairlie in South Canterbury failed at about 1.00 am that morning, releasing about 13 million cubic metres of water into the Opuha Riverbed (Figure 1).

Fortunately no lives were lost although in the days that followed there were stories of a number of very close escapes: campers scrambling through riverside berm areas with trees crashing around them and farmers in the same situation trying to shift stock. We were actually very fortunate.

Opuha Dam is built at the entry to the Opuha River Gorge about 12 km from the township of Fairlie and 170 km from Christchurch (Figure 2). The Opuha River is a typical Canterbury gravel bearing, braided river with a catchment area of 500 km^2. The average daily flow (pre-dam) is about 3 cumecs and the mean annual flood is 100 cumecs. Before this event, the biggest recorded flood in the Opuha River in recent times had been on 13 March 1986, when 600 m^3/s was recorded with a nominal return period of 50 years. A PMF for the Opuha River is estimated to be in the range of 1500–2000 cumecs.

Role of Environment Canterbury

ECan's role is to monitor rainfall and river flows. ECan has a network of telemetered raingauges in the mountains and foothills of Canterbury and water level recorders in most of the main rivers. Based on this monitoring and weather forecasts from the Metservice ECan staff make predictions on likely flood scenarios and pass advice to Police, District Councils and Civil Defence. Flood warnings are passed on to the public via radio stations and the ECan river and flood info telephone line.

In the Opuha area there is one raingauge in the catchment and one very close by. There is a water level recorder in the Opuha River about 13 km downstream of the dam (Figure 3). On 6 February 1997 there were no water level recorders upstream of the dam.

At the time of the failure, ECan's flood warning staff had little specific knowledge of the Opuha Dam or what stage construction was at.

---

[1] *Flood warning officer, Environment Canterbury (Timaru)* (philip.lees@ecan.govt.nz)

[2] *Flood warning officer, Environment Canterbury (Timaru)* (david.thomson@ecan.govt.nz)

Figure 1. Opuha Dam after the collapse, 6 February 1997.

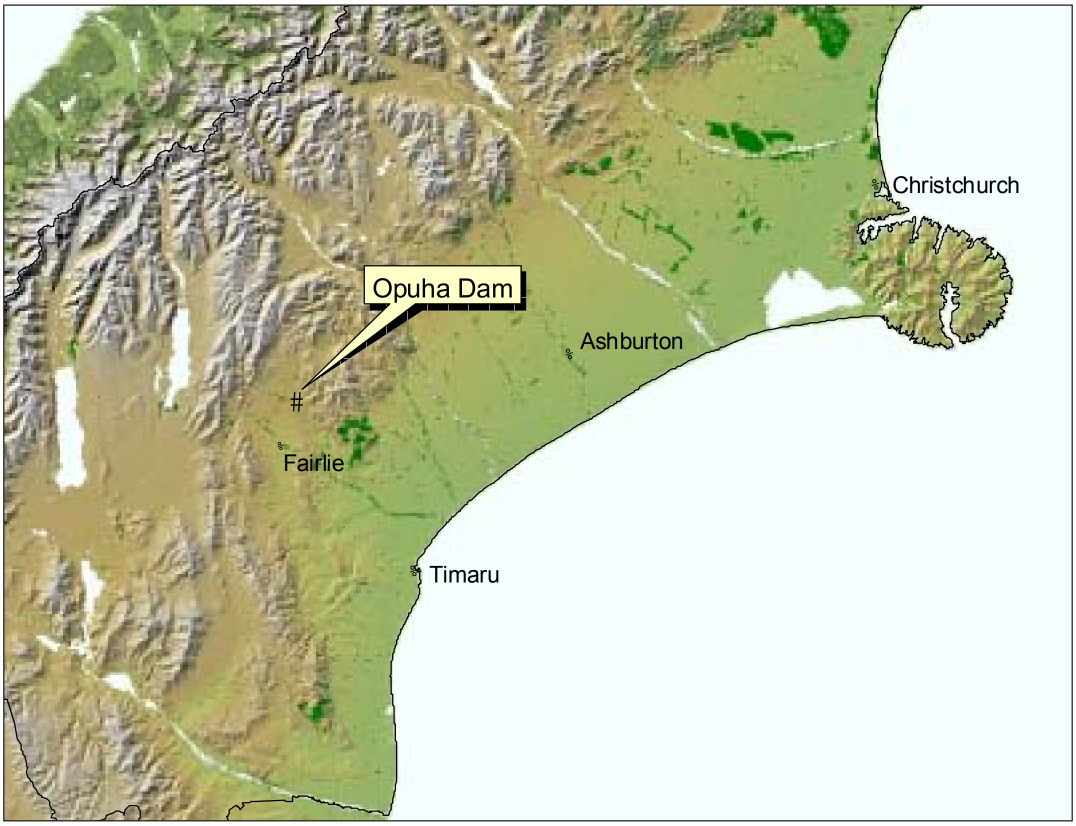

Figure 2. Location map for Opuha Dam, near Fairlie, South Canterbury.

The developing event

About 110 mm of rain had fallen in the Opuha Catchment on 3–4 February. About 10 mm had fallen up to midday on 5 February. The rain had been intermittent with the occasional heavy burst. The Met Service had forecast more of the same for the next day. Some rivers were in light fresh. The Opuha River flow was static at about 40 cumecs which was the controlled outlet flow through a 1.8 m diameter pipe through the partially completed dam.

ECan was first aware of the situation at the dam site when they were contacted at 11.00 am by Mackenzie District Council staff expressing concern at the amount of water impounded behind the dam.

When contacted, dam-site staff were confident the situation was under control. The lake level rise was slowing and the weather forecast was for intermittent rain with the occasional heavy burst.

Through the day, rainfall in the catchment was monitored and good communications were maintained between dam-site staff, ECan and Civil Defence.

By late afternoon, dam-site staff indicated a cut might have to be made near the left abutment of the dam over a rock saddle to avoid an uncontrolled breach of the dam. They were confident that due to the rock saddle the cut would be contained and the resultant discharge would be only about 50 cumecs.

Following discussion amongst ECan staff, it was felt that the discharge would be more likely to be in the order of 300 cumecs. This discharge was not of great concern, although some outflows from the Opuha River system could be expected. Because of this possible 300 cumec flow the following warning was issued, to be broadcast half-hourly over the local radio stations and was also recorded on the flood info line:

> "Intermittent heavy rain in the Opuha Catchment may result in extra water being released from the Opuha Dam. This may result in a rapid rise in water levels to moderate flood size in the Opuha/Opihi River system. Farmers are advised to move stock from low-lying areas and to monitor the situation carefully."

By late evening, ECan staff were advised that water was beginning to flow over the cut. Dam-site staff were still confident the outflow would be contained by the rock saddle. When questioned by ECan, dam-site staff advised that the volume of water impounded by the dam was about 2 million cubic metres. **This was critical.**

Initial calculations indicated that any resultant peak discharge from the dam would be 300–500 cumecs. The radio warnings already issued covered this scenario.

Civil Defence staff were updated. They had notified their wardens of the situation.

The dam breach

Just before midnight dam-site staff indicated the breach had widened. It was now 20 m wide and 6 m deep. They said the situation appeared serious for the dam.

Civil Defence were updated. River capacities were confirmed and no major problems were expected. Estimated times of travel for the peak down the 55 km river system were passed on to Civil Defence.

Around 1.00 am on 6 February ECan staff requested confirmation from dam-site staff on the volume of water impounded behind the dam. This was estimated at 13 million cubic metres.

The situation had changed dramatically.

Emergency management procedures

Quick calculations indicated a peak discharge of 1500 cumecs could be expected. This was getting close to a PMF for the Opuha River.

River system capacities were confirmed (Figure 3).

Major breakouts were expected in the Opuha River upstream of the Opihi River confluence (the river in this reach is not stopbanked, so outflows will begin to occur at flows over 300 cumecs), and there could be some overtopping of the Opihi River system upstream of the Tengawai River confluence (river system stopbanked, capacity about 1500 cumecs). Downstream of the Tengawai confluence was expected to be okay (river capacity about 2200 cumecs).

