Water Management and the Broader Determinants of Health

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Introduction

Health is defined by the World Health Organisation (WHO) as: "a state of complete physical, mental and social well-being and not merely the absence of disease". As this state cannot be achieved solely through the actions of health services, the WHO definition implies that good health is also a product of actions of the wider community. In some cases this concept is intuitive; it is clear that we need access to clean drinking water to remain healthy, yet this service is provided by municipal authorities rather than the health system. In other cases the concept is less clear; few people realise that the strong social links within a community are associated with improved health outcomes, yet there is extensive literature supporting such a relationship (Kawachi, Kennedy et al. 1997; Kawachi, Kennedy et al. 1999; Quigley, Cunningham et al. 2006). As health is important to individuals, communities and economies, it is advantageous to all members of society for decision makers to consider the health impacts of their decisions. This rapid review outlines some possible effects of water management decisions on the broader determinants of health.

Scope and limitations

This review considers the impact on health of water management decisions such as water allocations, project consents and allocation of conservation grants. The review is intended to inform health impact discussion at Canterbury Water Management Strategy (CWMS) Zone Committee meetings.

CWMS Zone Committee members are likely to be already familiar with the environmental and economic effects of Zone Committee decisions. As such, these effects are discussed only insofar as is necessary to examine their subsequent effects on health.

The primary limitation of the current review is the timeframe required for its preparation. Given this limited timeframe and the very broad scope outlined above, this review does not attempt to provide a comprehensive summary of the literature. Instead it provides an overview of the effects of water management on health supported by selected literature that is representative of the most frequently expressed concepts in this field.

Where possible, this review draws on literature that is specific to Canterbury or New Zealand. However, in many instances such literature is not available and international literature is used. The applicability of international literature to the situation in Canterbury is discussed where appropriate.

Dimensions of Health

The review is structured to reflect the fourteen dimensions of health outlined in the Canterbury District Health Board's Integrated Recovery Planning Guide Version 2 (Community and Public Health 2011), although some dimensions are grouped to better reflect their association with water management. The dimensions used in this document are:

- Lifestyles and neighbourhood amenity
- Natural capital
- Resource sustainability
- Transport and community safety
- Social capital
- Community resilience
- Cultural diversity
- Equity and economic development
- Public services
- Housing stock

Lifestyles and Neighbourhood Amenity

Physical activity is a major determinant of health in wealthy countries (Frank, Engelke et al. 2003). On an individual level the amount of physical activity undertaken is determined primarily by genetic and social factors (Seefeldt, Malina et al. 2002). However, at a community level, access to pleasant, affordable and aesthetic outdoor recreation opportunities can increase physical activity participation (Giles-Corti and Donovan 2002; Seefeldt, Malina et al. 2002) and improve the health of the community (Seefeldt, Malina et al. 2002).

In addition to the physical activity benefits of public greenspace, exposure to natural landscapes has independent beneficial effects for psychological health (Maller, Townsend et al. 2006). Even in those who do not actively seek to access natural landscapes for recreation, exposure to these landscapes reduces indicators of stress (Parsons 1991; Rohde and Kendle 1994; Kaplan 1995; Parsons, Tassinary et al. 1998). Reduced stress is a positive outcome in its own right, but it is also associated with reductions in the risk of other mental and physical health problems (Watson and Pennebaker 1989; Glaser and Kiecolt-Glaser 2005). Abraham et al. (2010) concluded that to promote health, communities need to have "easy access to natural landscapes and the availability of nearby (green) public open spaces. Landscapes need to be perceived as pleasant and attractive for all senses…".

By altering the recreation values of rivers, lakes and wetlands, water management decisions may have positive or negative impacts on natural landscapes and opportunities for physical activity. For example, consent for an irrigation project may be predicated on provision of an easement for public access. Similarly, funding for a riparian planting project may enable the riparian area to be used for recreation as well as improving the recreational value of the waterway by improving water quality and aesthetics (Greenley, Walsh et al. 1981; Johnson and Carothers 1982). Conversely, a reduction in water quality due to land use intensification and increased nutrient leaching (Doak, Parminter et al. 2004) might reduce the recreational and aesthetic

values of waterways, reduce participation in physical activity, and have a negative effect on community health (Greenley, Walsh et al. 1981).

