

Health Impact Assessment of Central Plains Water Scheme

April 2008

Lead agency: Community and Public Health, Canterbury District Health
Board

HIA lead: Alistair Humphrey

Report prepared by: Humphrey A, Walker M, Porteous A, Pink R,
Quigley R, and Thornley L

Acknowledgements

This rapid health impact assessment (HIA) has benefited from the knowledge, experience and skills of many people.

A steering group of Alistair Humphrey, Malcolm Walker, Ramon Pink, Andrew Porteous, Louise Thornley and Robert Quigley provided direction and insight into the process. An initial scoping meeting was held and stakeholders were invited to set the boundaries for the HIA. A list of invited members and participants is attached as Appendix 1.

A number of people provided valuable advice to the steering group beyond attendance at the meetings; Martin Ward, Margaret Leonard, Carl Hansen, Richard English, Geoff Fougere, Miria Lange, Professors Tony Blakely, Valerie Brown, Peter Crampton, Paul Dalziel, and Karen Witten.

Finally, Gina Erceg and others in the administration team of Community & Public Health provided valuable support in word processing and administration, often at short notice at a difficult time of year.

Table of contents

Acknowledgements	2
Executive Summary	4
1. Introduction.....	6
2. Methodology.....	11
2.1. Scope.....	11
2.2. Appraisal	21
2.3. Assessment of evidence	24
3. Background – water quality	26
4. Findings – water quality.....	31
4.1. Potential effects of CPWS on water quality.....	31
4.2. Potential effects of reduced water quality on health.....	37
5. Findings – socioeconomic impacts.....	42
6. Discussion	45
6.1. Relationship between CPWS and water quality.....	45
6.2. Potential impact of nitrates on health	47
6.3. Potential impact of CPWS on septic tank contamination and flooding	48
6.4. Pathways between CPWS, water quality and health outcomes.....	48
6.5. Socioeconomic effects of CPWS with respect to health	52
6.6. Issues for Maori with respect to health.....	54
7. Conclusion and recommendations	56
7.1. Overall recommendation	57
7.2. Suggested mitigating actions – water quality	58
7.3. Suggested mitigating actions – socioeconomic issues	60
References.....	62
Appendix 1	64
Appendix 2a	66
Appendix 2b	67
Appendix 2c.....	68

Executive Summary

The Central Plains Water Scheme (CPWS) is a proposed project designed to provide irrigation for 60,000 hectares of land in Canterbury. The scheme would encourage intensification of farming in order to meet increasing world demand for agricultural products. Community and Public Health, of the Canterbury District Health Board, has undertaken this Health Impact Assessment (HIA) to contribute to the consideration of the proposed scheme within the statutory resource consent process.

This HIA has considered the evidence for the benefits and risks of the CPWS with respect to population health and wellbeing. The assessment is based on evidence drawn from four workshops with key stakeholders and experts, literature reviews and interviews with experts. In particular, the HIA has considered the potential health implications in terms of water quality and socio-economic issues.

The HIA found there are potential adverse health implications associated with the scheme in relation to water quality. Rising groundwater levels associated with the scheme are likely to lead to septic tank failures on the central plains and, as yet, there is not enough evidence to rule out increased nitrate contamination in Canterbury, including of the Christchurch city aquifer. If the scheme went ahead as proposed there would be a small, but notable, risk of infant death at some time in the future from methaemoglobinaemia. As increased groundwater nitrate concentrations take a long time to reverse and are difficult to treat, this represents a considerable risk to the Canterbury community.

Appraisal of socioeconomic effects suggested that financial benefits of the scheme would initially be confined to a small proportion of the community, most of whom are not in the most socially deprived sector of society and whose families will therefore receive little, if any, health benefit from the scheme. There is little evidence of any likely “trickle down” effect from the scheme in improving the health of the most deprived of Canterbury’s population. Most of the job vacancies generated by the scheme are likely to be filled by people from outside Canterbury and New Zealand. While these people and their families may experience improved health as a result of their migration, it is unlikely that simply increasing the population of Canterbury will

improve the overall health of Cantabrians. Since there is no “rural decline” in Canterbury, there will be no significant benefit in terms of retention of businesses and services in the area. In fact, it is likely that current services, although they have expanded recently, would be stretched.

Based on assessment of the scientific literature, expert advice and key stakeholders’ views, the HIA has concluded that the potential risks of the CPWS to the health of Cantabrians as a whole outweigh the probable financial benefits to a few people. It is recommended that resource consent be declined at this stage. A set of potential actions to mitigate the anticipated health concerns is provided in the event that the scheme is granted consent to proceed.

1. Introduction

This report summarises the process and findings of a health impact assessment (HIA) on the proposed Central Plains Water Scheme (CPWS) in Canterbury. The area in the proposed CPWS is located between the Rakaia and Waimakariri Rivers. The CPWS is a proposal to irrigate up to 60,000 hectares of farmland by building a dam in the Waianiwaniwa Valley near Glentunnel to create a water storage lake. The lake would be filled from the Waimakariri and Rakaia Rivers. The stored water would then be distributed to local landowners for irrigation through canals radiating out from the lake. Due to the size and potential impacts of the proposed scheme, there is considerable public and media interest.

Under the New Zealand Public Health and Disability Act (2000), every District Health Board has the responsibility to:

- “improve, promote and protect the health of people and communities” [s22 (a)]
- “promote the reduction of adverse social and environmental effects on the health of people and communities” [s23 (1) (h)].

The Canterbury District Health Board (CDHB) partially fulfils this obligation through the participation of its Community and Public Health Division (Environmental Health Team) in the Resource Management Act (RMA) process. Consideration of the proposed Central Plains Water Scheme is within the RMA process. The Community and Public Health Division of the CDHB made a submission opposing the granting of resource consent for the CPWS. This was largely due to concern about insufficient information on the potential health implications of the proposed scheme. In its submission Community and Public Health recommended that an HIA be carried out to address this concern.

Community and Public Health considered that an HIA of the CPWS was warranted as:

- The CPWS would affect a large number of people, and have impacts on many determinants of health and wellbeing.

- Central Plains Water Ltd recognised that changing land use is a key determinant of the health and wellbeing of communities.
- The local authorities involved have a strong interest in health and wellbeing, and a willingness to try innovative approaches. This was recently demonstrated by an HIA on the Greater Christchurch Urban Development Strategy.
- Community and Public Health wanted to strengthen their work across sectors to promote health and wellbeing.
- The timing was right for informing the CPWS resource consent hearing.

In the year following the initial application, CPW Ltd carried out several pieces of work which touched on a number of health issues. CDHB commissioned HIA specialists Quigley and Watts Ltd to review this work. Quigley and Watts Ltd carried out a scoping report involving technical input from key stakeholders. In this scoping report the wider health implications of the expansion of agriculture and associated industry in the region were considered, along with the more specific health issues related directly to water. The report concluded that a full assessment of the potential health effects of the CPWS had not been carried out and that there was an opportunity to carry out some more detailed work. Given the amount of time available a rapid HIA was recommended. The findings of this scoping exercise were given to CPW Ltd to be included as part of the application if considered appropriate.

Community and Public Health sourced funding from the Ministry of Health's Health Impact Assessment Unit as there was mutual benefit in undertaking the HIA while building capacity in Canterbury in this developing field. Some of this funding was used to commission services from Quigley and Watts Ltd to support the work. The CDHB considered that the HIA could be used as a basis for their evidence to the resource consent hearings commencing in April 2008.

Definition of health impact assessment

HIA is a multidisciplinary approach that investigates the potential health and wellbeing outcomes of a proposal. Its aim is to deliver evidence based recommendations that inform the decision-making process, in order to maximise gains in health and wellbeing and to reduce or remove negative impacts or inequalities. HIA uses the broad definition of health used by the World Health Organization: "*Health is a state of complete physical, mental and social well-being*

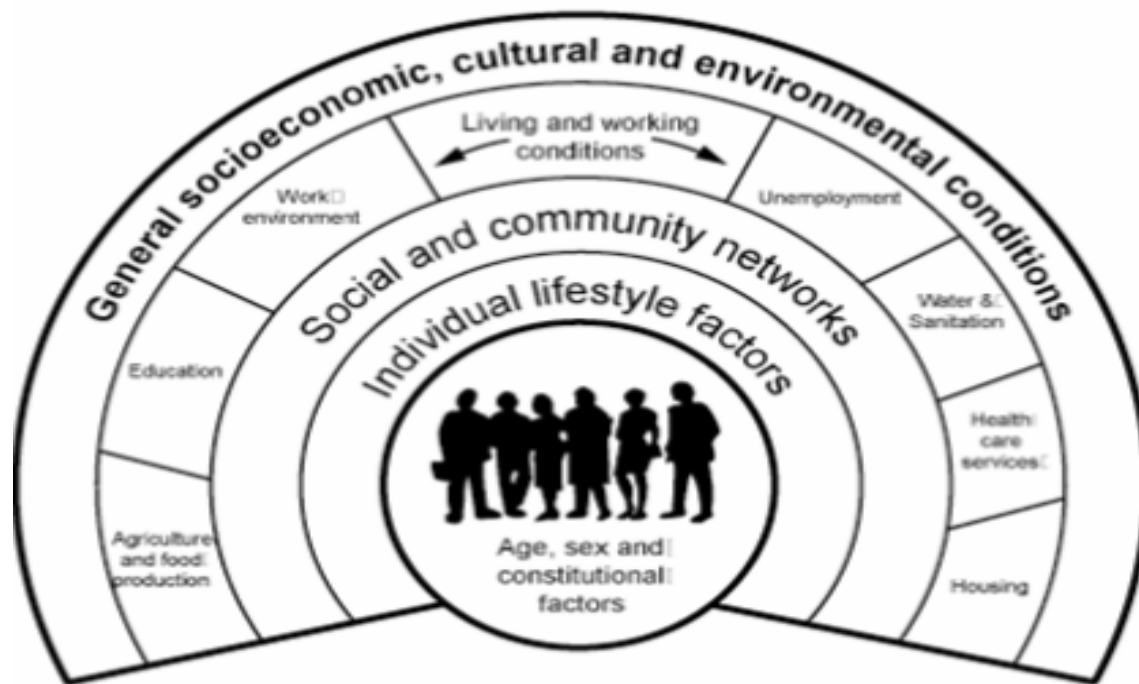
and not merely the absence of disease or infirmity"(WHO 1978). Flexible methodologies are used to ensure that the approach best fits with the proposal in question, the resources available, and the local populations affected. HIA is an internationally recognised approach that helps to protect and promote public health.

Factors influencing health

Health and wellbeing is not solely determined by the health sector. In fact, determinants of health such as education, employment, poverty and inequality have a far more profound and long lasting effect on health and well being than curative services. The health sector spends the majority of its budget on treating people when they are unwell (making a significant contribution to population wellbeing), but only a very small amount (approximately 2-5% in direct funding channels) is spent on trying to prevent illness. Thus, protecting the health and wellbeing of the population cannot rest with the health sector alone. This is well recognised by the Canterbury District Health Board, which collaborates with many other agencies, particularly at an operational level through their Community and Public Health Division. The Physical Environments team has been principally responsible for this HIA which, in common with other HIAs, largely focuses on proposals in sectors other than health.

In addition, public health and wellbeing is determined by the interplay between individual lifestyle factors, the environment in which people live and the services that people have access to, as well as broad social and economic factors. While individual lifestyle factors such as smoking, fruit and vegetable intake and/or obesity have an immediate or proximal effect on individual health, these factors are themselves fundamentally determined by the socioeconomic environment in which individuals live. For example, obesity is a known risk factor for diabetes, but unemployment and lack of education are determining factors for obesity. This relationship is well represented by the Dahlgren and Whitehead model (Dahlgren G. and I. 1991) (see Figure1 below).

Figure 1: Model of factors that determine health and wellbeing



Dahlgren & Whitehead 1991

The community in which people live, work, play and study is where illnesses and injuries develop and occur. For example, homes that are dry and warm, workplaces that are safe, and streets that promote walking and cycling are examples of how the environment can improve community health and wellbeing. Conversely, environments which are cold and damp, associated with crime, or which make physical activity difficult can increase the incidence of disease and other markers of poor health. Broad social and economic environments make a major contribution to wellbeing. These include sound and reliable governance, unemployment rates, general economic conditions, and social support structures. However, it is often difficult to determine the relative importance of each health determinant, particularly as they occur simultaneously and are often inter-related.

The Dahlgren and Whitehead model (Figure 1 above) indicates a number of these determinants of health in broad terms. When these determinants of health are affected by a proposal, then health and wellbeing will also be affected, either directly or indirectly, positively or negatively. HIA helps to assess how the broader determinants of health are affected by a proposal and the risks or benefits of this with respect to health outcomes. Since the broader determinants of health have to be considered in HIAs, the methodology and content tends to overlap with environmental impact assessments, social impact assessments and cultural impact assessments.