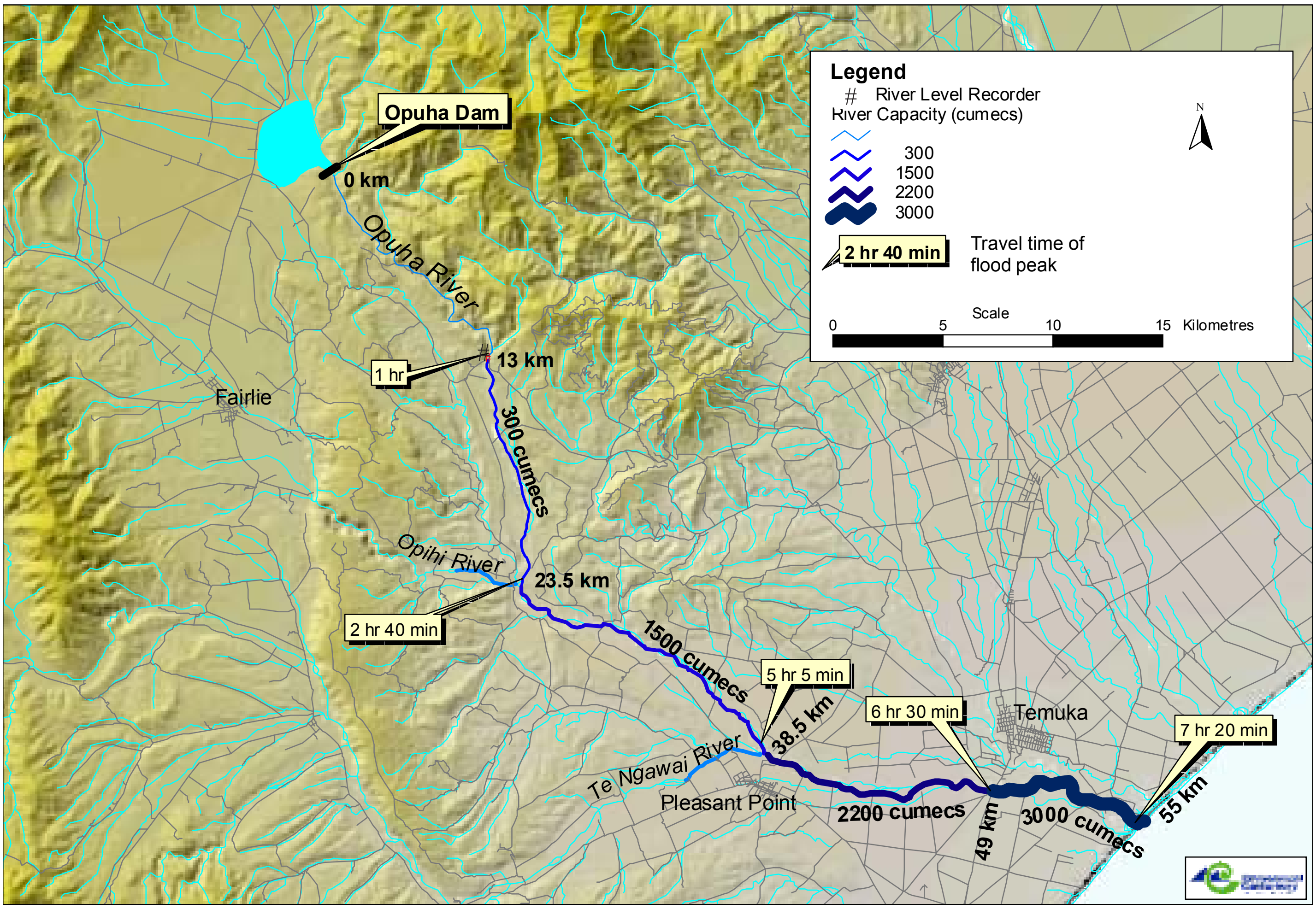

Figure 3. River capacities and travel time of flood peak, Opuha Dam Failure, 6 February 1997.

Overflow areas and key points were identified. Farm houses generally well back from the river, but 25 farms were threatened in the Opuha and Opihi River systems above the Tengawai confluence. Also three small riverside hut settlements (about 100 residents) downstream of the Tengawai River confluence might be threatened as they were immediately adjacent to the river. The Pleasant Point township (1200 residents) was expected to be okay. The question arose of how to deal with riverbed campers (there were several, as it was Waitangi Day).

Times of travel for the flood peak were assessed as 1–2 hours to Opihi River confluence, and 3–4 hours to Pleasant Point and riverside settlements.

All this information was passed on to Civil Defence and Police at the Civil Defence bunker.

A Civil Defence emergency was declared at 2.00 am.

An ECan staff person was put in the Civil Defence bunker to assist with interpretation of incoming information. Other ECan staff were placed at key sites to confirm water levels and travel times of the flood peak. Extreme care was taken regarding the safety of these staff. Information from these sites was passed on to Civil Defence.

Civil Defence contacted farmers through their warden system, but in the upper reaches it was too late for farmers to shift stock (many of the stock lost had already been shifted from the areas closest to the river).

About 200 residents were evacuated from the riverside settlements thought to be at risk.

As quickly as it had started, the peak flows had passed and the emergency was over. At any one point the river had peaked and then dropped within 10–15 minutes. Figure 3 shows the progress of the flood wave down the river. Figures 1 and 4 show the breached Opuha Dam and Figure 5 the effect of the flood wave sweeping everything from its path in the gorge about 5 km downstream of the dam.

Figure 4. Opuha Dam, looking downstream, 6 February 1997.

Flotsam and jetsam

Peak discharge immediately downstream of the dam was eventually estimated to be about 1800–2000 m^3/s, and the time the flood peak took to travel the 55 km from the dam to the sea was about 7.5 hours at an average velocity of 2.0 m/s. The dam height on 5 February 1997 had been 29 m, and the dam breach was about 35 m wide.

The failure resulted in the loss of more than 1000 head of stock, many hundreds of thousands of dollars of damage to about 25 farms adjacent to the riverbed, $500,000 worth of damage to river protection works in the Opuha and Opihi Riverbeds and a major breach of SH 79.

The flood carried all before it, sweeping the riverbanks clear of vegetation and soil (Figure 5). Shingle to a depth of 11 m was dumped over the turbine in the powerhouse. Two days after the failure, a concrete-mixer truck from the dam site was found buried in shingle about 500 m

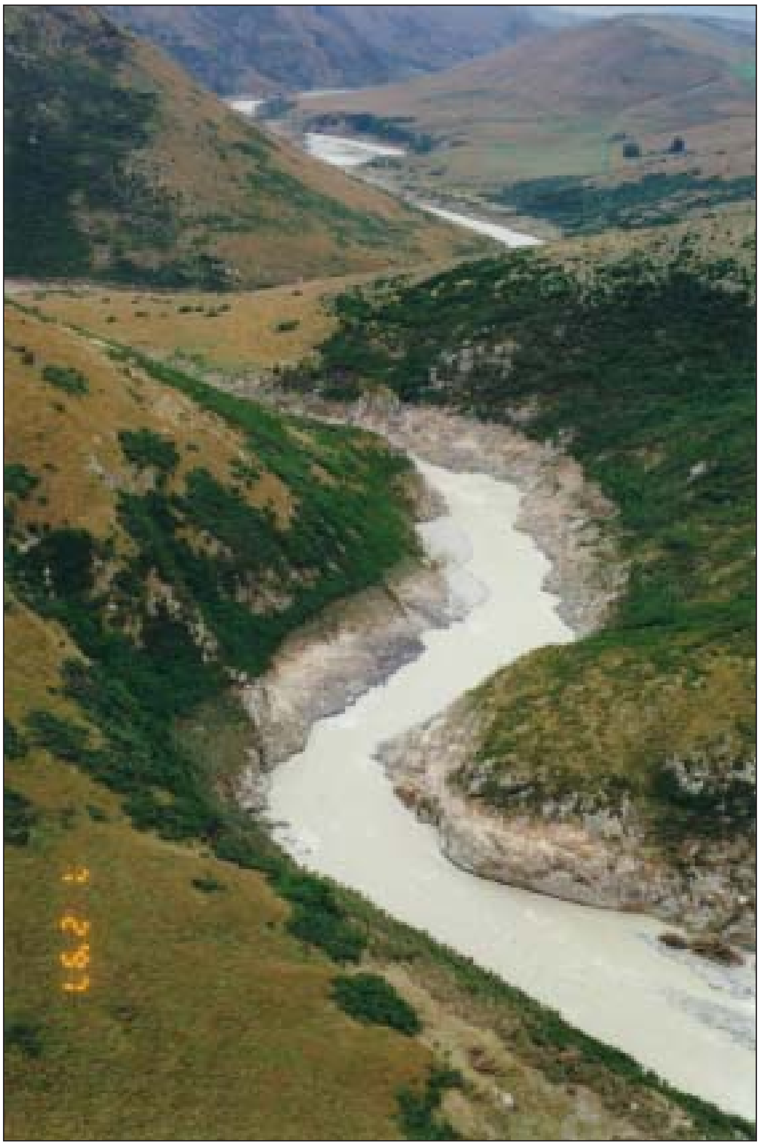

Figure 5. Opuha Gorge, 5 km downstream of Opuha Dam, swept clean of vegetation, soil and water recorders.

downstream of the dam. The 5 m concrete tower that contained the water level recorder and had been sited 13 km downstream of the dam was never found. The ECan water level recorder data logger from the Opuha River was found on the beach 10 km up the coast from the mouth of the Opihi River.

About 200 residents were evacuated from four hut settlements close to the river. Two groups of people camping in the Opihi riverbed downstream of SH 1 made miraculous escapes through trees and gorse after they were alerted to oncoming floodwaters by the sound of crashing trees. A farmer who noticed the SH 79 approach to the Skipton Bridge over the Opuha River was washed away leaving only the seal bridging the gap, was fortunately able to stop oncoming traffic.

The rebuilt Opuha Dam has a finished height of 47 m, with a lake full volume of 84 million m^3. The catastrophic failure of the dam with a full lake may inundate 1400 households.

Community response

People adversely affected by a disaster will always try to apportion blame. The feedback from a wide variety of sources in the local community was that there needs to be stricter controls during the construction of large dams and Territorial and Regional Councils must have clearly defined responsibilities.