Natural Capital

Natural capital refers to the natural resources, land and ecosystems that provide life-support for humans and other living things. Natural capital can be broadly divided into biodiversity and ecosystem services.

An ecosystem is said to have high biodiversity when it has a wide variety of species and a wide variety of genes within those species. High biodiversity enhances the ability of the ecosystem to respond to adverse events (e.g. disease or flooding (Horwitz, Lindsay et al. 2001)). Similarly, some minimum threshold of biodiversity is often required to provide the ecosystem services utilised by society (Swift, Izac et al. 2004). For example, a range of different plant species help to support populations of pollinator insects throughout the year. These effects can, in turn, improve health outcomes by allowing communities to continue to function in the face of adverse events. Analogous to the effect of public greenspace discussed in the previous section, biodiversity also contributes to individuals' sense of attachment to a particular community and place, and can improve mental health outcomes (Horwitz, Lindsay et al. 2001).

Ecosystem services are the functions of an ecosystem that provide utility for humans. In Canterbury, the ecosystem provides a variety of services including filtration and delivery of drinking water supplies, pollination, provision of fish and game populations, weed and pest control through parasite and predator species, soil stabilization, and carbon sequestration (Humphrey, Walker et al. 2008; Hearnshaw, Cullen et al. 2010). A comprehensive report published in Nature (Costanza, d'Arge et al. 1997) estimated that the annual value of ecosystem services was approximately double the global GNP.

Local biodiversity and ecosystem services will be supported by conservation or restoration of wetlands or riparian strips, and by improving water quality and preserving braided riverbed habitat (Hearnshaw, Cullen et al. 2010). However, biodiversity may also be increased by encouraging a diversity of land use within farming systems. By growing a range of crop and pasture species and keeping a range of animal breeds, ecosystem resilience and the ability of the ecosystem to provide services will both be increased (Swift, Izac et al. 2004).

Agricultural intensification tends to decrease biodiversity and supplant ecosystem services with artificial services (e.g. regulation of soil quality by the ecosystem is replaced by artificial fertilizer application (Giller, Beare et al. 1997) or control of pests by predator species is replaced by pesticide application (Matson, Parton et al. 1997)). While such changes may result in an increase in productivity, they may also increase the vulnerability of the ecosystem to adverse events (Swift, Izac et al. 2004), which may result in poorer human health outcomes after adverse events (Humphrey, Walker et al. 2008). Furthermore, increased abstraction of water, nutrient and agrichemical leaching, and faecal runoff may impede or overwhelm ecosystem services outside the immediate farm environment (Swift, Izac et al. 2004). Reduced

access to ecosystem services may, in turn, adversely affect health outcomes for other members of the community (Humphrey, Walker et al. 2008).

Resource Sustainability

Modern society requires a variety of resources to maintain and improve living standards and health outcomes. In the face of increasing global population and diminishing supplies of non-renewable resources, decisions which increase the sustainability of energy and food supplies will have a long-term positive effect on health (Brown, Grootjans et al. 2011).

In the context of water management, sustainability can be supported by projects such as small-scale hydroelectric generation (Kaygusuz 2002) and water allocations that do not require energy input (i.e. pumping) to utilise (Ramos and Ramos 2009). Conversely allocations which require pumping (Ramos and Ramos 2009) or encourage artificial fertilizer use may decrease sustainability (Takahashi 2004).

Public health is also likely to be significantly reduced by an increase in atmospheric greenhouse gas content leading to global climate change (Haines, Kovats et al. 2006; Frumkin, Hess et al. 2008). A warming climate could displace residents and inundate fertile land through sea-level rise, increase the transmission of disease, and decrease food production capacity (Frumkin, Hess et al. 2008). In the New Zealand context, agriculture was responsible for 46% of the country's greenhouse emissions in 2008 (Ministry for the Environment 2010), due primarily to the use of artificial nitrogen fertilizer and emissions from animal dung (Ministry for the Environment 2010). As such, water management decisions which encourage the use of nitrogen fertilizer or allow increased stocking rates are likely to have a small but world-wide negative impact on health via increased greenhouse gas emissions and climate change.