HIA is widely used in many countries throughout the world, particularly in Europe and Canada, and is a compulsory part of resource applications in Tasmania. It is an established methodology encouraged by the World Health Organization and the European Union. However, HIA is still in its infancy in New Zealand. This is rapidly changing as the Ministry of Health and the Public Health Advisory Committee have released guidance on carrying out policy-level HIA within New Zealand, the draft Public Health Bill promotes HIA as a tool to improve health within the NZ setting, and the NZ Health Strategy (2000) promotes the consideration of health in non-health sector decision making. The Human Rights Commission recommends the use of HIA at a strategic level, and government legislation is placing public health higher on the agenda within the transport and local government settings.

2. Methodology

2.1 Scope

The scoping stage of the HIA project clarified key requirements including:

- Aims and objectives of the HIA
- Timeframes
- Budgets and other resources available
- Determinants of health on which to focus
- Affected populations on which to focus
- Components of the scheme on which to focus.

Many of the requirements were determined during a scoping meeting where key stakeholders were invited to help set the boundaries for the HIA. A scoping workshop was held on 29 November 2007 with over 20 stakeholders attending. The full list of people and organisations who were invited is shown in Appendix 1. The scoping workshop was a half-day meeting including presentations by Robert Quigley (on HIA) and Bob Penter (on the CPWS). The meeting also involved two sets of small group discussions to identify priority determinants of health and population groups, and one large group discussion on priority components of the scheme and suggestions for key stakeholders and evidence sources.

Aims

The aim of the HIA is to contribute to the resource consent process by assessing the potential positive and negative implications of the CPWS for health and wellbeing in relation to the selected priority determinants of health. The HIA aimed to make recommendations to enhance the positive implications and mitigate the negative.

Objectives

1. To inform the resource consent process using an HIA, complementing other pieces of work such as environmental, social and cultural impact assessments, thereby supporting a full assessment of the CPWS.
2. To enhance partnership working between the Canterbury DHB, local councils, Central Plains Water, environmental and social scientists, and other agencies.
3. To involve Māori in all levels of the HIA process and to consider Treaty of Waitangi obligations.
4. To contribute to an increased awareness about social cohesion, equity and inequalities in relation to the scheme, and to assess how the proposed scheme may widen, maintain or narrow inequalities.
5. To build capacity and knowledge of the use of HIA in Canterbury and elsewhere.

Overview of CPWS

The CPWS is a proposal to irrigate the central plains of Canterbury using water diverted from the Waimakariri and Rakaia rivers stored in a dam in the Waianiwaniwa valley. The CPWS has been developed from earlier feasibility studies funded by the Selwyn District and Christchurch City Councils. Following those studies, the councils set up the Central Plains Water Trust. The Trust, in turn, set up Central Plains Water (CPW) Ltd, a private company with some 330 shareholders consisting mostly of local farm owners.

The key elements of the CPW scheme include:

- An intake on the Waimakariri River above the confluence with the Kowai River, a 3km canal and an approximately 10km long tunnel feeding water to the Waianiwaniwa Reservoir;
- An intake on the Waimakariri River at the Gorge Bridge to bring water into the main headrace across the plains;
- An intake on the Rakaia River approximately 8km downstream of the Gorge Bridge to bring water into the main headrace across the plains;
- A main headrace across the plains generally following the 235m amsl (above mean sea level) contour between the Waimakariri and Rakaia Rivers;
- An earth dam (with a maximum height of 55 metres) and consequent reservoir in the Waianiwaniwa Valley to provide stored water that will discharge into the main headrace;
- A distribution network of smaller canals down the plains providing water to all shareholder properties in the command area;
- Pump stations to lift water from the canals to land that is too high to be supplied by gravity in the Windwhistle and Springfield areas; and
- By-wash and turnout canals at the bottom of the scheme area to discharge surplus water back into surface water ways.

The total area encompassed by the Central Plains scheme is 101,800 hectares (ha). The total effective area within the boundary of the scheme is assumed to be 85,000ha, of which 60,000ha will be irrigated by scheme water. This represents an increase of 33% of the area currently irrigated from rivers and drains by community owned schemes.

The consent process is likely to take 2-3 years, while implementation of the scheme will take between 2-5 years. There are over 330 shareholders in the scheme, nearly all local farmers owning most of the land in the scheme's boundaries. It would be up to individual farmers within the scheme to use the irrigation as they wished, although spray irrigation is more likely than flood irrigation as there will be requirements on efficient use of the water. The CPWS would not take water from the rivers during a flood.

The question of future land use within the area is less clear as actual use would depend on individual landowners. It is likely there would be more dairy, cropping and sheep/beef farming, but also new uses may occur such as biofuel crops, viticulture and horticulture. It is acknowledged that dairy production in the area is likely to increase in the short to medium term as this is currently extremely profitable. CPW Ltd has estimated that the amount of land in the area used for dairying will double as a result of the scheme. Shares in the scheme would be sold on when landowners in the scheme sell their land so shareholders could not directly sell shares to people or companies outside the scheme.

An environmental impact assessment, a social impact assessment and a cultural impact assessment have already been carried out, commissioned by CPW Ltd., and these pieces of work overlap in some areas with this health impact assessment.

CPWS components for assessment

Several components of the CPWS could have been assessed within a health impact assessment:

- The Waianiwaniwa reservoir and dam, including construction and ongoing use of the dam
- The river takes and river flow regime (longer term)
- The water races including canals and underground tunnel
- Subsequent land use implications (longer term).

At the scoping meeting it was agreed that the most useful components for assessment would be the subsequent land use implications of the scheme, with some consideration of effects of the river flow regimes. Participants emphasised a need to focus on the ongoing and longer term effects of the scheme, rather than the short-term construction phase. Short term effects are acknowledged, but a detailed assessment was not conducted. These effects have been addressed in detail in other assessments such as the social impact assessment.

Population groups for assessment

While the entire population of the Canterbury region is likely to be affected, specific groups of interest identified at the scoping workshop included:

- People living within the CPWS boundaries (60,000 hectares), especially displaced families and non-home owners
- Residents of Coalgate and Glentunnel
- People living downstream of the CPWS boundaries
- Residents of Christchurch city
- Māori, including Ngai Tahu.
- Recreational river users
- Local businesses
- Older people, children and babies
- Low income people – unemployed, low skilled, migrants.

Workshop participants favoured an assessment that included all people whose drinking water quality might be affected. That is, people who live in the irrigated area, people who live down gradient from the area and people who drink from the Christchurch city aquifers.

The problem with selecting this population group, however, would be that this group represents hundreds of thousands of people and is not a targeted group. It was discussed in the workshop that sub-populations could be assessed to act as a 'marker' for change in the broader group. For example, infants and toddlers consume a large amount of fluids relevant to their body weight (through breast milk and water), and could be a useful group to represent the interests of people who drink from the Christchurch city aquifers. A similar sub-grouping suggested for within the scheme boundaries was low income people as they are also a vulnerable population group that would be a good marker for social change and employment opportunities. Finally, local Māori as tangata whenua were considered a useful target group on which to focus the assessment as implications of water quality go beyond simple biomedical models of ill-health and instead consider the holistic relationship that Māori have with water.

Recreational river users were also considered to be potentially affected, however it was noted that their interests were being put forward by other submitters. Hence the steering group decided to focus the HIA on those less likely to have a strong voice in the process.

Determinants of health for assessment

The determinants of health and wellbeing which could potentially be assessed in an HIA for a large irrigation project include:

- Water quality and supply e.g. risk of groundwater contamination, effects on drinking water quality and supply
- Accessibility to services and the community (health, shopping, support, etc), employment, education, the countryside, recreation and social networks
- Impact on the capacity of local healthcare infrastructure to deal with new or increased incidence of disease
- Community identity, for example severance, community facilities, social connectedness or isolation, cultural and spiritual participation, reputation of area
- Benefits relating to employment, economic and spatial development and social inclusion
- Stress and anxiety, disempowerment from relocation and uncertainty; grief from loss of home, community, history
- Loss of land
- Perceptions and reality of safety, especially water safety and perceived risk of dam failure
- Noise, vibration, and dust related health effects from construction
- Visual effects on the landscape.

Such impacts could be considered for the health of the CPWS workforce, as well as the health of the host communities. Also, inequalities in the determinants of health, and health itself that are observed in any of the above indicators may be considered.

The CPWS will influence other health determinants beyond those selected for this HIA, but given the limited time and resources available three key determinants were selected during the scoping meeting to be the focus of the HIA process. The three determinants of health chosen were:

- 1) water quality
- 2) regional and local economy and employment (including distribution of wealth)
- 3) social connectedness of communities.

Access to, stress and capacity of services were two further determinants of health that the participants were interested in. Participants noted that such issues could be included within the social cohesion determinant where appropriate, and that the social impact assessment had already covered these areas. Other factors that the group would have liked to see carried out, but to a lesser extent, were economic and spatial development, and climate change. However due to time constraints these were not be covered in this HIA.

Focus for the HIA

The scoping work selected the following populations as the focus of the HIA:

- Infants and toddlers (as markers of specific health problems)
- Low income people (as a group more sensitive to the wider determinants of health)
- Maori.¹

In addition, the three determinants for the HIA were water quality, socio-economic issues such as employment and wealth, and social connectedness. The populations and determinants were grouped in the following way.

	Infants	Low income	Māori
Water Quality	✓	✓	✓
Employment/Wealth	✓	✓	✓
Social connectedness	✓	✓	✓

Three key working groups were identified to deal with these issues. The determinants of employment/wealth and social connectedness were grouped together to form a socioeconomic working group. The three working groups focused on:

Socioeconomic issues
Water quality Issues
Maori issues

¹ A Cultural Impact Assessment was commissioned by CPW Ltd. and Ngai Tahu submitted its own submission to the RMA process. This HIA confined itself to issues from the CIA which related specifically to health, or health issues not identified.

Exclusions

Stakeholders at the scoping meeting acknowledged that a rapid HIA would need to be carried out to meet the resource consent timeframe, and inevitably that would mean certain issues could not be covered in detail and some aspects of the scheme could not be covered at all. Specific areas that were excluded from the assessment included the following.

1. The health effects of the construction of the dam and other engineering works were excluded
2. Consultation with those immediately affected in the area of the works could not take place
3. The risk and potential health effects of dam breach were excluded but these effects have been well covered in other assessments, including the social impact assessment.

2.2 Appraisal

Following the scoping stage, the Canterbury District Health Board hosted three other workshops with stakeholders to inform the health impact assessment. The workshops provided a key opportunity for wider stakeholders to contribute information to the HIA process. The workshops aimed to gather stakeholders' views on the question of how the CPWS may affect health and wellbeing; to build relationships amongst key stakeholders; and to inform the evidence base of the health impact assessment. The workshops also gathered mitigating suggestions for the proposal to improve health and wellbeing, or to reduce any harmful impacts on health and wellbeing.

The stakeholders in the workshops comprised topic experts and people who were knowledgeable about the local community, and/or the population groups of interest. Participants included both proponents and antagonists of the CPWS. A list of participants is attached as Appendix 2.

In preparation for the workshops, data was collected and summarised for presentation to, and use by, workshop participants. For the water quality workshop this included literature reviews on the relationships between health outcomes and water contaminants. For the socio-economic workshop it included phone discussions with a number of experts including Professors Peter Crampton, Tony Blakely, (both University of Otago Wellington School of Medicine), Professor Paul Dalziel (Lincoln University), Geoff Fougere (Canterbury University), Associate Professor Karen Witten (SHORE, Massey University), and Professor Valerie Brown (Australian National University). For the Maori stream there was a workshop involving Maani Stirling and Sandy Lockhart (Te Taumutu Rūnanga) followed by a discussion with Jason Arnold (Te Waihora Management Coordinator).

The workshops asked participants:

- for their views and further evidence on the direct or indirect potential health impacts predicted
- whether there were any gaps in the analysis that needed to be covered
- for a description of key factors that may encourage, prevent or mitigate the health impact.

After the workshops, additional information put forward by participants was followed up by reading literature or further discussion, and the information was integrated into the final report.

Māori were consulted at a workshop meeting on 21st December 2007, in a single further interview and at an appraisal workshop in January 2008. The final Māori workshop was not well attended for a number of reasons, including that many local Māori had already been involved in consultation for the cultural impact assessment. Input from the Māori working group has been inserted directly into the discussion section, as evidence and significance were discussed concurrently. This input was relatively brief compared with the other two working groups and the views expressed cannot be said to be representative of all local Māori.

Research questions

The literature reviews for this rapid health impact assessment reviewed a total of 63 papers. The majority of papers were sourced through the Christchurch School of Medicine and Health Sciences in January 2008. Searches were performed using the following databases; Medline, Embase, Current Contents, Biosis Previews, Science Citation Index and Georef.