Another clear community response was the requirement to have adequate provision for the safe passage of floodwaters during dam construction.

“How can something like this be allowed to happen?” was the most frequent response.

Conclusions

The experience with the failure of the Opuha Dam during its construction confirmed several axioms of good emergency management practice. Effective emergency management plans must be in place for large dams (both during and after construction) and be reviewed regularly in consultation with all affected parties.

Emergency situations tend to develop very quickly (and often at night). This reinforces the need to activate emergency procedures early and when there are several hours of daylight left.

Dam-site staff must give an honest appraisal of a potential emergency situation. If there is any doubt they should call in experts and emergency management people. In turn, dam-site staff must know who to contact during an emergency, and must provide accurate information to emergency management organisations.

As part of the emergency management plan:

- Emergency management staff must know who to contact regarding a dam-site in a potential emergency situation.
- Flood extent maps of dam break scenarios must be prepared, and emergency management people must have access to these maps.
- Critical information on estimated times of travel and water depths must be prepared.
- Evacuation routes should be identified.
- Appropriate monitoring and reporting to local authorities of key indicators at a dam site should occur.
- Appropriate methods of warning the general public of dam failure must be carefully thought through by emergency management staff.

Acknowledgements

The support of ECan in allowing us to prepare this paper is gratefully acknowledged.

The need for storage to meet future agricultural water demand

John Bright[1] and Matthew Morgan[2]

Irrigation is the largest consumptive use of water in New Zealand. Most of this demand is currently met on a run-of-river basis. In future, irrigation development will be based on further development of groundwater resources, complemented by the development of large amounts of surface water storage. This is largely because the reliability of supply from the remaining allocable river sources is too low. Several districts have adopted a strategic approach to planning to meet long-term water demands from environmental and consumptive-use sectors. This paper provides an overview of current and potential irrigation development, and describes the results of a strategic approach to water management that has been applied in east-coast districts in both the North and South Island. It highlights some of the water resource development issues that will arise as sustainable development of water and land resources is pursued.

Keywords: *Irrigation, strategic planning, water management*

Introduction

The provision of core infrastructure for supplying water for stock and irrigation, and for draining land, is one of the keys to the growth of agriculture's contribution to the New Zealand economy since the late 1800s. The re-use of old gold mining races in Otago as irrigation supply races sparked the development of small private irrigation schemes in about 1865. The development of stock water race systems in the 1880s enabled the subdivision of large runs and the development of more intensive and diverse land-uses. Growth in irrigation and stock water supplies from these small beginnings has enabled the development of highly productive, knowledge intensive, land-use businesses.

Most of the 468 000 ha of land now irrigated in New Zealand has been developed by the private sector. In general the private sector development has been based on the development of groundwater and run-of-river takes to irrigate riparian land. Between 1910 and 1988 central government promoted and financed the development of community irrigation schemes, particularly where the cost of the water supply infrastructure was a barrier to development. During this time government was directly involved in the development of about 160 000 ha of irrigation. The growth in irrigation development over time, which has approximately doubled every 15 years since 1975, is illustrated in Figure 1. The current distribution of irrigated land by region is summarised in Table 1. All irrigation schemes are now in private or corporate ownership, the government developed schemes having been sold off in the late 1980s.

A feature of irrigation development to-date is the relatively limited use of surface water storage. To this point in time the reliability of run-of-river water supplies, and thus agricultural production, has been adequate to sustain investments in irrigation infrastructure. This paper uses Canterbury as an example to demonstrate that if irrigated agriculture is to expand much further, it will require the development of significant amounts of storage. It then discusses some of the key non-environmental issues concerning irrigation scheme development.

A strategic approach to meeting Canterbury's water needs

Overview

One of the aims of the Canterbury Strategic Water Study (Lincoln Environmental 2002) was to identify upcoming issues in meeting the long-term water needs (excluding hydro-electric development) of the Canterbury region. A key motivation was concern that current, ad hoc, development may foreclose on future development options that would yield better regional socio-economic and environmental outcomes. The approach adopted involved an assessment of the potential consumptive water demands in 2020 for municipal, industrial and agricultural uses. It then developed answers to questions such as:

---

[1] *Principal, Lincoln Environmental, P.O. Box 133, Lincoln, Christchurch 8152* (brightj@lincoln.ac.nz)

[2] *Senior Water Resources Engineer, Lincoln Environmental, P.O. Box 133, Lincoln, Christchurch 8152* (morganm@lincoln.ac.nz)

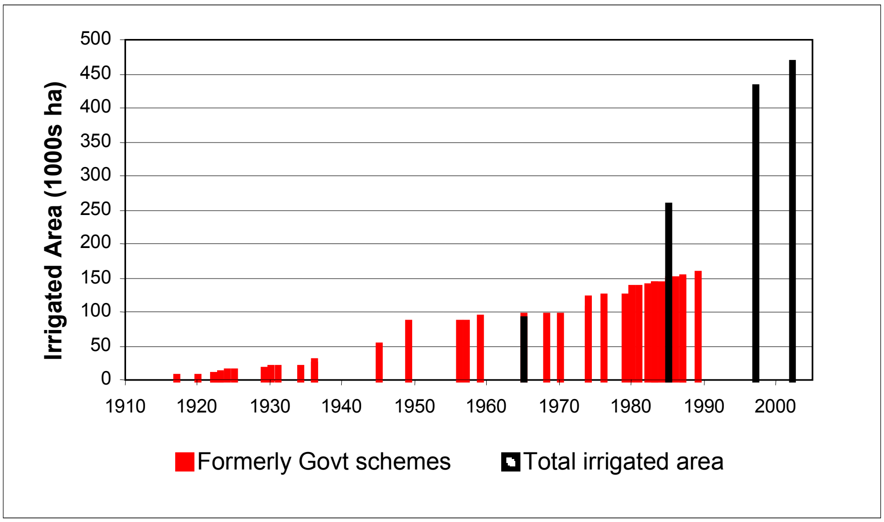

Figure 1. Growth in irrigated area in New Zealand.

Table 1. Land under an irrigation system during the year ended 30 June 2002.

Region	Area (ha)	Region	Area (ha)
Northland	7,041	Tasman	10,030
Auckland	6,266	Nelson	
Waikato	12,652	Marlborough	20,188
Bay of Plenty	8,839	West Coast	2,462
Gisborne	1,325	Canterbury	287,168
Hawkes Bay	18,138	Otago	68,869
Taranaki	2,941	Southland	4,075
Manawatu-Wanganui	7,967		
Wellington	9,550		
Total North Island	**74,718**	**Total South Island**	**393,013**

Source: Statistics New Zealand, 2002.

If the 2020 level of development had existed over the period 1972 to 2000,

- What would the daily water supply and demand balance have been?
- Which water bodies (surface and ground water) would have experienced the most environmental stress, and why?
- Where would water surpluses have occurred?
- What would have been the level of supply reliability in each catchment?
- Which areas are truly water short, and what would be needed to overcome shortfalls?

The assumption was made that current water allocation rules provide sufficient protection of environmental values to meet future expectations of the wider community. The validity of this assumption was tested by assessing the level of stress on surface and ground water bodies that would have occurred over the 1972 - 2000 period if the potential consumptive water demand had existed during that period.

Current and potential consumptive water demands

The total amount of water allocated for consumptive use in the Canterbury region may be derived from the Environment Canterbury consents database of April 2001. Expressed as the maximum 7-day average flow, the total consumptive water demand was 290 m^3/s, with irrigation abstraction, at 242 m^3/s, as the dominant consumptive use. The balance is made up of stock water takes (23.3. m^3/s), municipal use (15.5 m^3/s) and industrial uses (9.3 m^3/s).

To accurately characterise the pressure on surface water resources due to irrigation it is necessary to compare water supply and irrigation demand on a daily basis. A daily time series of potential irrigation demand was calculated using daily rainfall and other climate data from June 1972 to May 2000, and assuming that the potentially irrigable area in Canterbury was fully developed. In addition to climate, the methods used to calculate demand take account of soil, crop, irrigation system, and irrigation management characteristics (Lincoln Environmental 2002). The potentially irrigable area was estimated to be about 1,000,000 hectares. Factors considered in making this estimate include topography, rainfall, elevation, isolation, and the proportion of land taken out of direct production by other uses such as roads, trees, buildings and other infrastructure. The area currently irrigated is approximately 287 000 ha (Standards New Zealand, 2002).

Municipal and industrial water uses in 2020 were estimated from the projected population and unit-rate consumption figures derived from current water usage and population. The seasonal variation in municipal and industrial demand was modelled by applying a simple sinusoidal function to the peak estimated demands. The function was first fitted to the seasonal variation in Christchurch City's water supply, as measured over the period 1992–96. Stock water use in 2020 was assumed to be equal to the rates of take specified in recent applications for consents for the continuation of the stock water systems. Stock water takes were assumed to be constant throughout the year.

Total future peak 7-day average water demand is estimated to almost double, to 569 m^3/s. Irrigation demand is expected to increase from 83% to 89% of the total peak demand, and overall dominates the average annual distribution of water demand – as shown in Figure 2. It can be seen that irrigation requirements are at their maximum for a relatively short period of time, which implies low utilisation of water delivery systems developed to meet maximum demand.