Transport and Community Safety

Major projects assessed by the CWMS Zone Committees will sometimes require high volumes of construction traffic and upgrades to road infrastructure, which may affect health via impact on physical activity, air quality, and access to essential services. Community safety could also be affected by changes in the risk of traffic accidents. It should be noted that those health effects associated with construction traffic will be transitory, ceasing after construction is completed, but those associated with upgraded infrastructure will be more permanent.

Increases in local traffic elevate the perception of danger on roadways, which has been identified as a major barrier to physical activity in children (de Hartog, Boogaard et al. 2010) and is associated with lower levels of physical fitness in the community (Morrison, Thomson et al. 2004). Reduced physical activity is in turn associated with poorer health outcomes (Frank, Engelke et al. 2003).

There is some evidence that heavy local traffic may decrease air quality and increase the incidence of respiratory disease. In urban environments with good air quality, proximity of schools (Kim, Smorodinsky et al. 2004) or homes (McConnell, Berhane et al. 2006) to busy roads significantly increases the incidence childhood of asthma

and bronchitis. However, it is not clear whether these findings from urban environments may be generalised to a rural setting.

It is intuitive to assume that increased traffic volume will increase the risk of traffic accidents for road users, and on busy urban roads this assumption holds (Golob and Recker 2003). However, research that examined increased traffic flow on low-traffic rural roads such as those in rural Canterbury (< 10,000 vehicles·day^{-1} (Choueiri, Lamm et al. 1994)) found that the crash risk per vehicle km either did not change (Ivan 2000) or decreased (Hall and Pendleton 1990; Choueiri, Lamm et al. 1994) as traffic volumes increased.

There is also considerable evidence demonstrating that improved rural road infrastructure is associated with improved health outcomes in poor rural communities in developing countries (Jacoby 2000; Jalan and Ravallion 2002; Van de Walle 2002). However, similar evidence from developed countries is not available. In the Canterbury context is seems likely that the existing road infrastructure is sufficient to provide rural communities with access to health services and economic opportunities, so further improvements in the road network are not likely to have a major effect on health.

Social Capital

Social capital is a term to describe the "the advantage individuals and communities can gain from social participation, mutual assistance and trust" (Currie and Stanley 2008). Communities with high social capital (i.e. strong social links between all members of society) report better health status (Kawachi, Kennedy et al. 1999) and have lower all-cause mortality (Kawachi, Kennedy et al. 1997). Furthermore, the health benefits of high social capital are particularly marked in otherwise disadvantaged social groups (Quigley, Cunningham et al. 2006).

Social capital tends to be enhanced by projects that require participation by many members of the community. In systems where every person in the community has a stake in the productivity of the land (e.g. terraced paddy field villages in Asia (Wade 1979)), social cohesion is strengthened when the whole community works together to build or operate irrigation systems. However, where only a few members of a community have a stake in the irrigation scheme it tends to divide the community and reduce social capital (Wade 1979; Pigram and Mulligan 1991).

Community conservation projects such as wetland restoration tend to build relationships and increase social capital. Even when initiated and funded by central government, community conservation projects aimed at improving water quality were also associated with an increase in social capital in rural communities in Australia (Sobels, Curtis et al. 2001) and the United States (Boody, Vondracek et al. 2005).

Community Resilience

Community resilience is the ability of communities to respond positively to adversity (Adger 2000). Communities with high resilience have better health outcomes in the face of natural disasters, poor economic conditions, and other adverse events (Adger 2003).

Community resilience is higher in communities with high social capital. In these communities, strong social networks and a "sense of place" encourage community members to support each other and improve health outcomes in difficult times (Adger 2003). Community resilience is also supported by ecosystem resilience. Resilient ecosystems continue to provide communities with ecosystem services during and after ecological disruption (Adger 2000; Doak, Parminter et al. 2004). As such, the factors which affect social capital and ecosystem resilience (see the Social Capital and Natural Capital sections) can also be applied to community resilience.

Community resilience is also increased by a diversity of business activity within a community. Communities who generate their income from a range of different sectors are less vulnerable to market variability and better able to tolerate a downturn in any one sector (Doak, Parminter et al. 2004). As such, water management decisions which support less well developed sectors of the business community are more likely to have a positive health effect than decisions which support sectors that are already well developed.