The research questions were as follows:

Water Quality:

- Is land use intensification in conjunction with irrigation implicated in rises in pathogen levels in groundwater? If yes, what are the effects on human health?
- Does land use intensification result in contamination of ground and surface waters by herbicides /pesticides/insecticides? If yes, what are the effects on human health?
- What will be the likely effect of rising groundwater on septic tank disposal fields? What effect will this have on pathogen levels in groundwater?
- Does irrigation facilitate pathogen transport in groundwater? If yes what is the effect on human health?
- What is the evidence that intensive farming can give rise to increased nitrification of drinking water in New Zealand? If yes, does this constitute a

Socioeconomic effects

- What is the evidence that increased economic output improves health?
- What is the evidence that inequity independently reduces health status?
- Under what circumstances does the evidence show that job creation improve health?
- Are there institutions which improve social connectedness in a rural environment? Under what circumstances does this improve health?

Maori consultation questions

- What does Te Waihora (Lake Ellesmere) mean for individuals and iwi?
- What are the key roles as kaitiaki in relation to Te Waihora?
- What kinds of physical environmental impacts might the CPWS proposal have on Te Waihora and the Waimakariri River?
- What kind of cultural impacts could the CPWS have?
- What sorts of impacts on health and well being are possible?
- What are the ways in which individuals, hapū, or Maori as a group have been engaged or involved in the proposal development or consultation process?

2.3 Assessment of evidence

In assessing the potential relationships between the CPWS, determinants of health such as water quality and employment, and health outcomes, this HIA uses a consistent language and method to interpret the scientific evidence. The evidence considered for the HIA was assessed using the following levels of strength in terms of potential causal relationships/associations:²

² Evidence levels and definitions used by the World Cancer Research Fund and American Institute for Cancer Research

Level of evidence	Definition
Convincing	<p>Evidence of causal relationship is conclusive</p> <p>Epidemiological studies show consistent associations, with little or no evidence to the contrary. Substantial number of acceptable studies (more than 20) preferably including prospective designs, conducted in different population groups, controlled for possible confounding factors. Associations should be biologically plausible. Laboratory evidence is usually supportive or strongly supportive.</p>
Probable	<p>Evidence is strong enough to conclude that a causal relationship is likely</p> <p>Epidemiological studies showing associations are either not so consistent (with some not supporting the association) or the number or type of studies is not extensive enough to make a more definitive judgement. Mechanistic and laboratory evidence are usually supportive or strongly supportive.</p>
Possible	<p>A causal relationship may exist, but the evidence is not strong enough to generate statements about causality primarily derived from this evidence</p> <p>Epidemiological studies are generally supportive, but are limited in quantity, quality or consistency. There may or may not be supportive mechanistic or laboratory evidence. Alternatively, there are few or no epidemiological data, but strongly supportive evidence from other disciplines.</p>
Insufficient	<p>There is suggestive evidence, but this is too scanty or imbalanced to make any more positive judgement about causality</p> <p>There are only a few studies, which are generally consistent, but really do no more than hint at a possible relationship. Often, more well-designed research is needed.</p>

3. Background – water quality

At the scoping meeting held in November 2007, a broad range of stakeholders chose water quality as a key issue to be considered by the rapid HIA. This section provides background information on water quality issues.

The ready availability of a sufficient quantity of good quality, safe drinking water remains one of the cornerstones of health (Ministry of Health 2005). While water quality in the 19th and 20th centuries was the single greatest factor affecting life expectancy in Europe and Asia respectively, high quality water is taken for granted in New Zealand in the 21st century. It is regarded as much an inalienable right as universal suffrage or access to emergency health care. The loss of such a right is considered unconscionable. For Canterbury DHB, maintaining high drinking water standards is 'business as usual'. Therefore, any real or potential risk to Canterbury's water supply is taken seriously by the CDHB.

International context

Internationally, there is increasing recognition of the importance of protecting source waters as part of the process of ensuring the delivery of safe drinking-water. Relying on treatment alone is not sufficient to manage the risk posed by drinking-water contamination to public health. A number of major outbreaks of water-borne disease in developed countries resulting in serious illness and death have shown that risks to health need to be reduced at every step - not just in the treatment plant and distribution network, but by reducing the amount of contamination that enters water sources in the first place.

Reducing the loading of contaminants not only decreases the loading on treatment plants, but also decreases the risk of large amounts of contaminants entering community water supplies if a treatment plant fails. In addition, there are a number of disease-causing organisms and chemicals that can only be removed with sophisticated and expensive treatment. Preventing these contaminants from entering water in the first place is preferable to investing large amounts of money in sophisticated plants that are not only expensive to run but may break down, exposing communities to health risks. This 'multiple barrier' approach is

recommended by the World Health Organisation as a key principle in preventing or reducing drinking-water contamination (*WHO, 2006*).

Safety is increased if multiple barriers are in place, including protection of water resources, proper selection and operation of a series of treatment steps and management of distribution systems (piped or otherwise) to maintain and protect treated water quality. The preferred strategy is a management approach that places the primary emphasis on preventing or reducing the entry of pathogens into water sources and reducing reliance on treatment processes for removal of pathogens. Identification and implementation of control measures should be based on the multiple-barrier principle. The strength of this approach is that a failure of one barrier may be compensated by effective operation of the remaining barriers, thus minimising the likelihood of contaminants passing through the entire system and being present in sufficient amounts to cause harm to consumers (*WHO, 2006*).

National context

In New Zealand, one of the main tools that the Ministry of Health uses to assess whether a drinking water supply is safe is the Drinking Water Standards for New Zealand, currently in its 2005 publication (*DWSNZ2005*). These are based on the World Health Organization Guidelines with specific changes for the New Zealand context, as appropriate. The main body of *DWSNZ2005* consists of tables of MAVs (maximum acceptable values) for a wide range of organic and inorganic substances. The MAV is the level of exposure that a person may have throughout their lifetime, on the basis of present knowledge, without expecting any significant risk to their health. An exception to this is the setting of the MAV for nitrate which is based on short term exposure, as appropriate for methaemoglobinaemia (a condition affecting infants which will be discussed in the next section).

To improve how drinking-water is managed at source, the Ministry for the Environment adopted a National Environmental Standard for the management of human drinking-water sources which complements Ministry of Health legislation and standards for improving drinking-water supply and delivery. This is in keeping with the multiple-barrier approach to managing human drinking-water advocated by the World Health Organization. Specifically, the National Environmental Standard (NES) ensures there is a catchment component to managing human drinking-water.

In the DWSNZ2005 the term 'security' in relation to groundwater sources has a specific meaning. Groundwater is considered to be secure when it can be demonstrated that contamination by pathogenic organisms is unlikely because the groundwater is both;

- not directly affected by surface or climate influences and
- abstracted from a bore head that provides satisfactory sanitary protection.

Groundwater that has been assessed as secure under the DWSNZ2005 does not require any further treatment to comply with the section of the standards regarding protozoa otherwise filtration and/or UV would be required to obtain compliance with DWSNZ2005. For determination of microbial contamination *Escherichia coli* (*E. coli*) is used as an indicator of the presence of faecal bacteria and therefore the potential presence of pathogenic organisms.

Canterbury context

In New Zealand many drinking water supplies are from surface catchments and require treatment to control quality parameters like colour, sediment, odour and taste, and to provide protection from protozoal bacteria. In contrast, the majority of drinking water in the Canterbury region comes from groundwater. The public drinking water supply is of very high quality and is not treated. Most of the drinking water supplies in the CPWS area and below come from wells and small drinking water reticulated systems, which can have variable quality. The Natural Resources Regional Plan (NRRP) produced by Environment Canterbury establishes objectives, policies and methods for sustainably managing the region's high quality water resources. One of the main objectives is the protection of drinking water sources used for communities in Canterbury. Protection of water quality is very important to the Canterbury public. In the Greater Canterbury Urban Development Strategy HIA, feedback indicated "over 96 percent of respondents considered protecting water quality in the greater Christchurch area as very important" (Stevenson 2006).

The Christchurch aquifer system was formed from glacial and river derived gravels, deposited during the alternating glacial and inter-glacial periods over the last 500,000 years. The sequences of glacial and interglacial periods in the Christchurch area has resulted in the formation of permeable, glacial and river-derived gravel layers originating from the inland area to the west. These aquifers

are replenished by rain falling on the land and outflows of water from the Waimakariri River. To the west of the city, across the plains, recharge of the aquifers is mainly through infiltrating rainfall whereas in the north-west of the city the gravel aquifers are primarily recharged by seepage from the Waimakariri River. Environment Canterbury plans describe two groundwater recharge zones for the Coastal Confined Gravel Aquifer System which is the source of Christchurch city's water supply.

Zone 1 is described as the area of land to the west of Christchurch bounded by the Waimakariri River to the north and a line approximately between Haket and Prebbleton to the south. Groundwater in Zone 1 lies close to the ground surface. This aquifer is unconfined with little or no impermeable material overlaying it, so rainfall soaks quickly down into the aquifer, and there is little natural protection to prevent contaminants entering the groundwater.

Zone 2 of the Christchurch Groundwater Recharge consists of land covered largely by urban Christchurch. In this area there are layers of fine-grained sediments – clays and sands alternate with layers of water bearing gravels (aquifers). The aquifers are also under pressure, the deeper aquifers having higher pressure than the shallower ones. This creates a natural upwards or artesian pressure which in combination with the fine sediments provides a high level of protection against contaminants moving downwards.

In addition to the urban Christchurch supplies many public drinking water supplies are scattered throughout the CPW area, predominantly owned by Selwyn District Council. A few of these are sourced from surface water but most are from reasonably deep aquifers considered under the DWS2005 to be 'secure'. Within the rural community covered by the CPW proposal there are many individual households and some private supplies that source their water directly from bores – these tend to be from shallower unconfined aquifers that are particularly vulnerable to contamination.

Catchment protection for surface water recognises that strict catchment controls should be in place for drinking water sources. This has recently been strengthened by the release of the National Environmental Standard for Sources of Human Drinking Water and the Health Drinking Water Amendment Act which places

responsibility on the supplier for the potential contamination of their water sources. However, catchment protection for ground water has not been given the same priority as for surface water catchments. Environment Canterbury's recognition of the Christchurch Ground Water Protection Zone in the NRRP is a step toward acknowledging the importance of protecting the recharge zones for groundwater.

4. Findings – water quality

This section presents the findings of this HIA on the relationships between CPW and water quality, and between water quality and various health outcomes including infant methaemoglobinaemia. Since water quantity and quality are inherently linked, water quantity is not considered separately.

4.1 Potential effects of CPWS on water quality

Canterbury residents have expressed concern about the potential impact of the CPWS on water quality. Submissions and interviews for the SIA suggested the key public concerns are:

- the consequences for human health and the environment of potentially reduced surface and groundwater quality from more intensive land use and population growth in the scheme area – which will cause possible increased nitrate and other farm run-off to surface water, nitrate etc. leaching to groundwater, and contamination from cows and septic tanks
- the consequences for people's living and working environments and management of scheme bywashes and discharges to downstream water bodies – giving rise to a possible wetter environment on the lower plains and in the Ellesmere area, and localised flooding/ponding (Hayward 2008; Weir 2008).

The main groundwater quality concerns in relation to the CPW scheme are as follows, and are discussed in turn below.

- Potential effects on security and integrity of the aquifer system
- Effects of raising the groundwater table
- Potential contamination from increased nitrate levels
- Potential contamination from septic tanks and associated waste disposal fields
- Potential effects on Christchurch city aquifer.

Security/integrity of aquifer system and drinking water supplies

There are existing concerns about the consistency of water quality in Canterbury. Intensified land use and subsequent groundwater nitrate concentrations have already increased in some areas, such as Ashburton, Rakaia Plains and the Waimakariri District, and septic tank failures can result in bacterial contamination of shallow wells (Hanson 2008). Existing data from ECAN monitoring of wells indicates regular exceedences of the 50% of the MAV and of the MAV for nitrate-nitrogen (11.3.mg/l), particularly in rural areas. Environment Canterbury has observed several key trends in its sampling programme for groundwater quality.

- Groundwater quality is being degraded by human induced contamination such as intensification of farming activities, particularly in relation to microbes and nitrogen nitrate. These are linked to effluent leaching from the increase in dairy farming in Canterbury.
- Organic compounds such as chlorinated solvents have been detected in the western suburbs of Christchurch.
- Currently, deeper aquifers in general provide higher quality water.

Canterbury's water supply, especially the shallower aquifers, is vulnerable to contamination from land use and discharges upstream of the water supply. The effect of the Central Plains Water Scheme will be to potentially move away from farming with a low stocking rate to more intensive farming whether that is dairy, other animals or arable crops. This is likely, whatever the use of the land, to result in increased irrigation and more point source and diffuse waste discharges to land.