Assessment of the pressures on water resources due to current water abstractions clearly show that foot hills catchments are generally under considerable abstractive pressure - particularly from stock water takes. In addition, the allocation methods used for some rivers do not protect important flow regime characteristics. It is reasonable to conclude that pressure to raise the in-stream 'use' of water, or for 'fix-up' degraded rivers, will continue to increase. That is, the environmental water demand will grow.

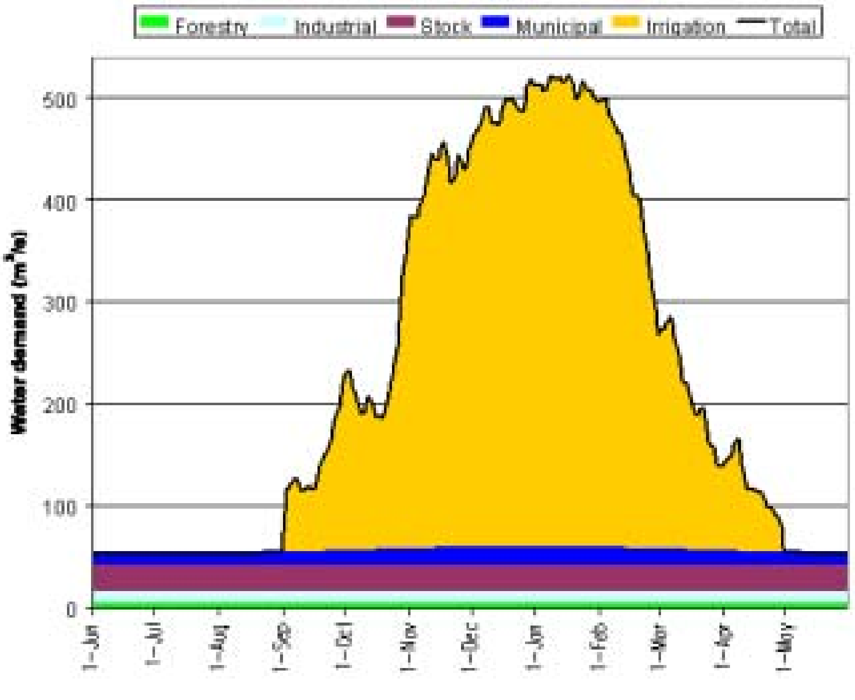

Figure 2. Annual distribution of potential water demand in Canterbury.

Canterbury's potential to meet water demand

A whole-of-region perspective on Canterbury's potential to meet future water demand can be gained by comparing the peak 7-day water demand with the availability of water for abstraction, from all sources, under mean annual low-flow conditions. This comparison indicates whether demand can be met reliably on a run-of-river basis during mid to late summer, when river flows are generally low. Figure 3 shows that the amount of water currently allocated by Environment Canterbury for abstractive uses cannot be met reliably. Future water demand is almost three times the amount of water available for abstraction on a run-of-river basis. Growth in water demand cannot be met reliably from run-of-river sources.

At the regional level, a different picture emerges when total consumptive water demand is compared to total water availability, from all sources, on an average annual basis. Figure 4 shows that the total average annual water supply is about three times greater than the potential average annual water demand. The region's future water demand can be met, providing water can be stored during periods of surplus for use during river low-flow periods.

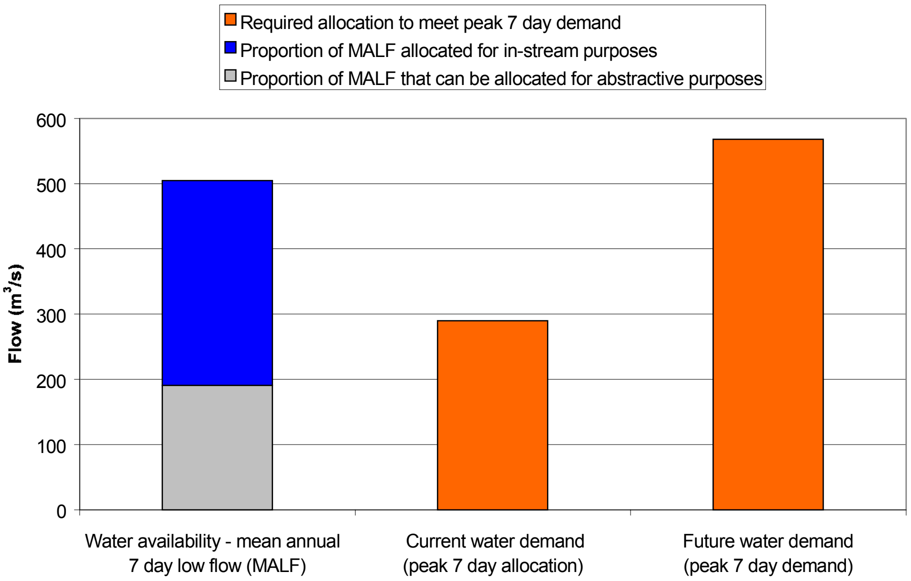

Figure 3. Short-term peak water demand in Canterbury compared to water availability during low-flow conditions.

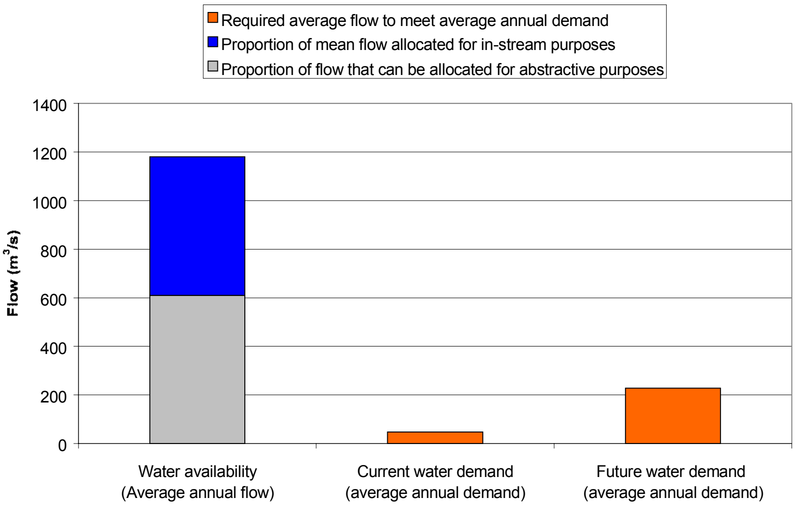

Figure 4. Average annual water demand in Canterbury compared with average annual water availability.

At a sub-regional level, future water demand is not easily met in all sub-regions. Future water demand in each of 14 water resource zones was compared with water demands in each zone, on a daily basis. It was assumed that within each zone individuals would prefer to meet their own water requirements through private developments. The sources tapped first were therefore assumed to be rivers, to irrigate a 2 km-wide riparian strip on each side of the river, as well as groundwater along a coastal strip of varying width. Demand within each riparian and groundwater strip was compared to the resource's capacity to supply. If demand could not be reliably met, the demand was lumped with demands from any areas outside of the riparian and groundwater strips. It was assumed that this aggregated demand would be met by community development of surface water resources within the relevant water resource zone.

An assessment was then made of the run-of-river reliability of water supply to the community water supply scheme areas, and the scope of works required to reliably meet community scheme water demand. The scope ranged from "all demand can be met reliably on a run-of-river basis" through to "no amount of storage will enable demand to be met from this zone's water resources – water must be imported". The relative difficulty of meeting future water demand in the Canterbury region is shown in Figure 5. It is clear that large parts of Canterbury will need to depend on stored water, in combination with inter-catchment water transfers, to meet long-term water demand – if irrigation continues to develop at the market-driven rate and environmental demands continue to increase.

Development issues

Irrigation development involves large up-front capital investments by both the water supply business and individual farmers. Depending on how the water supply business is financed, farmers may have to bear a proportion of the capital cost (typically 50%) of the water supply business, in addition to the on-farm irrigation development. Assuming this is the case, irrigation development at present could involve a total up-front capital investment by farmers of \$3,000–\$5,000 per hectare, plus on-going water charges to cover the water supply business' requirements for debt servicing, operation and maintenance, and profit. The large entry cost – \$1 million for a 250 ha farm, for example – is a significant hurdle for many farmers, even when they understand that the return on investment is likely to be high.

Irrigation schemes are typically designed to fully meet irrigation demand for 90% of the time. Consequently irrigation schemes operate at peak capacity for only 3–4 weeks per year, on average. This represents a low utilisation of the capital invested in water supply infrastructure. When it is technically feasible to do so, development for multiple use of the infrastructure may significantly reduce the financial risk of the water supply business, and reduce both capital and annual costs to farmers.

Financial contributions to community irrigation scheme developments are now seldom compulsory. Not all farmers in a scheme's command area will take up irrigation, even if it is clearly profitable and within their financial and managerial capacity to do so. Yet all schemes require a critical mass of signed-up participants (total area or flow under supply contracts) before commitments to finance and develop a scheme can be made. The rate at which a scheme's irrigated area develops up to that critical mass is crucial to the financial viability of the water supply business. The greater the capital cost of the bulk water supply (i.e. intakes, storage and conveyance), the more critical is the uptake rate. Because of the nature of the bulk water supply infrastructure it is often not financially beneficial or practical to stage development of these components to better match supply capacity to water demand growth.