Cultural Diversity

CWMS Zone Committee processes and decisions have the potential to include or alienate cultural groups depending on how their views and cultural practices are integrated into the decision making process. People with a strong sense of social inclusion and community are more likely to report excellent or very good mental health (Shields 2008).

Māori are especially likely to be affected by water management decisions as Māori have a traditional association with the land and water of Canterbury. Consultation with local Māori is necessary to make informed water management decisions. However, in addition to consultation, it is also useful for Zone Committee members to be familiar with the concepts of taonga, wāhi tapu, and the connection between tāngata whenua and the landscape.

Māori have a spiritual connection with water, an important taonga which must remain pure and uncontaminated to maintain its mauri (life force) so it may support both physical and spiritual life in the present and for future generations (Te Runanga o te Rarawa 2004). Māori also have "a sense of landscape that is intrinsically connected to health and wellbeing" (Public Health Advisory Committee 2008). The land includes the past, present and future in both the physical and spiritual dimensions, and is described as "not just where we live, but who we are" (Public Health Advisory Committee 2008). It is important to consider a Māori viewpoint to improve community health (National Advisory Committee on Health & Disability 1998) and to comply with the principles of the Treaty of Waitangi.

Wāhi tapu are designated sites of cultural significance which may be associated with important landmarks, food gathering opportunities, sources of raw materials, or other important features or events (Te Runanga o te Rarawa 2004). Wāhi tapu are sacrosanct and it is a direct violation of tapu to "turn the sod" within the boundaries of the wāhi tapu (Te Runanga o te Rarawa 2004).

Apart from wāhi tapu, many other places are important to Māori, and preservation of these places may help to promote social inclusion. Waterways and wetlands are often important traditional food gathering areas even though they may not be designated as wāhi tapu (Ministry for the Environment 2001). Similarly, the health and continuity of all rivers and waterways are culturally significant (Te Runanga o te Rarawa 2004).

Equity and Economic Development

The ultimate purpose of most projects considered by CWMS Zone Committees is the economic development of the community, region or country. In Canterbury it was estimated that, in 2003, irrigation accounted for $330 million of increased production at the farm gate (Doak, Parminter et al. 2004) and will account for considerably more production today. Economic development allows community to support high average incomes, which are associated with good health outcomes.

The health benefits of an increase in income are greatest for low-income groups who can use the additional income to improve their access to education, social opportunities, goods, and services (Siddiqi and Hertzman 2001; Lawn 2005). However, increased income has minimal health benefit for the wealthier members of society who already have good health outcomes (Hsing 2005). Similarly, job creation improves health outcomes in population groups with high unemployment, but not in groups with low unemployment (Humphrey, Walker et al. 2008). In fact, there is strong evidence suggesting that income equality within a society is just as important as the average income of a society in determining health outcomes (Wilkinson 1997; Siddiqi and Hertzman 2001; Schell, Reilly et al. 2007).

Economic development due to irrigation schemes is likely, in the first instance, to increase incomes primarily for existing landholders who already have good health outcomes (Humphrey, Walker et al. 2008). The trickle-down of wealth may eventually improve health outcomes for people who do not directly benefit from the irrigation scheme. However, trickle-down effects take a long time to occur (Humphrey, Walker et al. 2008) and if there is a short-term increase in income inequality there may be a concomitant decrease in overall health outcomes (Wilkinson 1997; Siddiqi and Hertzman 2001; Schell, Reilly et al. 2007). If a project will result in job creation then it is likely to improve health outcomes for those employed, but the improvement may be limited if the jobs are of low quality or are insecure, seasonal work (Gibson, Mckenzie et al. 2008).

Water management decisions also have the potential to affect economic development by changing the tourism value of an area. A change in tourism value can have a large impact on the economy of communities which rely on tourism for a large portion of their income (Doak, Parminter et al. 2004). For example, residents of Hopetoun in Victoria, Australia identified that water quality in the local lake was important to attract tourists and support the local economy (Townsend, Moore et al. 2002). However, a change in tourism value is not likely to affect the economy of communities where tourism is not an important source of income (Doak, Parminter et al. 2004).