Even for the supplies that have been considered to be secure there are concerns that the security status could be affected. It is possible that increased hydraulic loadings may alter the flow regime of an aquifer with subsequent effects on groundwater residence times. Similarly, the effects of pumping groundwater from a bore would also alter the hydraulic regime and may affect the age of the groundwater extracted from nearby bores. The 'age' of water from a particular bore is a transient phenomenon which may change due to many factors, especially when the aquifer is increasingly subject to human-induced influences such as artificial

recharge due to irrigation”.³ If a groundwater source loses its security status then treatment for pathogens, including protozoa would be required to enable compliance with the DWSNZ2005.

Effects of raising the groundwater table

An increase in irrigation will likely decrease the depth to groundwater and also increase the period throughout the year when groundwater levels in individual areas are considered to be raised, particularly in respect of microbial contamination. The substrate between the surface and the groundwater can provide considerable treatment to reduce contaminant levels but the general effects of raising groundwater levels is to reduce the amount of treatment from natural attenuation and so increase the levels of a contaminant that may reach groundwater.

Possible positive changes in ground and surface water from the CPWS include aquifer recharge and increased groundwater levels (resulting in greater water security for farmers and other water users downstream and reduced local competition for groundwater resources), and increased flow in lowland rivers and streams such as the Selwyn River and its tributaries and lowland streams. This increased flow may improve recreational opportunities downstream.

Contamination from increased nitrate

Nitrate is a compound that contains nitrogen, existing in the atmosphere and as a dissolved gas in water. Nitrate occurs naturally but nitrate pollution of drinking water is known to be increasing due to dramatic human-induced alteration of the nitrogen cycle in the past 50 years (Field 2004, cited in Ward et al 2006). The main contributor to the steady accumulation of nitrate is nitrogen fertiliser use, as well as human and animal waste and air pollution (Field 2004, cited in Ward et al 2006). Vegetables are the major source of nitrate exposure for humans when drinking water is low in nitrate (Coss 2004). When nitrate levels are near or above the maximum contaminant levels, drinking water nitrate constitutes the majority of nitrate intake (Ward et al 2006). The Maximum Acceptable Value (MAV) set by the New Zealand Ministry of Health for nitrate in drinking water is based on international guidance and

³ personal communication Rob van der Raaij, Water Dating Laboratory GNS Science February 2008

is 50 mg/L when expressed as the nitrate ion.⁴ When expressed as nitrate nitrogen, the MAV is equivalent to 11.3 mg/l.⁵

Based on previous Canterbury studies and other evidence, it is considered that increased irrigation and more intensive land use will result in increased amounts of leaching of nitrate, pathogenic micro-organisms and pesticides into the ground water from the soil. These all have significance for human health (Parliamentary Commissioner for the Environment 2004).

Land use and ground water nitrate concentrations have already increased in certain areas, often with exceedences greater than the MAV. Areas such as Ashburton, Rakaia Plain and Waimakariri District have also noted higher bacterial contamination occurring especially in shallow aquifers.⁶ Increases in nitrate concentrations in the Ashburton and Rakaia areas has resulted in many private groundwater supplies becoming unfit for human consumption without treatment (Haywood & Hanson 2004).

Contamination from septic tanks and associated waste disposal fields

Many rural properties in Canterbury dispose of their effluent and stormwater on site. In addition many rely on shallow wells for drinking water. In this environment there is the possibility of septic tank system failure, especially in older systems where cracks in the septic tank will allow movement of groundwater into the tank and movement of poorly treated effluent out of the tank directly into groundwater.

Higher groundwater levels resulting from increased irrigation may affect septic tank disposal fields in some areas leading to higher levels of viruses, bacteria and some nutrient contamination. If effluent distribution lines become immersed in water, reductions in bacteria levels that may normally be expected will not occur, hence raising the possibility of localised contamination events. Where irrigation flows result in raised groundwater levels then localised saturated flow conditions may occur

⁴ From *Drinking Water Standards for New Zealand 2005*, pg 9, accessed 7/2/08
<http://www.moh.govt.nz/moh.nsf/by+unid/12F2D7FFADC900A4CC256FAF0007E8A0?Open>

⁵ From ECAN document, *The Facts about Nitrates in Drinking Water*, accessed 7/2/08
<http://www.ecan.govt.nz/Our+Environment/Water/Groundwater/Nitrates/nitrates-factsheet.htm>

⁶ "Nitrate Contamination observed in Environment Canterbury's Annual Groundwater Quality Survey" Report U04/79 Phil Abraham and Carl Hanson

which could allow rapid movement of viruses and other contaminants into the groundwater (Scandura and Sobsey 1997).

As well as an increased potential for localised contamination, the plume of effluent from the septic tank will extend for an increased distance down-gradient with the ability to contaminate shallow domestic wells. In one study, groundwater collected at all distances from septic tanks during the wet season contained twice as many faecal coliforms and higher concentrations of nitrates and phosphates (Shutter, Sudicky et al. 1992).

This raises the question as to whether septic tank separation distances should be increased if saturation of the ground is predicted to occur more frequently. However, for existing rural households these are already established and for those on 'lifestyle blocks' there is often not the available space for alternative placement that would have greater separation (Nicosia, Rose et al. 2001). Locally, Dr Williams has reported failures of onsite domestic sewage discharge systems within the Amuri irrigation system.⁷

The potential effects of increased irrigation can be extrapolated from those effects shown during periods of heavy rain or flooding. Pathogen levels in the groundwater, particularly viruses, are likely to increase with increased irrigation, as is the case with flooding (Phanuwan, Takizawa et al. 2006). Fractions of viruses that enter groundwater may persist and travel significant distances therefore posing a potential infectious threat to down-gradient potable water supplies (Blanford, Brusseau et al. 2005).

Effects of CPWS on use of fertilisers, pesticides and antibiotics

Land use intensification, whether focused on crops or animals, is likely to mean an increase in application of fertilisers, pesticides and potentially antibiotics. Several studies were found in literature reviews for the HIA that looked at the fate of groundwater down-gradient of intensive live stocking operations such as pig production. Extensive use of antibiotics can result in the dissemination of antibiotic resistant genes in the environment. Antibiotic resistant genes were detected in groundwater and surface water downstream of pig production facilities. There were also significantly higher levels of E. Coli in these studies. However, participants in

⁷ CPW S42a Report Leo Fietje para 171

the HIA workshop on water quality generally agreed that health risks from antibiotics were relatively less likely compared with those from nitrate contamination.

Potential health risks could be exacerbated by the presence of antibiotic resistant bacteria. E. Coli has shown higher levels of resistance to antibiotics. This is an example of how land use intensification combined with extra water on the land can transport a range of contaminants into the groundwater (Sapkota, Curriero et al. 2007). Good irrigation practice, such as complying with 'best practice' to ensure the application of the least amounts of water possible consistent with individual needs, would be an important mitigation measure.

Implications for Christchurch city aquifers

The aquifer sitting below Christchurch takes between one third and one half of its water from the Waimakariri River, and this input is the most dominant influence on recharge. The flow is predominantly from the river towards the city in a southerly direction. Under current circumstances groundwater from the Central Plains area does not enter the Christchurch aquifer, as the groundwater flows in a southeasterly direction towards Lake Ellesmere (Te Waihora). However, the recharge of the Christchurch aquifer by river water is dependent on the flow in the river, which will be affected by the take further upstream.

It is possible that not only will the proportion of water entering the aquifer from the Waimakariri be reduced by the CPWS take upstream, but that this will also result in a change in the flow of groundwater from the Central Plains. Water could be drawn from west to east under the city, bringing with it contaminants (particularly nitrates) from the proposed intensive farming on the plains. Moreover, since there is potential for increased groundwater levels on the western fringes of the city, it is possible that further contamination of the Christchurch aquifer could occur from old industrial sites and landfills in that area. There is little evidence to support or refute these possibilities, but even if the probability of underground water direction change is low, this represents a risk to the 350,000 residents of Christchurch who currently enjoy untreated water.

4.2 Potential effects of reduced water quality on health

Participants in the HIA process considered the most substantial risk to health would be likely to occur through increased nitrate contamination. Other health concerns associated with viruses and bacteria may arise from contamination of septic tanks. There was discussion about the effects of antibiotics at the water quality workshop for the HIA, but this was considered to be less likely.

Potential impact of nitrates on health

In assessing the potential negative effects of nitrates on human health there is not a simple causal pathway. Adverse health effects related to nitrates are likely to be due to a complex interaction of the amount of nitrate ingested, the associated intake of nitrosation cofactors and precursors (factors that affect the processing of nitrate to nitrite), and specific medical conditions that affect processing of nitrates (Ward et al 2005).

The primary health concern regarding nitrates is methaemoglobinaemia, or so-called “blue-baby syndrome” (Ward, Heineman et al. 2005) (World Health Organization 2007). It is a rare disease that mainly affects infants aged less than 6 months old (World Health Organization 2007). Exposure to high levels of nitrates can prevent blood from delivering oxygen effectively to different parts of the body. Nitrate is reduced to nitrite in the stomach, and nitrite can oxidize haemoglobin to methaemoglobinaemia (MetHb), which is unable to transport oxygen around the body (World Health Organization 2007). Infants are particularly at risk because they have a high proportion of foetal haemoglobin which is more likely to be affected. The risk reduces as an infant ages because foetal haemoglobin is replaced with haemoglobin.

Due to the replacement rate of foetal haemoglobin and haemoglobin, consumption of water above the MAV for approximately one month would be sufficient to cause methaemoglobinaemia. Less than one month of exposure may be enough to cause the condition where the baby has gastro-intestinal infection, as evidence suggests that gastro-intestinal infections can exacerbate the conversion from nitrate to nitrite.

As most instances of infant methaemoglobinaemia in the literature have been associated with the consumption of private well water, there is a high likelihood of bacterial infections playing a key role. The likely interaction with concurrent bacterial contamination means it is difficult to separate out the risk of nitrate intake specifically. Several recent evidence reviews and findings from an international symposium suggest there are some inconsistent findings on the definitive role of nitrates in the development of methaemoglobinaemia, although an association is generally accepted. Researchers have emphasized a need to better understand the interaction of causative factors. There is evidence for a role of both diarrhea and respiratory disease in increasing methaemoglobinaemia levels and for a protective role of Vitamin C (Ward et al 2005). There is a strong consensus from researchers on the need for further studies that address the complexities of how nitrates enter the body and are broken down, and the causal pathways that operate.

When methaemoglobinaemia occurs an infant may have blueness around the mouth, hands and feet. Severe cases of methaemoglobinaemia can affect breathing and may be life-threatening. Bottle-fed infants are at particular risk due to the potential for exposure to nitrate/nitrite in drinking water and the relatively high intake of water in relation to infant body weight. Therefore toxic effects can occur at a much lower concentration of nitrate compared with adults (World Health Organization 2007).

Although methaemoglobinaemia has serious consequences it appears to be very rare. In New Zealand only one case of methaemoglobinaemia has been reported (in 1994) but it is a difficult condition to diagnose and the true incidence may be masked by other conditions with similar symptoms, for instance SIDS⁸, that are attributed as the primary cause of death. The regulatory level for nitrate in drinking water supplies was set following a survey of infant methaemoglobinaemia case reports in the USA which found that no cases were observed at drinking-water nitrate-nitrogen levels less than 10mg/l (Walton 1951, cited in Ward et al 2005)⁹. Since the drinking water standard for nitrate was set in the 1950s there have been few cases reported in the US (Ward et al 2005). However there may be under-reporting as methaemoglobinaemia is not a notifiable disease. Moreover, deaths from

⁸ Sudden Infant Death Syndrome

⁹ Note that the New Zealand Maximum Accepted Value standard for nitrate-nitrogen is 11.3mg/l

methaemoglobinaemia are difficult to distinguish from some other causes, such as SIDS.

Other health outcomes from nitrates

Emerging research has investigated associations between drinking water nitrates and other health outcomes including cancer, diabetes, adverse reproductive health outcomes such as miscarriage and birth defects, and thyroid problems in children.

An association with cancer is considered to be biologically plausible. Nitrite has been shown to react with nitrosatable compounds in the human stomach to form N-nitroso compounds (World Health Organization 2007). Studies with animals have found that nitroso compounds are strongly carcinogenic. There is a consensus among researchers that the carcinogenic nitroso compounds in animals are likely to be similarly carcinogenic in humans (Van Grinsven et al 2006, World Health Organization 2007). However, the emerging area of research regarding cancer has considerable uncertainties and gaps (Van Grinsven et al 2006). There appears to be some disagreement among international experts on the overall assessment of the current evidence for cancer and nitrates. For instance, the World Health Organization's guidance on nitrates states that the evidence is currently against an association between nitrates and cancer in humans (World Health Organization 2007), although other international experts conclude that the evidence is not yet developed enough to make a call (Van Grinsven et al 2006, Ward et al 2005).