Financing is not the only significant impediment to the provision of sufficient water storage to met growth in water demand. Suitable storage sites are a scarce resource. Increasingly, sites relatively close to population centres are being subdivided for rural lifestyle uses. Examples include sites in Masterton, Tasman and Selwyn districts. Given their scarcity, and land acquisition difficulties, it is essential that storage sites be identified early, and protected. The development of bulk water supply infrastructure would appear to have many similarities to the development of transport infrastructure. Designation of areas as future water storage sites should be seriously considered is a method for protecting this scarce resource.

Collectively, these development issues threaten to stop storage-based irrigation development projects that would, based on prior experience, bring significant socio-economic benefits – in addition to private financial benefits.

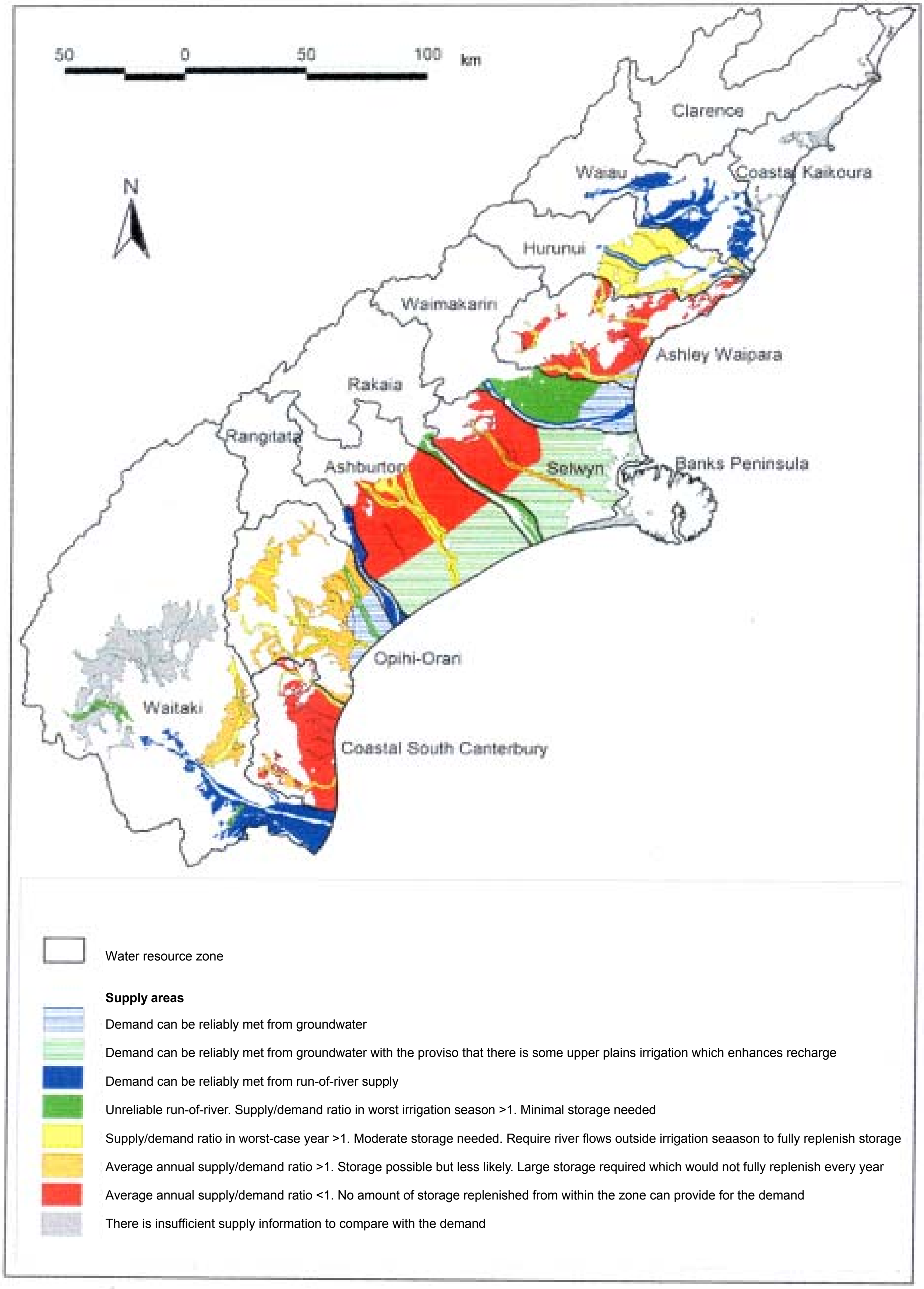

Figure 5. Long-term water supply and demand balance for Canterbury.
Note the supply demand comparison has been carried out assuming the demand from each supply area has been compared with the available water from the zone in which it is located (i.e. water transfer within the zone but not between zones).

Conclusions

A study of future consumptive water use in Canterbury has shown that demand will continue to grow in response to market-driven economic pressures and the pressure of population growth. Pressure will also continue to grow to 'fix up' rivers that have been significantly degraded by water abstraction.

Similar studies in other regions of New Zealand (Lincoln Environmental 2001, 2003a, 2003b) confirm the findings of the Canterbury study, that additional run-of-river water takes are now too unreliable to warrant investment in irrigation development. In some areas the known limit on sustainable groundwater abstractions has been reached. In other areas that constraint is very likely to limit water use well short of the potentially irrigable area.

However, in most areas the average annual supply of water from both surface and groundwater sources is sufficient to meet the potential long-term demand for water, providing significant amounts of storage are developed. Carefully conceived and well-managed storage-based water supply systems will be required if long-term potential water demand is to be met reliably. They are potentially the solution to a number of problematic water allocation and economic sustainability issues.

There are significant financing and land acquisition issues that threaten to prevent the development of storage-based water supply infrastructure, in spite of their considerable socio-economic and environmental benefits.

References

Lincoln Environmental. 2001. Wairarapa Irrigation Development Study. Prepared for Go Wairarapa. *Report no. 4438/1, Lincoln Environmental.*

Lincoln Environmental. 2002. Canterbury Strategic Water Study. Prepared for Environment Canterbury, Ministry of Agriculture and Forestry, and Ministry for the Environment. *Report no. 4557/1, Lincoln Environmental.*.

Lincoln Environmental. 2003a. Tasman Regional Water Study. Prepared for the Tasman Regional Water Augmentation Committee. *Report no. 4487/4, Lincoln Environmental.*

Lincoln Environmental. 2003b. Southland Water Demand Strategy. Prepared for Venture Southland. *Report no. 4597/2, Lincoln Environmental.*

Statistics New Zealand. 2002. Statistics New Zealand Agricultural Production Survey, 2002.

Discussion sessions

Morning session 1

Peter Riley (Riley Consultants): Wick drains have been used in upstream and downstream foundations to consolidate them when the upstream and downstream shoulders of the dam are constructed. How was the potential for connection between these upstream and downstream pressure systems dealt with in Wilsons Dam? There is also a potential connection between the two via gravel lenses in the foundations.

> ***Steven Woods***: The upstream and downstream wick fields are separated by a 12.5 m width of unwicked ground underneath the core, and the upstream field is separated from the lake by a 10 m unwicked zone. Installation of the wicks was aimed at minimising connection to the lower gravels layer. The increased vertical permeability due to the wick drain system was included in the seepage model and the total seepage flow was acceptable as calculated.

Tom Newson (Mighty River Power): How were the instrumentation installations and reliability managed both during construction and post-commissioning of Wilsons Dam, given the large consolidations?

> ***Andrew Hurley***: Foundation piezometer cables were trenched out of the construction area below the dam fill, cables were snaked in the trenches to allow some extension. Inclinometer tubing was brought up through the embankment and protected by hand placing fill ahead of the main fill platform, with big plant kept away from these locations. Fill piezometer cables were typically trenched to the nearest inclinometer tube. Despite these measures there was still some damage from machinery, and this was repaired as it occurred.

Morning session 2

Neil Jacka (URS Ltd): I was intrigued by the use of wood shavings to protect the underdrain when grouting the Arapuni Dam.

> ***Peter Amos***: We did considerable testing to determine the nature of the connection between the foundation leak and the drain, so we knew where the connection was and the size of the voids in the drain. We had positioned a drillhole right at the point of the leak's connection with the drain, so could apply the wood shavings with confidence. Wood shavings were cheap, readily available locally, and worked well with flushing arrangements to prevent grout entry into the drain.

Afternoon session 1

Dennis Crequer (Environment Waikato): Questions for the speakers from the Ministry for Economic Development: 1. Who pays for the Regional Council's role in dam safety? 2. Are tailings dams included? 3. If so, is there special provision for tailings dams? 4. Will Regional Councils become liable for abandoned dams?