Public Services

Water management decisions have the potential to impact on municipal water supplies, stormwater drains and sewerage. In Canterbury, municipal water supplies are predominantly sourced from gravel aquifers beneath the Canterbury plains. These aquifers are vulnerable to a reduction in water quality caused by increased irrigation, farm intensification and increased fertilizer use. In particular there is a risk of increased levels of nitrates, but viral or bacterial contamination may also occur (Humphrey, Walker et al. 2008).

There is a paucity of quality research describing the population-wide health effects of drinking water nitrates. However case studies and physiological investigations implicate drinking water nitrates as a primary cause of methaemoglobinaemia (blue baby syndrome). Drinking water nitrates are also candidate factors for increased risk of cancer, reproductive problems and thyroid problems (Humphrey, Walker et al. 2008).

There is extensive evidence supporting a negative impact of viral or bacterial contamination on public health. In fact, the concentration of the bacteria *Escherichia coli* is considered the best indicator of water quality for public health purposes (Edberg, Rice et al. 2000). Bacterial contamination can spread serious diseases such as cholera and typhoid, while viral contamination can spread diseases such as hepatitis A and gastroenteritis (Burke, Dufour et al. 1993).

Water management decisions may also affect public services, particularly health services, via their impact on economic development. Access to a local general practitioner (GP) is a major determinant of health in rural populations (Brabyn and Barnett 2004). Economic development may increase income or population in a community, which may encourage additional GPs to practice locally, or may enable existing practices to remain viable (Kearns and Joseph 1997).

Housing Stock

The link between inadequate heating, damp and mould and poor health is well documented in the international literature. Inefficient home heating also places additional costs on households. Health effects are worse for vulnerable groups such as low income families, older people, babies and sick people (Howden-Chapman, Matheson et al. 2007).

Water management decisions are most likely to affect housing by raising the water table through increased irrigation. A higher water table can lead to septic tank failure (Humphrey, Walker et al. 2008), which puts a cost on households and could force low-income residents into lower-quality housing. Similar considerations apply to residents displaced by dam construction and lake formation.

Food Security

Food security is an important determinant of health at household (Vozoris and Tarasuk 2003), regional (Alderman and Garcia 1994) and global (Rosegrant and Cline 2003) levels. Food security at each level is affected by different factors. Food insecurity can be defined as a long-term condition of poverty which usually takes the

form of skipped meals, limited portions or poor quality food. In developed countries food insecurity is associated with poor nutrition and overweight and obesity (McIntyre 2003). A recent New Zealand study also found that food insecurity is associated with an up to two times greater likelihood of experiencing psychological distress (Carter, Kruse, Blakely and Collings 2011).

In wealthy countries such as New Zealand, household level food security is primarily a function of household income (Chen and Kates 1994). As such, the factors discussed in the Equity and Economic Development section also apply to household food security. Food security is also affected by opportunities for hunting, fishing, collecting mahinga kai (tradition food gathering) and personal gardens (Gorton, Bullen et al. 2010). Water management decisions which improve water quality and household water supplies will also improve community health outcomes.

In the face of increasing population and a finite supply of land, food prices in New Zealand are likely to increase. Price rises have a negative health impact on communities, particularly on vulnerable and low-income households (Allen 1999). Water management decisions which decrease the cost of food production will therefore have a positive effect on community health.

At a regional level, food security is affected by resilience in the face of adverse events (e.g. drought, disease). Resilience against drought can be positively or negatively impacted by water allocations depending on the reliability of the water supply used (Hearnshaw, Cullen et al. 2010). For example, the over-allocation of the Opihi River water prior to building the Opuha dam reduced the resilience of South Canterbury communities, but the improved reliability of supply provided by the dam improved resilience (Hearnshaw, Cullen et al. 2010). Food production is also affected by ecosystem resilience so the factors discussed in the Natural Capital section also apply to food security.

Conclusions

This review serves to highlight the broad and sometimes contradictory range of pathways by which water management decisions may affect the health of the wider community. While all the factors in this review are worthy of consideration, every situation is different and a solution that produces a good health outcome for one community may produce a poor health outcome for another. However, constructive use of the information in this review should help to realize positive health impacts from water management decisions.

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