A small set of studies on nitrates and childhood Type 1 diabetes have found conflicting results (Muntoni et al 2006, Moltchanova et al 2004, Van Maanen et al 2000). A branch of research investigated possible links between nitrate in drinking water and adverse reproductive and developmental outcomes, such as miscarriage, intrauterine growth restriction, and various birth defects. A review of evidence recently concluded that the current literature does not provide sufficient evidence of a causal relationship (Manassaram et al 2006). However, the reviewers noted that the evidence is sparse and further research should be undertaken, especially in relation to birth defects as there have been several studies indicating possible links.

Studies in several European countries have found relationships between exposure to high nitrate intake, through both drinking water and home-made meals from local products, and thyroid problems in children (Tajtakova et al 2006, Gatseva and Argirova 2005). However, the studies tended to be small and used cross-sectional designs so potential confounding factors may not have been addressed. Dietary

iodine levels are thought to play a key role in the development of thyroid problems (World Health Organization 2007).

Some studies have indicated possible chronic health effects associated with consumption of elevated levels of drinking water nitrate but there are mixed findings from other research and a lack of consistency across studies (Van Grinsven et al 2006). The overall quality of studies in this area is poor, with a majority of cross-sectional, case-control studies rather than longitudinal cohort designs. It is of concern that some studies have found associations with various cancers at nitrate concentrations *below* the regulatory limit, for instance with colon cancer (Ward et al 2005). Experts agree that more experimental studies are needed, especially those that consider susceptible subgroups with increased endogenous nitrosation – the process of conversion to nitroso compounds within the body (Ward et al 2005).

In summary, the HIA found that there would be possible adverse health implications associated with the CPWS in terms of water quality. There is some evidence to indicate that groundwater quality may be diminished with increased irrigation in the area, in particular there may be more regular exceedences of the MAV for nitrate. Nitrate contamination is associated with an increased risk of infant methaemoglobinaemia, which although rare is a serious condition.

5. Findings – socioeconomic impacts

The HIA examined evidence on the potential implications for health and wellbeing in relation to socioeconomic issues. There is international evidence suggesting adverse socioeconomic implications from the development of large dams. The United Nations Environment Programme's World Commission on Dams Report 2000, while recognising that many dams had undoubtedly provided benefits for communities, described in many cases that an unacceptable price was paid to secure those benefits (UNEP 2004). Commissioned by the World Bank, the report investigated the social and economic impacts of large dams around the world, defining large dams as those greater than 15 metres high. The proposed dam in the CPWS may be up to a maximum of 55 metres high. The evidence cited in the UN report included the following summary points.

- Building large dams is increasingly contested to the point where many countries are considering moratoriums on building such dams
- Investments made in dams often do not produce an acceptable return, often being less profitable than predicted and sometimes failing to recover costs.
- Adverse impacts include debt burden, cost overruns, displacement and impoverishment of people, destruction of ecosystems and fisheries, and inequitable sharing of costs and benefits.
- Environmental and social costs of large dams are often not accounted for in economic terms.

Poverty

The negative effect of poverty on health has been well documented (Black 1980; Acheson 1998). However, the benefits of increased wealth to health status are not linear. At high levels of deprivation increased wealth tends to produce marked increases in health. As relative wealth increases, however, the marginal benefits of increased wealth decrease (World Health Organisation 2000). Therefore the greatest health benefit from increased wealth is to the poorest sectors of society (Lawn 2005). Where wealth increases are confined to a small sector of society, improvements in health are minimal (Hsing 2005). Hence with any scheme that

aims to generate wealth, it is important that the more deprived sectors of society have access to the economic benefits.

The assumption that increased wealth, even if it is equitably distributed, inevitably benefits a population in terms of their health or any aspect of their well being has been increasingly challenged (Talberth, Cobb et al. 2006). If, for example, productivity is increased at the cost of leisure or family time, then many would argue that the cost was greater than the benefit. If an industry destroys an environment, even if that industry generates wealth, then many would argue that the cost outweighs the benefit. Water is one of the most important components of our environment with regards to health, and it is therefore important to attribute a “cost” to water, even when users may consider it a free or unlimited resource. Even where water appears unlimited there are communities which now charge for water, in order that a value can be ascribed to it by all users.

Inequity

A number of studies have demonstrated that even in wealthy societies poor health is generated by inequalities through a psychosocial etiology (Wilkinson 1996). There is now a considerable body of evidence that inequity independently reduces overall health status in a community, even if overall wealth increases. This has been demonstrated in New Zealand (Salmond 2000) and overseas (Acheson 1998). If wealth becomes redistributed through a ‘trickle down’ effect, health problems due to inequity are likely to decrease over time. Market forces are likely to redistribute such wealth relatively slowly, leading to poor health outcomes overall.

Employment

Unemployment is well recognised as a determining factor for poor health (National Health Committee 1998). However, like wealth, the reverse is not necessarily true (Mathers 1998). Where there is high unemployment creation of jobs can reduce the health effects of that unemployment. However, there is little evidence to suggest that job creation improves health where the unemployment rate is not high.

Social connectedness

The so-called rural decline in New Zealand, in common with Australia and some other OECD countries, manifests itself as net outward (or urban) migration followed by closure of businesses and services which, in turn, leads to more net outward

migration. A number of studies have described the importance of medical practices (Coster 1999) and schools (Witten, McCreanor et al. 2001) in the retention of families in rural areas through the support of social connectedness in their communities. A number of issues have been identified around intensification of farming practices on social connectedness. Young families in an area help generate support for primary schools and other businesses and services, and may reduce or reverse rural decline. However, the situation with high schools is less clear, since many farmers send their older children to boarding schools. In addition, some reports have suggested that the transient nature of modern farming in New Zealand means that many young people find it difficult to settle in schools which they are likely to move from, and large numbers of transient school students can create social and health problems in a community (Miria Lange unpublished data 2008).

6. Discussion

This section summarises and discusses the findings of this health impact assessment on potential associations between CPWS, water quality, socioeconomic issues and health.

6.1 Relationship between CPWS and water quality

Land use intensification is likely to continue in the Central Plains Water area due to increased access to irrigation through the CPWS. This will tend to exacerbate trends already underway which have been noted by ECAN. Groundwater qualities currently being degraded by human induced contamination, such as intensification of farming activities, can be expected to continue under an intensive irrigation regime, particularly in relation to microbes and nitrogen nitrate. Canterbury's water supply is vulnerable to contamination from land use and discharges upstream of the water supply. The effect of the CPWS will be to move land use and farming activities away from a low stocking rate to more intensive farming whether that be dairy or arable crops. This is likely, whatever the use of the land, to result in increased irrigation and more sources of waste discharges to land.

Based on previous Canterbury studies (Hanson 2008) and the application of other evidence (Parliamentary Commissioner for the Environment 2004) (Vant and Hoare 1987), it is considered that greater irrigation and more intensive land use will result in increased amounts of leaching of nitrate, pathogenic micro-organisms and pesticides into the groundwater from the soil. These all have significance for human health. It is unclear as to whether *overall* nitrate concentrations are likely to increase substantially with the CPWS, but there may be areas where nitrate concentrations could increase markedly.

Higher groundwater flows resulting from increased irrigation may affect septic tank disposal fields in some areas leading to higher levels of viruses, bacteria and some nutrient contamination. Localised saturated flow conditions may occur which could allow rapid movement of viruses and other contaminants into the groundwater. Increased use of antibiotics, associated with land use intensification, could result in the dissemination of antibiotics into groundwater. It is likely however that these will

be minimal or localised, and could be mitigated through adjustment of farming practices.

It should be noted that the Central Plains and Christchurch city aquifer systems are unlikely to be mutually exclusive. It is considered possible that the CPWS may have some effect on the Christchurch city aquifer, particularly if reduced overall flows in the Waimakariri result in reduced recharge of the Christchurch aquifer. Catchment protection for groundwater has not been given the same priority of risk ranking as for surface water catchments. The Christchurch groundwater protection zone does not include some western parts of the city where increased groundwater levels could result in chemical contamination of the aquifer from old industrial sites or landfills.

Potential impact of CPWS on nitrates

Recent reports in relation to the CPWS indicate the scheme is likely to produce an increase in nitrate concentrations beneath and down-gradient of the scheme area, although there is uncertainty around the estimated size of the increase (Fietje 2008; Hanson 2008). The proposal for irrigation will allow an intensification of farming in the area, which is associated with increased amounts of nitrate leaching into the groundwater from the soil (Fietje 2008).

The HIA workshop discussion suggested that the possibility of nitrates or other contaminants entering the Christchurch city water supply as a result of the scheme cannot be ruled out, although this is considered to be a low risk. In particular, there may be a minor effect on nitrate concentrations in the southern suburbs of Christchurch (Hanson 2008). Discussion at the workshop indicated that the southwest corner of Christchurch has experienced previous contamination of the water supply. Nitrate concentrations in some parts of Canterbury have increased over the last decade, particularly in rural areas. However, there is much variation with some areas showing either a declining trend (typically in land retired from heavy industrial or farm use) or no trend.

Experts at the stakeholder workshop on water quality stated it is not possible to quantify the potential increase in nitrate concentrations associated with the implementation of the CPWS. It is predicted that nitrate concentrations down-gradient of the scheme (south-east of State Highway 1) are likely to be increased, along with an increase in seasonal peaks in nitrate levels, and more frequent

exceedences of thresholds such as the MAV (Fietje 2008; Hanson 2008). Nitrates do not leach into the ground at a standard rate. Hanson has noted that the predicted changes will not be uniform, with a greater effect expected in the Te Pirita area if land currently used for forestry and dryland grazing is converted to dairy.

In summary, an increase in nitrate concentrations is predicted as a result of the scheme. It is not possible to predict exactly the extent of this increase but it is likely that the MAV will be exceeded more frequently than at present.

6.2 Potential impact of nitrates on health

This HIA has assessed that the possibility of health risks associated with nitrates in drinking water cannot be ruled out. The potential risk of methaemoglobinaemia is supported by evidence, which has been used to set the current national and international drinking water standards. The HIA determined that there is *probable* evidence of a relationship between high nitrate levels in drinking water and methaemoglobinaemia. Evidence of a causal relationship exists, and while the epidemiological studies are generally supportive, they are limited in quantity, quality and consistency. A rise in nitrate concentrations therefore has the potential to increase risks to health, particularly for bottle-fed infants.

The HIA has assessed that the evidence is too sparse to make any judgement about causality in relation to cancer and other health outcomes, aside from methaemoglobinemia. There is currently *insufficient evidence* to support or reject any potential associations of high levels of nitrates in drinking water causing other health outcomes (including cancer, childhood Type 1 diabetes, adverse reproductive health outcomes and thyroid problems in children). As there is insufficient evidence to make a call either way, the possibility of health risks in terms of cancer and other health outcomes cannot be excluded, though given current knowledge this is less likely than that for methaemoglobinaemia.

In light of the available scientific evidence, a precautionary approach should be taken in situations where nitrate concentrations may rise. The European Commission has defined the precautionary principle as applying “where scientific evidence is insufficient, inconclusive or uncertain and preliminary scientific evaluation indicates that there are reasonable grounds for concern” in relation to

human, environmental, animal or plant health (European Commission Communication on the Precautionary Principle, 2 February 2000). In this case there are reasonable grounds for concern in relation to human health. Reasons for concern include:

- epidemiological evidence for a *probable association* between nitrates and methaemoglobinaemia
- *insufficient evidence* to include or exclude potential risk in relation to cancer and other health outcomes
- the continuation of national and international drinking water standards based on the risk of methaemoglobinaemia
- the unacceptability of an increased risk of any cases of infant methaemoglobinaemia.

6.3 Potential impact of CPWS on septic tank contamination and flooding

It is expected that groundwater levels will increase in varying amounts across Canterbury with the CPWS. In places where groundwater levels are low this will not affect septic tanks, but some eastern areas have ground water close to the surface. Septic tank failure and seepage into groundwater will result in contamination of the groundwater in these areas. Shallow bores could be contaminated with bacteria, and recent evidence suggests that deeper bores may be contaminated by viruses (Pang, Close et al. 2005).

In eastern areas of Canterbury, the groundwater is within one metre of the surface. Since the groundwater levels are predicted to rise with the implementation of the CPWS, there will be a serious risk of flooding in these areas. Flooding inevitably brings a risk of human contact with a number of pathogens and hence could have adverse effects on health.

6.4 Pathways between CPWS, water quality and health outcomes

The evidence can also be summarised visually. Drawing from the findings of this HIA, Figures 2 and 3 represent possible causal pathways of adverse effects from

increased leaching and increased groundwater levels respectively, which may result from the CPWS.