> ***Suzanne Townsend***: The Building Act works on a policy of user pays, for example there are fees for Compliance Schedules. Tailings dams are included, without special provision in the legislation. However, details of compliance that have to be met are given in the details of the Resource Consent, the Building Code, and the Compliance Schedules. The policy about abandoned dams with regard to liability, etc. is yet to be fixed, but I would expect the abandoned dams to be risk-managed, as the whole purpose of the policy is to ensure public health and safety.

David Thomson (Environment Canterbury): Do you confirm that the Building Act Amendment will include other water-retaining structures, such as canals on embankments; and will it include the construction phase?

> ***Jeff Jones***: The definition of a dam is a structure that confines, stores, or transports water or other fluids, but it does not include earthworks stopbanks.

Tony Pickford (MWH): Jeff Jones, you mention that Regional Councils will have the power to act on dangerous dams. It is interesting to consider how this may work in practice. Presumably it will require regular reporting by owners to Regional Councils on the performance of their dams. In some instances it could result in some differences of opinion between owners and Regional Councils. Could you comment on these issues?

> ***Jeff Jones***: I am commenting on the basis of seeing a draft of the legislation , but I imagine it will be embodied in the Act in the reporting requirements. It probably would entail more inspections for high-

risk dams, and this would probably be contracted out, as I would not expect most Regional Councils to have the expertise in-house.

Suzanne Townsend: The regulations are about avoiding dangerous dams. There will be no need to check every dam, but when one has an issue, the Act will give Regional Councils the power to act.

Jeff Jones: From personal experience, I would expect most owners of medium- to high-risk dams to take their responsibilities seriously and to contact the regulatory authority as soon as there appears to be a problem. As Chief Executive of a Regional Council I want to know where all the dams are as I am concerned about people downstream of them. The legislation will empower Regional Councils to take positive action to deal with the issue, whereas previously they were not able to take actions that they considered warranted.

Additional questions submitted after the session

Grant Webby (Opus International Consultants): The definition of a 'dam', as quoted by Jeff Jones, would appear to include natural dams such as landslide dams. Is this intended or an unintentional product of the definition? Do you need to restrict the definition of a dam to a man-made structure? No-one wants to be responsible for a landslide dam, particularly Regional Council ratepayers. Yet they form on a reasonably regular basis – every two or three years or so.

Peter Mulvihill: The definition of a dam in the Bill:

dam –

(a) means an artificial barrier constructed for the purpose of confining, storing, or transporting water or other fluid;

and

(b) includes –

(i) a natural feature that has been modified to function as a dam; and

(ii) a canal; but

(c) does not include an earthwork stopbank designed to control floodwaters.

My understanding is that unless your natural feature has been modified to function as a dam it is not a dam under the Act.

Grant Webby (Opus International Consultants): As one who is directly involved in the classification of dams from a potential impact perspective, I sometimes find it very difficult to classify a dam structure within the categories specified in the NZSOLD Guidelines. Sometimes this is because there is limited information on the downstream area, particularly the size of the population, and in other cases it is because of the difficulty of actually quantifying the size of any dam break flood due to the imprecise understanding of the physics of dam failures. The end result is that it is necessary to define it by a 'medium to low' classification. How do you see the proposed legislation coping with this situation? Also, how do you see the legislation coping with descriptions in the NZSOLD Guidelines such as 'significant' damage?

Peter Mulvihill: With regard to Potential Impact Classification, the NZSOLD Guidelines set out a broad set of categories for dams in terms of Failure Consequences. The guidelines are open to interpretation and judgement by experienced professionals. At this stage I doubt if the proposed legislation or regulations will be any more definitive on this issue than the NZSOLD Guidelines. With regard to structures in the Medium to Low category I suggest that a conservative approach would be appropriate and the dam would be initially classified as a Medium Impact Structure. Give the examples provided, it would appear that the owner would still have the option of carrying out a more detailed analysis of the particular situation to prove otherwise.

Don Bagnall (MAF): Regional Councils have expressed concern at the proposed 8 m/50 000 m^3 threshold and consider it a matter for individual Council decision. The threshold was discussed in the 1990s. Initial proposals for a 5 m/20 000 m^3 threshold drew concern from the rural sector about compliance costs for structures where risks of potential failure were minimal. The proposal for a 8 m/50 000 m^3 threshold together with a provision for Regional Councils to require greater monitoring for dams with higher public risk seemed politically acceptable. Does NZSOLD support the general New Zealand-wide proposal for a 8 m/50 000 m^3 threshold?

Peter Mulvihill: From an NZSOLD viewpoint, in general we have never been comfortable with the concept of an arbitrary threshold. These threshold do not account for the consequences of failure and can be misleading in situations where there is stored material other than water, and there is a significant population at risk in the immediate vicinity of the dam. The Potential Impact Classification criteria as outlined in the NZSOLD Guidelines are considered a more appropriate mechanism for determining the level of safety standards required for design construction and ongoing performance monitoring of an individual dam structure. This approach is also consistent with the risk-based philosophy, which is likely to become more relevant as formal risk management techniques are adopted in the future. We are conscious of unnecessary compliance costs, but the current legislation is targeted at medium- and high-impact dams and will have limited if any impact on small farm dams.

Afternoon session 2

No questions

Afternoon session 3

Dennis Crequer (Environment Waikato): Peter Lilley, how many of the consent conditions that have been made on your applications have been appealed by TrustPower itself?

Peter Lilley: All four have been appealed, in fact it is almost necessary to do so, but then to resolve the issues through mediation.

Peter Birch (Marsh Insurance): Gary Campbell, is it an issue with insurers to be needing upgrading of the system in the South Island when it is getting power to the North Island?

Gary Campbell: The main concern in Project Aqua is Stage 2, which needs an upgrade. Although it is a common belief that all the power is going to the North Island, in fact the trend is for the South Island to be getting towards self-sufficiency.

Afternoon session 4

Neil Jacka (URS): Philip Lees, were there lessons to be learnt from some actions perhaps being insufficient in terms of the Emergency Management Plan, or was there not one there at the time of the Opuha dam breach?

Philip Lees: No, there wasn’t one at the time of the breach.

Peter Foster (MWH): How important is it to lengthen the time of early warning in view of the times shown by Philip for the flood peak to travel downstream?

Philip Lees: The earlier the warning the better. I’d estimate that to evacuate a settlement the size of Pleasant Point (just over 1000 people) would need about six hours.

Dennis Crequer (Environment Waikato): John Bright, when you referred to water storage, was it in relation to in-stream or off-stream storage? And if off-stream, why are you concerned about the allowable operating range?

John Bright: It was primarily out-of-river storage. The temptation is to promote other benefits of the storage lakes, e.g. recreational uses, but these require design to low operating ranges. The concern is that we don’t oversell these benefits and promote too great public expectations over time.

Peter Riley (Riley Consultants Ltd): John, how can planning for future agricultural needs be encouraged so as to set aside sites for water storage? As Angela Arthington said, planning for availability of sites and recognising their ecological requirements is essential.

John Bright: The motivation for the Canterbury Strategic Water Study was the concern over the number of ad hoc developments leading to suboptimal outcomes and inefficient use. The study has led to ongoing discussion with the local authorities to see how long-term water demand can be met, including maintaining flows. Some of the smaller rivers are highly over-allocated and in need of significant restoration. This is possible as well as meeting longer-term needs, as long as it is all part of a strategic development plan that includes substantial amounts of storage. Part of the strategic planning process has to be the identification and protection of potential storage sites.

Angela Arthington (Griffiths University): Perhaps somebody in NZSOLD can tell me whether there is a process for defining rivers of such high conservation significance that no water resource developments can ever occur.

Would it not be useful in terms of the consents process to have some forward planning (a blueprint for conservation versus development) rather than every consent process addressing a single river system in isolation?

> ***Peter Foster*** (MWH): Regarding your first question, some rivers do have Conservation Orders placed on them so that they cannot be developed, for example the main stem of the Rangitata River
>
> ***Peter Mulvihill***: To answer the second part of the question requires some background information. Central planning and development became "unfashionable" in New Zealand in the late 1980s with the drive towards a market economy and in some part as a backlash to the Think Big Projects that had achieved limited success in the early 1980s. With the introduction of the Resource Management Act in 1991, the administration of natural resource use and development was delegated to Regional and Territorial Local Authorities, although the Government still reserved "call in" rights on projects of national significance. Some of the criteria or "tests" governing development included sustainability and avoiding, remedying or mitigating adverse environmental effects. As part of the forward planning process, Regional and Territorial Authorities were given the job of producing plans and policies covering resource use for land, water, air and the coastline. These plans are effects-based, and the process required to produce them has taken significant time as they are subject to public consultation and appeal processes. With regard to water resources, some regions have been more successful at producing and implementing these plans than others. The objective of the plans was to some extent to provide the "blueprint" and to avoid ad hoc development. This was seen as a preferable system to, say, a "zoning system", as it allowed for changes in public/environmental values and needs with time. However, the system or process does not appear have evolved quickly enough to handle some of New Zealand's current issues such as water allocation and potential energy shortfalls.

Summary overview

Murray Gillon

I am sure that everyone here will agree that we have had an outstanding day, with a compelling keynote speech and a really interesting collection of papers illustrating current trends.

We have been fortunate to have Angela Arthington as our keynote speaker. I had heard her speak in Australia, and I gained so much from that first hearing that I was very keen that her work should also be presented here. I suspect that I am not untypical of today's audience in that I have no ecological training – I am a dam engineer. I like technical problems, I like building things and fixing things. However, although I'm not a biologist, I warmed to her simple, logical listing of the effects of dams and I understood and appreciated her four principles. Her outline of river flow methodologies and their significance left me with a desire to learn more, and, for those jobs I'm involved with, to see some of these aspects addressed.

Then came a morning of papers with a more technical focus – a feast of geotechnology and design. This is the stuff I really like – instruments and behaviour of materials and what's going on. We heard details about the recent construction and commissioning of a water-storage dam, Wilsons Dam. Then we heard about the environmental issues that had to be dealt with from drawdown of the lake in order to carry out remedial works at Cosseys Dam, including the reduction of local environmental effects by having the storage area for excavated fill in the empty reservoir. The maintenance-level activity at Arapuni Dam also presented a considerable challenge. The grouting operation was, however, done without compromising dam safety or blocking the foundation drainage system. Finally, we were given a good overview of international and national practice with our least known dams in New Zealand, tailings storage dams.

The next group of papers dealt with new legislation – its history, a Regional Council view, and the content of work in progress. We've been moving into a new regulatory regime for dams for some years, as previous NZSOLD symposia testify. The reality now for dam owners is that they operate by permission, not as of right. Our hope for environmental systems lies in these regulatory processes, which force ecology to be taken into account. However imperfect our processes still are, at least it is taken into account more now, and I've no doubt that there will be refinements over time. The legislation is reaching the Select Committee stage and is open to our input. I hope we can contribute, because we want the new legislation to be seen as of value not as a constraint.

We then had papers about the re-consenting process, which is being undertaken by a large number of dams at present. Two of these papers were from dam owners and one from a regulator, and there was also a paper on the consenting process for a new project, Project Aqua. The huge effort involved in consent processes is very evident.

Then we heard the emergency management story of a dam overtopping – the Opuha Dam – during its construction, with some guidance for comprehensive emergency management of dams during the construction phase.

Finally we heard about the need for water storage to meet agricultural irrigation demand if it is to grow.

For me, the two overriding impressions from the day come from remarks by two of our speakers:

- Dennis Crequer said: We're moving into a new regulatory regime, and
- John Bright said that the biggest challenges in meeting long-term water demand were environmental and economic, not technical.

List of participants

Paula Alkema	Connel Wagner Ltd, P.O. Box 186, Blenheim	alkmap@conwag.com	03 578 9967
Peter Amos	DamWatch Services Ltd, P.O. Box 1549, Wellington	peter.amos@damwatch.co.nz	04 381 1300
Clive Anderson	URS NZ Ltd, P.O. Box 4479, Christchurch	clive_anderson@urscorp.com	03 374 8513
Lambert Anderson	Opus International Consultants, P.O. Box 12-003, Wellington	lambert.anderson@opus.co.nz	04 471 7572
Angela Arthington	Centre for Riverine Landscapes, Griffith University, Brisbane 4111, Australia	a.arthington@griffith.edu.au	0061 7 3875 7403
Don Bagnall	MAF, P.O. Box 2526, Christchurch	Don.bagnall@maf.govt.nz	04 474 4162
Ghasson Basheer	Environment Waikato, P.O. Box 4010, Hamilton	ghasson.basheer@ew.govt.nz	07 856 0555
Peter Birch	Marsh, P.O. Box 2221, Auckland	peter.r.birch@marsh.com	09 366 9236 021 637 707
Peter Blackwood	Environment Bay of Plenty, P.O. Box 364, Whakatane	peterb@envbop.govt.nz	0800 368 267
Jarrod Bowler	Genesis Power Ltd, Private Bag 36, Turangi	jarrod.bowler@genesisP.O.wer.co.nz	07 386 1120
John Bright	Lincoln Environmental, P.O. Box 133, Lincoln	brightj@lincoln.ac.nz	03 325 3700
Robbin Britton	Environment Bay of Plenty, P.O. Box 364, Whakatane	robbin@envbop.govt.nz	021488013
James Burr	Tonkin & Taylor Ltd, P.O. Box 5271, Wellesley St, Auckland	jburr@tonkin.co.nz	09 356 7885
Craig Cairncross	Sinclair Knight Merz Ltd, P.O. Box 9806, Newmarket, Auckland	ccairncross@skm.co.nz	09 913 8994 021 280 3603
Gary Campbell	Meridian Energy Ltd, P.O. Box 2454, Christchurch	gary.campbell@meridianenergy.co.nz	03 357 9786
Peter Campbell	DamWatch Services, P.O. Box 1549, Wellington	Peter.Campbell@damwatch.co.nz	04 381 1300
Basil Chamberlain	Taranaki Regional Council, Private Bag 713, Stratford	basil.chamberlain@trc.govt.nz	06 765 7127
Nigel Connell	Nigel A Connell Engineers, 321 Marine Dr., Eastbourne	naconnell@xtra.co.nz	04 381 1322
Dennis Crequer	Environment Waikato, P.O. Box 4010, Hamilton East	dennis.crequer@ew.govt.nz	07 856 0555
Steve Currie	Energy Surveys Ltd, 121 Mapara Road, RD1, Taupo	energysurveys@xtra.co.nz	07 378 2224 025 967 735
Annabel Davies	WaterCare Services, Private Bag 92-802, Penrose, Auckland	adavies@water.co.nz	09 634 4829
Ross Davis	Davidson Partners Ltd, P.O. Box 256, Blenheim	Ross@DavidsonPartners.co.nz	03 578 7029
Brian Ellwood	Meridian Energy Ltd, P.O. Box 2454, Christchurch	brian.ellwood@meridianenergy.co.nz	03 357 9700
Steve Everitt	Bright Spark Group, P.O. Box 474, Whakatane	steve.sheryl.everitt@xtra.co.nz	07 308 2440
Debbie Fellows	URS, P.O. Box 821, Auckland	debra_fellows@urscorp.com	09 355 1300
Nathan Fletcher	DamWatch Services, P.O. Box 1549, Wellington	nathan.fletcher@damwatch.co.nz	04 381 1300
Dan Forster	DamWatch Services, P.O. Box 1549, Wellington	dan.forster@damwatch.co.nz	04 381 1300
Peter Foster	MWH NZ Limited, P.O. Box 9624, Wellington	peter.f.foster@mwhglobal.com	04 381 6700
Neil Gillespie	Contact Energy, P.O. Box 25, Clyde, Otago	neil.gillespie@contact-energy.co.nz	03 440 0319
Murray Gillon	DamWatch Services, P.O. Box 1549, Wellington	Murray.Gillon@damwatch.co.nz	04 381 1300
Tim Gillon	DamWatch Services, P.O. Box 1549, Wellington	Tim.gillon@damwatch.co.nz	04 381 1300
Geoff Gregory	Word Therapy, 27a Ratanui Road, Paraparaumu, Kapiti Coast	ggregory@kapiti.co.nz	04 297 3258
Richard Griffiths	Meridian Energy Ltd, P.O. Box 2454, Christchurch	richard.griffiths@meridianenergy.co.nz	03 357 9700
John Grimston	Tonkin & Taylor Ltd, P.O. Box 5271, Wellesley St, Auckland	jgrimston@tonkin.co.nz	09 355 6025
David Hamilton	David Hamilton and Associates Ltd, P.O. Box 1420, Dunedin	david@davidhamilton.co.nz	03 454 3380
Gordon Hamilton	Meridian Energy Ltd, Private Bag 950, Twizel	gordon.hamilton@meridianenergy.co.nz	03 435 0818
Gary Hancock	GRD Macraes Ltd, P.O. Box 84, Palmerston, East Otago	gary.hancock@macraes.co.nz	03 474 8241
Athol Henderson	Meridian Energy Ltd, Private Bag 950, Twizel	athol.henderson@meridianenergy.co.nz	03 435 0818
Phillip Hindrup	Hawkes Bay Regional Council, Private Bag 6006, Napier	phillip@hbrc.govt.nz	06 835 3200
Bonny Hooker	Genesis Power Ltd, Private Bag 36, Turangi	Bonny.hooker@genesispower.co.nz	07 386 1211 021 745 657
Mick Howland	Hydro Tasmania, GPO Box 355, Hobart, TAS 7001, Australia	mick.howland@hydro.com.au	0061 3 6230 5534
Andrew Hurley	MWH, P.O. Box 13-299, Wellington	andrew.hurley@mwhglobal.com	03 343 8714
Neil Jacka	URS, P.O. Box 821, Auckland	neil_jacka@urscorp.com	09 355 1300
Dave Jenks	DamWatch Services, P.O. Box 1549, Wellington	Dave.jenks@damwatch.co.nz	04 381 1300
Ron Johnston	Eastland Network Ltd, P.O. Box 1048, Gisborne	ron.enl@xtra.co.nz	06 838 8349
Jeff Jones	Environment Bay of Plenty, P.O. Box 364, Whakatane	jeff@envbop.govt.nz	07 922 3335
Alasdair Keane	Keane Associates Ltd, 10a Heretannga Square, Upper Hutt	keane.associates@xtra.co.nz	04 528 4024 021 451 952
Murray Kennedy	Greater Wellington Regional Council, P.O. Box 11-646, Wellington	murray.kennedy@gw.govt.nz	04 381 7791
Andrew King	Inst. Geological & Nucl. Sci., P.O. Box 30-368, Lower Hutt	a.king@gns.cri.nz	04 570 4726
Colin Krumdieck	MWH, P.O. Box 13-249, Christchurch	colin.krumdieck@mwhglobal.com	03 343 8779
Hank Kruitbosch	Meridian Energy Ltd, Private Bag 950, Twizel	hank.kruitbosch@meridianenergy.co.nz	03 435 0818
Philip Lees	Environment Canterbury, P.O. Box 550, Timaru	philip.less@ecan.govt.nz	03 688 9069
Peter Lilley	TrustPower Ltd, Private Bag 12-023, Tauranga	peter.lilley@trustpower.co.nz	07 574 4788
Nick Logan	DamWatch Services, P.O. Box 1549, Wellington	Nick.logan@damwatch.co.nz	04 381 1300
Grant Lovell	Tonkin and Taylor Ltd, P.O. Box 13-055, Wellington	glovvell@tonkin.co.nz	03 353 4400
Don MacFarlane	URS NZ Ltd, P.O. Box 4479, Christchurch	don_macfarlane@urscorp.com	03 374 8507