Figure 2
Predicted causal pathway on water quality and health (1) – increased leaching

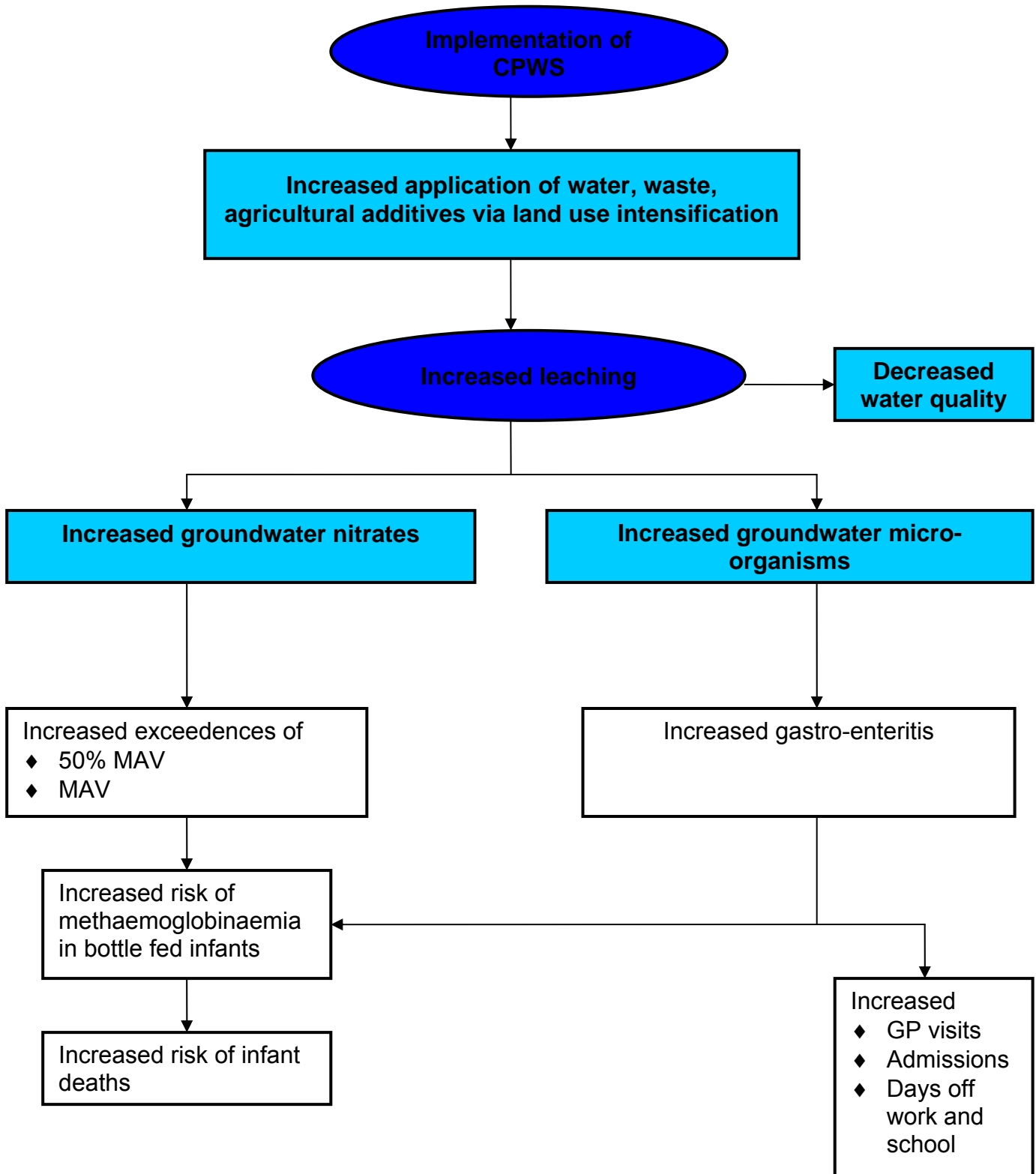
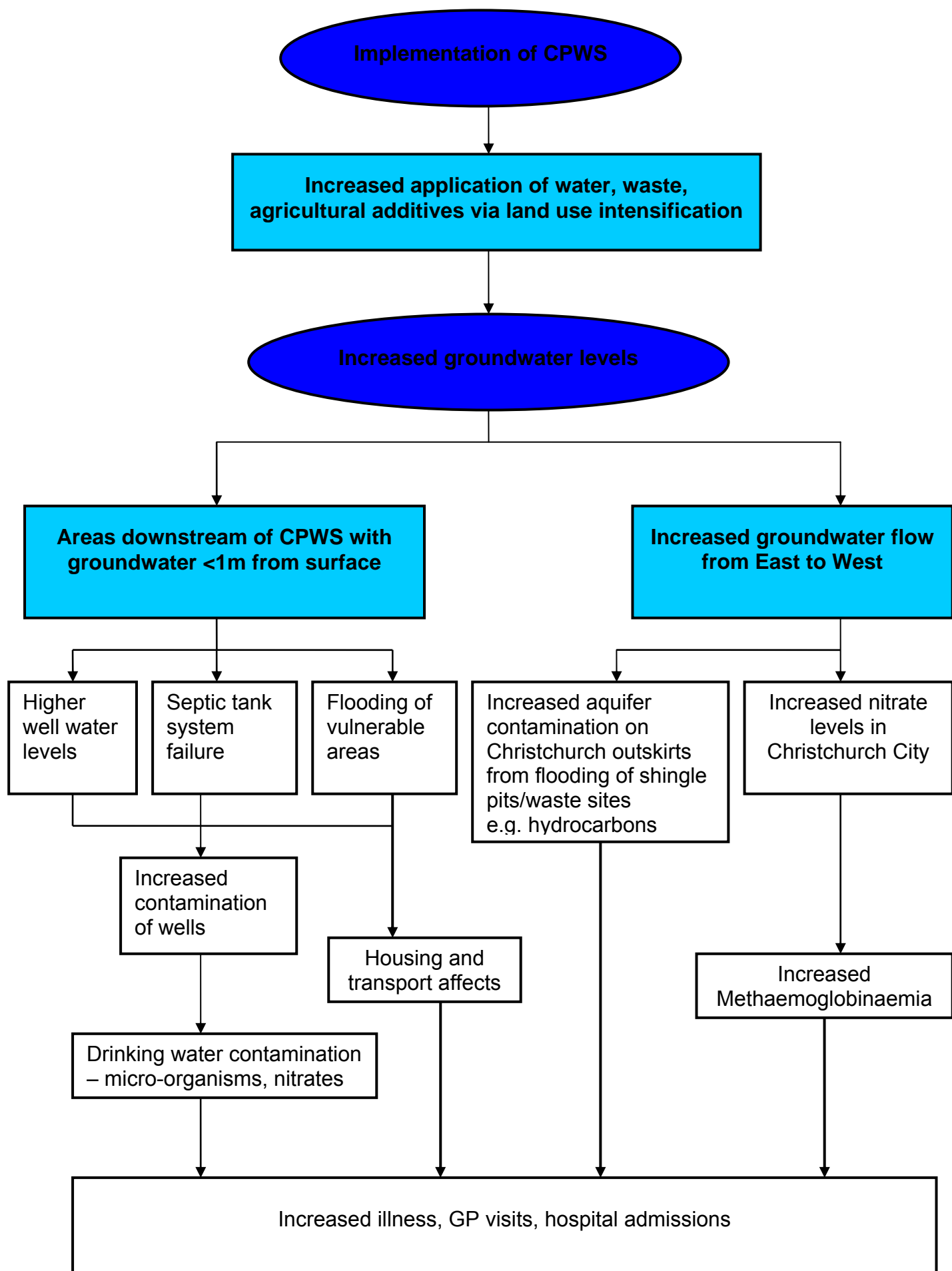


Figure 3

Predicted casual pathway on water quality and health (2) – increased groundwater



6.5 Socioeconomic effects of CPWS with respect to health

There are a number of socioeconomic issues associated with the CPW scheme which potentially have an effect on the health of Cantabrians. This health impact assessment considered poverty, inequity, employment and social connectedness.

Poverty

Export of dairy products topped \$1 billion in December 2007 and constitute a significant part of New Zealand's export earnings (Statistics New Zealand 2007) . Confidence in return on dairying and other agricultural products has driven Canterbury farmers to consider investing in the CPW scheme, which was strongly oversubscribed. However, the investment costs are high and wealth generation is dependent on a significant return. Assuming that the scheme is successful, and that dairying or other types of farming continue to provide the returns required to cover the costs of investment, it is important to consider whether the increased wealth generated by the scheme will improve health in Canterbury.

It should be noted that a number of stakeholders at the HIA socioeconomic workshop said they agreed with the following three key aspects of William Brown's economic analysis of the CPWS (Brown 2008).

- Applying zero opportunity cost to abstracted water artificially inflated the relative benefit of the scheme
- "Downstream benefits to the community" are not independent of the initial profitability of the scheme.
- The scheme is on the "cusp of farmer affordability".

In the case of the CPW scheme, the greatest initial benefits are to the investing farmers themselves. The spinoff into other industry, both rural and urban, is considerable, but there is little evidence as to how quickly such benefits are distributed. Poverty in rural areas of Canterbury is confined to older people, who have little earning potential. Poverty in urban areas of Canterbury is predominantly confined to a band through Christchurch extending from Aranui, Linwood through Addington and south Christchurch to Hornby. There is no evidence that benefits of

increasing profits of the farming community will be spread quickly, if at all, to these communities, other than redistribution through taxation.

It is important to consider the costs and benefits of all commodities when the overall benefits of the CPWS are being calculated. Since water has a high intrinsic value, not least because of its importance to health, any economic analysis of the benefits of the CPW scheme should attribute a cost to the water. Other aspects of the scheme which are known to have an effect on health and therefore to which a cost should be attached include social upheaval (caused by some people moving away from and many people moving towards the area of the scheme), increased traffic and loss of recreational value to the river.

Inequity

If the CPW scheme was unsuccessful, it could generate poverty in a small number of otherwise relatively well-off investors. If the scheme succeeds it will generate inequity in the medium term until the wealth generated for the 330 investors in the scheme is redistributed among the rest of the Canterbury community.

The effect of inequity on the Canterbury community is likely to generate a number of health problems even if overall wealth increases. With the evidence available it is difficult to evaluate whether the effect of increased monetary wealth on health at every level (but especially among farmers) will outweigh the negative effects of increased inequality in the Canterbury community as a whole. Moreover, local and national government policies to accelerate the redistribution of wealth in the medium term may reverse a net short term decrease in health status.

Employment

The unemployment rate in Canterbury to December 2007 was 3.0%, 0.6% lower than the national average with a growth in advertised vacancies that year in the region of 13.5% compared with a national fall of 2.2% over the same period (Dept of Labour Quarterly regional labour market update). The CPW scheme is predicted to generate 2500 jobs per annum, nearly twice the number of people currently drawing the unemployment benefit in the region. Farming in New Zealand requires increasingly skilled labour, and therefore positions are unlikely to provide work for

the small number of unemployed in Canterbury, who are more likely to be unskilled or semiskilled people.

In the Ashburton district, where the number of unemployed people is extremely low, local positions in the dairy industry have been mostly filled by European or South African migrants. Unskilled and semiskilled vacancies in the meatworks in Ashburton have been filled by Tongan migrants, who tend to have particular health needs associated with people who use English as a second language from a developing country. Therefore increased job creation from the CPWS is unlikely to provide any value to local residents. Rather, it will provide work for migrants from elsewhere in the country or the world. The net benefit for local residents is likely to be small, particularly if local services are stretched by the arrival of many new families.

Social connectedness

The Central Plains region of Canterbury is currently not suffering from rural decline. Indeed, towns such as Darfield are growing rapidly as they become populated with “lifestylers” and those prepared to commute longer distances. Because of this, it is unlikely that the anticipated population boom associated with the proposed CPW scheme is likely to improve services in the area. In fact, the rapid growth anticipated by the scheme is more likely to outstrip current services, resulting in a temporary declining health status of its residents until services can catch up with population growth. Furthermore, if jobs are filled by migrants from overseas the level of social connectedness is likely to decrease in the short to medium term, until new migrants and local people become more connected.

6.6 Issues for Maori with respect to health

The relatively brief consultation with Maori for this HIA highlighted the following issues in terms of health-related implications of the CPWS.

Participants in the consultation emphasised that Te Waihora (Lake Ellesmere) has a whakapapa and mythological importance, particularly to Taumutu runanga and for Ngai Tahu. It has provided kai awa (seafood) for Maori in the past, and its rehabilitation may be compromised by potential increased nitrification from the

CPWS. Local Maori have a Kaitiaki (caretaker) role for Te Waihora and consider it important to maintain the Mauri (life force) and the Wairua (spirit) of the lake. This includes fish stocks not just in Te Waihora, but creeks and other tributaries including the Selwyn River.