Bruce McAuliffe	Environment Waikato, P.O. Box 4010, Hamilton East	bruce.mcauliffe@ew.govt.nz	07 856 0555
Alastair McCarthy	Greater Wellington Regional Council, P.O. Box 11-646, Wellington	alastair.mccarthy@gw.govt.nz	04 802 0316
Matt McDonald	Meridian Energy Ltd, Private Bag 950, Twizel	Matthew.McDonald@Damwatch.co.nz	03 435 0818
Kevin McFall	Environment Canterbury, P.O. Box 550, Timaru	kevin.mcfall@ecan.govt.nz	03 688 9069
Stephen McInerney	DamWatch Services, P.O. Box 1549, Wellington	Stephen.mcinerney@damwatch.co.nz	04 381 1300
Tony McKormick	Meridian Energy Ltd, P.O. Box 2454, Christchurch	tony.mckormick@meridianenergy.co.nz	03 357 9700
Tim McMorran	URS NZ Ltd, P.O. Box 4479, Christchurch	tim_mcmorran@urscorp.com	03 374 8500
Ian McPherson	Connell Wagner, P.O. Box 1591, Wellington	mcphersoni@conwag.com	04 472 9589
Wal McQuarrie	WaterCare Services Ltd, Private Bag 92802, Penrose, Auckland	wmcquarrie@water.co.nz	09 6344 827 027 249 6517
Sally Marx	Tonkin & Taylor Ltd, P.O. Box 2083, Wellington	smarx@tonkin.co.nz	04 381 8573
Trevor Matuschka	Engineering Geology Ltd, P.O. Box 33-426, Takapuna	enggeo@clear.net.nz	09 486 2546
Ian Meredith	Genesis Power Ltd, Private Bag 36, Turangi	ian.meredith@genesispower.co.nz	07 386 1136
Paula Meredith	Rotorua District Council, Private Bag, Rotorua	paula.meredith@RDC.govt.nz	07 348 4199
Graeme Mills	DamWatch Services, P.O. Box 1549, Wellington	Graeme.mills@damwatch.co.nz	04 381 1300
Tim Mills	Meridian Energy Ltd, Private Bag 950, Twizel	tim.mills@meridianenergy.co.nz	03 435 0818
Paul Mitchell	Riley Consultants, P.O. Box 100-253, North Shore, Auckland	pmitchell@riley.co.nz	09 489 7872
Murray Mulholland	Environment Waikato, P.O. Box 4010, Hamilton	murray.mulholland@ew.govt.nz	07 856 0555
Peter Mulvihill	Pioneer Generation Ltd, P.O. Box 275, Alexandra	ptm@pioneergen.co.nz	03 448 6081
Mark Nelson	Opus International Consultants, Private Bag 1913, Dunedin	mark.nelson@opus.co.nz	03 474 8899
Tom Newson	Mighty River Power, P.O. Box 445, Hamilton	tom.newson@mightyriver.co.nz	07 857 0154
Colin Newton	Meritec Ltd, P.O. Box 4241, Newmarket, Auckland	colin.newton@meritec.org	09 379 1214
W. J. Page	Page & Associates Ltd, 106 Collingwood St, Nelson	bill@pageltd.co.nz	03 548 2189
Glen Parker	Marlborough District Council, P.O. Box 443, Blenheim	gpa@marlborough.govt.nz	03 578 5249
Warwick Pascoe	Environment Canterbury, P.O. Box 345, Christchurch	warwick.pascoe@econ.govt.nz	03 365 3828
Kathy Perreau	Ministry for the Environment, P.O. Box 10362, Wellington	kathy.perreau@mfe.govt.nz	04 917 7546
Alan Pickens	Pickens Consulting Ltd, 45 Alice Avenue, Orewa	apickens@tonkin.co.nz	09 427 6400
Tony Pickford	MWH, P.O. Box 13-249, Christchurch	tony.pickford@mwhglobal.com	03 3438745
Rebecca Polvere	DamWatch Services, P.O. Box 1549, ellington	rebecca.polvere@damwatch.co.nz	04 381 1300
Stuart Read	Inst. Geological & Nucl. Sci., P.O. Box 30-368, Lower Hutt	S.Read@gns.cri.nz	04 570 4728
Donald Richardson	Duffill Watts & King Ltd, P.O. Box 330, Tauranga	donald.richardson@duffillwatts.com	07 928 3410
Peter Riley	Riley Consultants, P.O. Box 100-253, North Shore, Auckland	priley@riley.co.nz	09 489 7872
Ken Roberts	Contact Energy, P.O. Box 25, Clyde, Otago	ken.roberts@contact-energy.co.nz	03 440 0327
Ross Roberts	RWV Roberts Consultancy, 572 Waitomo Valley Rd, RD 7, Otorohanga	rw.v.roberts@xtra.co.nz	07 873 8208
Wayne Robinson	Mighty River Power, P.O. Box 145, Hamilton	wayne.robinson@mightyriver.co.nz	07 857 8256
David Roper	NIWA, P.O. Box 11-115, Hamilton	d.roper@niwa.co.nz	07 856 1727
Jeff Ruddock	Newmont Waihi Operations, P.O. Box 190, Waihi	jeff.ruddock@newmont.com.au	07 863 8192
Paul Russell	MWH New Zealand Ltd, P.O. Box 3455, Richmond, Nelson		03 546 0720
Don Scarlet	Mighty River Power, P.O. Box 445, Hamilton	don.scarlet@mightyriver.co.nz	07 857 0157
Craig Scott	Riley Consultants Ltd, P.O. Box 4355, Christchurch	cscott@riley.co.nz	03 379 4402
Brendan Sheehan	35 Cotswold Avenue, Bishopdale, Christchurch		03 359 5768
Jon Sickling	Sinclair Knight Merz, P.O. Box 10-283, Wellington	jsickling@skm.co.nz	04 914 8476
Peter Silvester	Contact Energy, P.O. Box 25, Clyde, Otago	peter.silvester@contact-energy.co.nz	03 440 0310
Mike Southby	Doug Hood Ltd, P.O. Box 4361, Christchurch	m.southby@doughood.co.nz	03 348 1745
John Stewart	Mighty River Power, P.O. Box 445, Hamilton	john.stewart@mightyriver.co.nz	07 857 0226
Gerald Strayton	Pattle Delamore Partners, P.O. Box 9528, Newmarket, Auckland	gerald.strayton@pdp.co.nz	09 523 6900
Don Tate	Riley Consultants, P.O. Box 100 -253, North Shore, Auckland	dtate@riley.co.nz	09 489 7872
David Thomson	Environment Canterbury, P.O. Box 550, Timaru	david.thomson@ecan.govt.nz	03 688 9069
Scott Vaughan	Riley Consultants, P.O. Box 100 -253, North Shore, Auckland	svaughan@riley.co.nz	094897872
Jim Walker	Meridian Energy Ltd, P.O. Box 2454, Christchurch	jim.walker@meridianenergy.co.nz	03 357 9700
Neil Watkins	Mighty River Power, P.O. Box 445, Hamilton	neilwatkins@mightyriver.co.nz	07 857 0199
John Waugh	Opus International Consultants, P.O. Box 12- 003, Wellington	john.waugh@opus.co.nz	04 471 7000
Grant Webby	Opus International Consultants, P.O. Box 12 -003, Wellington	grant.webby@opus.co.nz	04 471 7101
Simon Weston	Whangarei District Council, Private Bag 9023, Whangarei	simonw@wdc.govt.nz	09 430 4268
Derek Wilshere	NZSOLD, P.O. Box 41-069, Eastbourne, Wellington	derek.wilshere@xtra.co.nz	04 562 7920
Steven Woods	MWH, Tower 2, 7 Deans Ave, Christchurch	steven.j.woods@mwhglobal.com	03 343 8799
Keith Woolley	Greater Wellington Regional Council, P.O. Box 11-646, Wellington	keith.woolley@gw.govt.nz	04 384 5708