It is anticipated that the mixing of the Waimakariri and Rakaia rivers that would occur with the CPWS, and hence the mixing of the whakapapa associated with the rivers, would have an impact on the Mauri of Te Waihora and the broader catchment. This includes the risk of didymo infection of the lake. In addition, greater volumes of water from the CPWS may have adverse effects on Waahi Tapu sites, archaeological sites of significance to Ngai Tahu. It is difficult to quantify this impact but it is clearly important to local Maori and in terms of the protection of New Zealand's heritage.

In terms of the potential risk of methaemoglobinaemia, Maori are more likely to be bottle fed as infants (Ministry of Health 2002). Since bottle fed infants are more vulnerable to the effects of nitrates in drinking water, Maori would be likely to be disproportionately affected by methaemoglobinaemia as nitrate levels in groundwater increase.

In relation to socioeconomic implications, in order for Maori to benefit overall from the CPWS there would need to be a high proportion of Maori anticipated to be employed in those industries associated in the scheme, particularly dairying.

7. Conclusion and recommendations

To conclude, this HIA assessed that the CPWS is likely to result in increased nitrate concentrations, in particular an increase in exceedences of the MAV, and therefore a greater risk of infant methaemoglobinaemia. There was also evidence for an increased risk of contamination through septic tank failure, with health implications in terms of viruses and bacteria.

Evidence suggested that potential socioeconomic implications of the CPWS include a possible increase in inequity through the financial benefits of the scheme primarily accruing to the relatively small group of farmer shareholders in the scheme. Potential benefits through increased employment may not significantly affect the local community, especially if most of the new labour force comes from outside the region. In addition, the economic and social benefits associated with population growth may be outweighed by inequity and pressure on local social and health services.

There was insufficient evidence for associations between nitrates and a range of health outcomes including cancer, diabetes and adverse reproductive health outcomes.

7.1 Overall recommendation

This HIA has been conducted with the best available evidence collected over a relatively short period. It has considered the effect of the scheme on health separately from the scheme's direct social, economic and environmental effects, but has taken these broader determinants of health into consideration where they are likely to affect the health of the Canterbury population.

With the constraints of a short timeframe, this HIA has not referenced or consulted *all* the possible evidence. The available evidence is mixed and at times incomplete, with some evidence indicating health benefits from the CPWS and some suggesting adverse health effects from the scheme. None of the evidence, whether considered separately or together, can provide any conclusion beyond reasonable doubt. However, the health of the Canterbury population is considered by the Canterbury District Health Board to be paramount, ethically, professionally and under legislation. For this reason, the recommendations of this health impact assessment necessarily must take a precautionary approach.

The health of the whole community is one of Canterbury's greatest assets and this is highly dependent on a clean, safe water supply. There is a degree of risk in any major investment and the CPWS is no exception, even though investors may perceive the risk as small with high potential returns. However, the evidence suggests that the nature of the risk in the case of the CPWS is not simply a financial one – there is potential risk to the health of the community. The risk, although small, is significant. On the basis of available evidence and the need to take a precautionary approach, this HIA recommends that resource consent for the scheme is declined.¹⁰

If the scheme is granted consent to proceed, it is recommended that the following actions are undertaken to prevent or mitigate the potential adverse effects on human health.

¹⁰ Ashburton Mayor Bede O'Malley and the Ashburton District Council CEO Mr. Brian Lester, who participated in the HIA workshop discussions, specifically asked that their objections to the conclusions of this HIA be noted.

7.2 Suggested mitigating actions – water quality

Controls on farm management practices

CPW has proposed an Environmental Management System which includes a Sustainability Protocol and a binding Farm Management Plan for shareholders in the scheme. This is expected to address stocking levels, fertilizer use practices and standards, stock management near waterways, and riparian zone/strip protection (Taylor 2008). In evidence for the resource consent process, Ian Brown has noted that the farm management plans cannot guarantee that environmental degradation will not occur, but argues that the technical basis for the plans is sound (Brown 2008).

It is recommended that CPW's proposed Environmental Management System is reviewed to ensure that controls on land management and use, including stocking rates, require nitrate-reducing practices. An independent assessment of the Environmental Management System should be undertaken to ensure that it will be stringent enough to protect the quality of the water supply. As recommended in the SIA, codes of practice should include a mechanism for on-going water-quality monitoring and reporting to ensure the quality of community water supplies is maintained independent of any changes in land use and land ownership (Taylor 2008).

Measures to reduce bywash effects

CPW have suggested measures to reduce bywash effects, such as incorporation of wetlands to filter sediment prior to bywash discharge to rivers (Taylor 2008). It is recommended that there is independent assessment of the bywash measures to ensure they will be stringent enough to protect health and the quality of the water supply.

Monitoring of water quality and water-related risks

Participants at the HIA water quality workshop recommended more effective and regular monitoring of water systems for micro-organisms and nitrates, particularly in the CPWS area and downstream of the scheme area. Monitoring of well water/community supplies is especially important. As recommended in the SIA, it will also be important to monitor the issue of possible flooding of low-lying areas outside the scheme area, any damage to people's environments, health, and

property that might result, and how such impacts might be compensated for and/or actively avoided or mitigated in the design and operation of the scheme (Taylor 2008).

Increase separation distances between bores and septic tanks

Participants at the water quality workshop suggested that current distances separating water bores and septic tanks in vulnerable areas could be reviewed and widened or deepened.

Increase surface drainage

A range of measures have been proposed by consultants to CPWS to increase surface water drainage, including widening or deepening drains, installing more drains, providing pumped drainage in some cases, upgrading sewage reticulation systems, and ensuring more frequent maintenance of existing drains. Lewthwaite recommends the principle of adaptive management where local solutions would be developed on a case by case basis as the scheme develops (Lewthwaite 2007). He argued it is not possible to provide site-specific information or mitigation at this stage.

Use of new technologies to reduce contaminants

There is potential for further prevention or mitigation of adverse effects through new technologies. For instance, widespread use of the nitrification inhibitor “eco-n” would be likely to have an impact in reducing nitrate levels. Lincoln University researchers and Ravensdown fertiliser have recently developed a nitrification inhibitor which in trials has reduced nitrate leaching from pastoral soils by 60% while increasing pasture yield by 10 to 15% (Cameron, Di et al. 2004).

7.3 Suggested mitigating actions – socioeconomic issues

Compensation and support

Participants at the HIA's socioeconomic workshop advocated for the need to ensure adequate compensation, rehabilitation and support for the people most adversely affected by the CPWS (displaced local residents). There is also a need to ensure better communication with local people and to disclose the details of compensation being offered.

Participants recommended the introduction of a local levy which could be used for community projects in order to build social cohesion and increase community resources. This could be along the lines of an existing local levy at Waipara associated with the Kate Valley Landfill. Another recommendation from participants at the workshop was the need for community development/regeneration in local communities most affected by the CPWS.

Manage growth

The socioeconomic workshop made the following suggestions to manage local population growth associated with the CPWS:

- Planning for infrastructure and services in order to meet population growth demands – anticipate new social, education and housing needs in specific communities, for example, work with government agencies on school/early childhood education needs
- Introduction of a 'newcomers network' (similar to a network in Ashburton through the Safer Communities Council). This would be an organised network for new residents/workers/families to the area.

Promote equitable access to benefits of scheme

A range of mitigating actions was suggested in the HIA in relation to promoting more equitable access to the potential benefits of the CPWS. These included:

- Planning/training for school leavers to encourage employment of locals on the scheme and in associated businesses.
- Planning for older person's health care.
- CPW Trust should supervise the use of water rights.
- Establishment of water charges in order that this community resource.
- Promotion of recreational opportunities associated with the scheme, e.g. use of reservoir for recreation, walks, etc.
- Undertake analysis of the community involvement process to ensure that it is not simply a 'token gesture'.

References

- Acheson, D. (1998). Independent inquiry into inequalities in health report. London, The Stationery Office.
- Black, D. (1980). Inequalities in health; report of a research working group. London, Department of Health and Social Services.
- Blanford, W. J., M. L. Brusseau, et al. (2005). "Influence of water chemistry and travel distance on bacteriophage PRD-1 in sandy aquifer." Water Research **39**: 2345-2357.
- Brown, I. (2008). Statement to RMA Commissioners. CPWS RMA application for consent. Christchurch.
- Cameron, K., H. Di, et al. (2004). A Progress Report on the 'Eco-N' Project. Report to Ravensdown Fertiliser Co-operative Ltd. . Christchurch, Ravensdown Fertiliser Co-operative Ltd. .
- Coster, H. (1999). Community responses to change in rural health service delivery. Department of General Practice. Auckland, University of Auckland. **Masters**.
- Dahlgren G. and W. I. (1991). Policies and strategies to promote social equity in health. Stockholm, Institute of Futures Studies.
- Fietje, L. (2008). Section 42A Officers Report (Ecan).
- Hanson, C. (2008). Section 42A advice on groundwater quality for Ecan.
- Hayward, S. (2008). Section 42A Officer's Report. RMA application by Central Plains Trust.
- Hsing, Y. (2005). "Economic growth and income inequality: the case of the U.S." International Journal of Social Economics **32**(7): 639-47.
- Lawn, P. (2005). "An assessment of the valuation methods used to calculate the Index of Sustainable Welfare (ISEW). Genuine Progress Indicator (GPI) and Sustainable Net Benefit Index (SNBI)." Environment, Development and Sustainability **7**: 185-208.
- Lewthwaite, W. (2007). Brief of Evidence of Walter James Lewthwaite. CPWS RMA application. Christchurch, Buddle Findlay & Co.
- Ministry of Health (2002). Breastfeeding: A guide to Action. Wellington, Ministry of Health.
- Ministry of Health (2005). Drinking Water Standards New Zealand (DWSNZ), Ministry of Health
- Nicosia, L., J. Rose, et al. (2001). "A Field Study of Virus removal in Septic Tank Drainfields."
- Pang, L., M. Close, et al. (2005). "Filtration and transport of *Bacillus subtilis* spores and the F-RNA phage MS2 in a coarse alluvial gravel aquifer: Implications in the estimation of setback distances." Journal of Contaminant Hydrology **77**: 165-194.

- Parliamentary Commissioner for the Environment (2004). Growing for good: Intensive farming, sustainability and New Zealand's environment. Wellington.
- Phanuwan, C., S. Takizawa, et al. (2006). "Monitoring of human enteric viruses and coliform bacteria in waters after urban flood in Jakarta, Indonesia." Water Science & Technology **54**(3): 203-210.
- Sapkota, A., F. Curriero, et al. (2007). "Antibiotic Resistant Enterococci and faecal Indicators in Surface water and Groundwater Impacted by a Concentrated swine Feeding Operation ".
- Scandura, J. and M. Sobsey (1997). "Viral and Bacterial Contamination of groundwater from off site sewage Treatment Systems."
- Shutter, S., E. Sudicky, et al. (1992). "Chemical fate and Transport in a Domestic Septic System Application of a variability saturated Model for Chemical Movement."
- Statistics New Zealand (2007) **Volume**, DOI: <http://www.stats.govt.nz/products-and-services/ext-trade-stats/key-pints-jun-06.htm?print=Y>
- Stevenson, A. (2006). Health Impact Assessment: Greater Christchurch Urban Development Society Options. A. Stevenson. Christchurch, Canterbury DHB.
- Talberth, J., C. Cobb, et al. (2006). The Genuine Progress Indicator: A tool for sustainable development. Oakland.
- Taylor, C. (2008). Brief of evidence of Charles Nicholas Taylor. CPWS RMA application. Christchurch.
- UNEP (2004). World Commission on Dams. Geneva, United Nations Environment Programme.
- Vant, W. and R. Hoare, Eds. (1987). Determining input rates of nutrients. Water & Soil Miscellaneous Publication No. 103. Wellington.
- Ward, M., E. Heineman, et al. (2005). "Drinking Water and Dietary Sources of Nitrate and Nitrite and risk of Glioma."
- Weir, J. (2008). "Brief evidence of Julian James Weir in the applications of Central Plains Trust."
- WHO (1978). Alma Ata Declaration, World Health Organisation.
- Witten, K., T. McCreanor, et al. (2001). "The impacts of a school closure on neighbourhood social cohesion: narratives from Invercargill, New Zealand." Health and Place **7**: 307-317.
- World Health Organisation (2000). World Health Report. Geneva.

Appendix 1

Attendees who attended the scoping meeting on 29th November 2007

Alistair Humphrey (Community and Public Health, Canterbury DHB)

Bede O'Malley (Ashburton Mayor)

Brian Laster (CEO, Ashburton District Council)

Paul Cottam (Christchurch City Council)

Bob Penter (GHD On behalf of CPW Ltd.)

Derek Benfield (Community and Public Health, Canterbury DHB)

Malcolm Walker (Community and Public Health, Canterbury DHB)

Andrew Ball (ESR)

Lois Griffiths (Forest and Bird)

Grant and Marilyn Nelson (Forest and Bird)

Rosalie Snoyink (Malvern Hills Protection Society)

Paula Hawley-Evans (Ministry of Health HIA Unit)

Frances Graham (Ministry of Health HIA Unit)

Mojo Mathers (Green Party)

Alan Liefing (Green Party)

David Lynch (Momentum PR Malvern Hills Protection Society)

Richard English (individual engineer)

Andrea Lobb (Te Taumutu Runanga)

Mary Sparrow (Waimakariri District Council)

Janet Ralph (Waimakariri District Council)

Rob Quigley (Quigley and Watts)

Louise Thornley (Quigley and Watts)

Martin Ward (Environmental Consultant)

Gina Erceg (Community and Public Health, Canterbury DHB, notetaker)

Invited stakeholders who did not attend the scoping meeting on 29th November 2007

Representative (Ashburton Community Water Trust)

Peter Mitchell (Christchurch City Council)

Erin Jamieson (Convergence Communications On behalf of CPW Ltd.)

Derek Crombie (GHD On behalf of CPW Ltd.)

Chrissie Williams (Christchurch City Councillor)

Cliff Tipler (URS On behalf of CPW Ltd.)

D Newey (Department of Conservation)

Bryan Jenkins CEO (ECAN)

Margaret Leonard (ESR)

Murray Close (ESR On behalf CPW Ltd.)

Evon Currie (Canterbury DHB)

Representative (Federated Farmers)

Jay Smith (Fish and Game Temuka)

C Todd (Forest and Bird)

Gordon Davies CEO (Canterbury DHB)

Bob Parker (Christchurch Mayor)

Ann Callaghan (Ministry for the Environment)

Paul Prendergast (Ministry of Health)

Kerry Glass (National Council of Women)

Jennifer Walsh (Ngai Tahu)

Paul Horgan (Ngai Tahu)

Douglas Marshall (Selwyn District Council)

Representative (Te Taumutu Runanga)

Ted Te Hae (Canterbury DHB)

Jim Palmer CEO (Waimakariri District Council).

Appendix 2a

Water quality stakeholders and experts (14th February 2008)

His Worship	Bede	O'Malley	Mayor	Ashburton District Council
Mr	Brian	Lester	CEO	Ashburton District Council
His Worship	Bob	Parker	Mayor	Christchurch City Council
Mr	Paul	Cottam	Recreation/Sports Officer	Christchurch City Council
Mr	Peter	Mitchell	General Manager Regulation & Democracy Services	Christchurch City Council
Ms	Chrissie	Williams	Councillor	Christchurch City Council
Dr	Alistair	Humphrey	Public Health Physician	C&PH Division, CDHB
Mr	Braden	Leonard	Health Protection Officer	C&PH Division, CDHB
Mr	Derek	Benfield	Manager, Environmental Health	C&PH Division, CDHB
Ms	Evon	Currie	General Manager	C&PH Division, CDHB
Ms	Gina	Erceg	Administrative Officer	C&PH Division, CDHB
Mr	Gordon	Davis	CEO	Canterbury District Health Board
Ms	Michele	Hider	Communications Manager	Canterbury District Health Board
Mr	Greg	Brogden	Corporate Solicitor	Canterbury District Health Board
Mr	Malcolm	Walker	Health Protection Officer	C&PH Division, CDHB
Ms	Judy	Williamson	Drinking Water Assessor	C&PH Division, CDHB
Dr	Andrew	Porteous	Occupational Health Registrar	C&PH Division, CDHB
Mr	Pat	Morrison	Chairman	Central Plains Water Ltd.
Mr	Doug	Marsh	Chairman	Central Plains Water Trust
Mr	David	Newey		Department of Conservation
Mr	Bryan	Jenkins	CEO	Environment Canterbury
Dr	Leo	Fietje	Principal Consents Advisor	Environment Canterbury
Ms	Shirley	Hayward	Water Quality Analyst	Environment Canterbury
Mr	Andrew	Ball	Water Microbiology Consultant	ESR
Ms	Jacqui	Ritchie	WINZ Data Management	ESR
Dr	Margret	Leonard	Water Research Scientist	ESR
Dr	Murray	Close	Principal Scientist (Groundwater)	ESR
Mr	Rupert	Curd	President	Federated Farmers
Mr	Ross	Millichamp	Regional Manager	Fish and Game
Mr	Chris	Todd	South Island Field Coordinator	Forest & Bird
Mr	Bob	Penter	Group Manager, Environmental Services	GHD Ltd
Mr	Derek	Crombie	Project Manager (CPW)	GHD Ltd
Ms	Mojo	Mathers	Member	Green Party
Dr	Louis	Tremblay	Built Environments Researcher	Land Care Research
Mr	David	Lynch	Lawyer	Momentum Public Relations Ltd
Ms	Rosalie	Snoyink	Spokesperson	Malvern Hills Protection Society
Ms	Christina	Robb	Senior Advisor	Ministry for the Environment
Dr	Paul	Prendergast	Principal Public Health Engineer	Ministry of Health
Ms	Frances	Graham	Senior Advisor, Environmental Health	Ministry of Health
Ms	Paula	Hawley-Evans	Senior Advisor, HIA Unit	Ministry of Health
Ms	Jane	Demeter	Environmental Advisor	National Council of Women
Ms	Louise	Thornley	Senior Research Associate	Quigley & Watts Ltd.
Mr	Rob	Quigley	Director	Quigley & Watts Ltd.
Mr	Douglas	Marshall	Corporate Services Manager	Selwyn District Council
Mr	Hugh	Blake-Manson	Water Asset Manager	Selwyn District Council
Mr	Cliff	Tipler	Senior Principal	URS (NZ) Ltd
Mr	Martin	Ward	Consultant	NZAIA Inc
Mr	Richard	English	Engineer	Twelfth Night Consulting

Appendix 2b

Maori stakeholders and experts (14th February 2008)

His Worship	Bede	O'Malley	Mayor	Ashburton District Council
Mr	Brian	Lester	CEO	Ashburton District Council
His Worship	Bob	Parker	Mayor	Christchurch City Council
Mr	Paul	Cottam	Recreation/Sports Officer	Christchurch City Council
Mr	Peter	Mitchell	General Manager Regulation & Democracy Services	Christchurch City Council
Dr	Alistair	Humphrey	Public Health Physician	C&PH Division, CDHB
Mr	Braden	Leonard	Health Protection Officer	C&PH Division, CDHB
Mr	Derek	Benfield	Manager, Environmental Health	C&PH Division, CDHB
Ms	Evon	Currie	General Manager	C&PH Division, CDHB
Ms	Gina	Erceg	Administrative Officer	C&PH Division, CDHB
Mr	Gordon	Davis	CEO	Canterbury District Health Board
Ms	Michele	Hider	Communications Manager	Canterbury District Health Board
Mr	Greg	Brogden	Corporate Solicitor	Canterbury District Health Board
Dr	Ramon	Pink	Public Health Physician	C&PH Division, CDHB
Mr	Ted	Te Hae	Cultural Manager	C&PH Division, CDHB
Mr	Pat	Morrison	Chairman	Central Plains Water Ltd.
Mr	Doug	Marsh	Chairman	Central Plains Water Trust
Ms	Shirley	Hayward	Water Quality Analyst	Environment Canterbury (ECAN)
Mr	Bob	Penter	Group Manager, Environmental Services	GHD Ltd
Mr	Derek	Crombie	Project Manager (CPW)	GHD Ltd
Ms	Mojo	Mathers	Member	Green Party
Ms	Frances	Graham	Senior Advisor, Environmental Health	Ministry of Health
MS	Paula	Hawley-Evans	Senior Advisor, HIA Unit	Ministry of Health
Mr	David	Lynch	Lawyer	Momentum Public Relations Ltd
Ms	Rosalie	Snoyink	Spokesperson	Malvern Hills Protection Society
Ms	Jane	Demeter	Environmental Advisor	National Council of Women
Mr	David	O'Connell	Manager Kaupapa Taiao	Te Rūnanga o Ngāi Tahu
Mr	Paul	Horgan	Environmental Advisor Ngā Rawa Taiao	Te Runanga o Ngāi Tahu
Ms	Louise	Thornley	Senior Research Associate	Quigley & Watts Ltd.
Mr	Rob	Quigley	Director	Quigley & Watts Ltd.
Ms	Fiona	Pimm	CEO	He Oranga Pounamu
Mr	Douglas	Marshall	Corporate Services Manager	Selwyn District Council
Mr	Jason	Arnold	Te Waihora Management Co-ordinator	Te Rūnanga o Ngāi Tahu
Mr	Maani	Stirling	Te Taumutu Rūnanga	Te Rūnanga o Ngāi Tahu
Ms	Sandy	Lockhart	Te Taumutu Rūnanga	Te Rūnanga o Ngāi Tahu
Ms	Alana	Pitama	Te Tūāhuriri Rūnanga	Te Rūnanga o Ngāi Tahu
Mr	Te Maire	Tau	Te Tūāhuriri Rūnanga	Te Rūnanga o Ngāi Tahu
Mr	Donald	Couch	Te Hapū o Ngāti Wheke (Rāpaki)	Te Rūnanga o Ngāi Tahu
Mr	James	Daniels	Wairewa Rūnanga	Te Rūnanga o Ngāi Tahu
Ms	Andrea	Lobb	Papatipu Runanga	Te Rūnanga o Ngāi Tahu
Ms	Janet	Ralph	Policy Planner	Waimakariri District Council
Mr	Jim	Palmer	CEO	Waimakariri District Council
Ms	Mary	Sparrow	Policy Analyst	Waimakariri District Council
Mr	Martin	Ward	Consultant	NZAIA Inc

Appendix 2c

Socioeconomic stakeholders and experts (15th February 2008)

His Worship	Bede	O'Malley	Mayor	Ashburton District Council
Mr	Brian	Lester	CEO	Ashburton District Council
His Worship	Bob	Parker	Mayor	Christchurch City Council
Mr	Paul	Cottam	Principle Advisor Social Policy	Christchurch City Council
Mr	Peter	Mitchell	General Manager Regulation & Democracy Services	Christchurch City Council
Ms	Chrissie	Williams	Councillor	Christchurch City Council
Dr	Alistair	Humphrey	Public Health Physician	C&PH Division, CDHB
Mr	Braden	Leonard	Health Protection Officer	C&PH Division, CDHB
Mr	Derek	Benfield	Manager, Environmental Health	C&PH Division, CDHB
Ms	Evon	Currie	General Manager	C&PH Division, CDHB
Ms	Gina	Erceg	Administrative Officer	C&PH Division, CDHB
Mr	Gordon	Davis	CEO	Canterbury District Health Board
Ms	Michele	Hider	Communications Manager	Canterbury District Health Board
Mr	Greg	Brogden	Corporate Solicitor	Canterbury District Health Board
Mr	Malcolm	Walker	Health Protection Officer	C&PH Division, CDHB
Mr	Pat	Morrison	Chairman	Central Plains Water Ltd.
Mr	Doug	Marsh	Chairman	Central Plains Water Trust
Ms	Shirley	Hayward	Water Quality Analyst	Environment Canterbury (ECAN)
Mr	Rupert	Curd	President	Federated Farmers
Mr	Bob	Penter	Group Manager, Environmental Services	GHD Ltd
Mr	Derek	Crombie	Project Manager (CPW)	GHD Ltd
Ms	Mojo	Mathers	Member	Green Party
Dr	Louis	Tremblay	Built Environments Researcher	Land Care Research
Professor	Paul	Dalziel	Professor of Economics	Lincoln University
Ms	Frances	Graham	Senior Advisor, Environmental Health	Ministry of Health
Ms	Paula	Hawley-Evans	Senior Advisor, HIA Unit	Ministry of Health
Ms	Mercedes	Lentz	Project Manager	Ministry for the Environment
Mr	David	Lynch	Lawyer	Momentum Public Relations Ltd
Ms	Rosalie	Snoyink	Spokesperson	Malvern Hills Protection Society
Ms	Jane	Demeter	Environmental Advisor	National Council of Women
Ms	Louise	Thornley	Senior Research Associate	Quigley & Watts Ltd.
Mr	Rob	Quigley	Director	Quigley & Watts Ltd.
Mr	Douglas	Marshall	Corporate Services Manager	Selwyn District Council
Dr	Geoff	Fougere	Senior Lecturer Sociology	University of Canterbury
Ms	Janet	Ralph	Policy Planner	Waimakariri District Council
Mr	Jim	Palmer	CEO	Waimakariri District Council
Ms	Mary	Sparrow	Policy Analyst	Waimakariri District Council
Mr	Martin	Ward	Consultant	NZAIA Inc