THE ROLE OF RAINWATER TANKS IN REDUCING VULNERABILITY DURING LAND AND WATER RELATED EMERGENCIES

Stan Abbott[1], Robyn Moore[2] & Franklin Golay[3]
[1]Director Roof Water Research Centre, Massey University
[2] Community Operations Researcher, Porirua City Council
[3] Water Research Intern, Swiss Federal Institute of Technology of Lausanne

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ABSTRACT

Wellington is extremely vulnerable to large earthquakes since it is bisected by large active faults and isolated in terms of supply lifelines. The potential for loss of water and food supplies is real and could render large areas uninhabitable for weeks to months. The purpose of this study was to explore the options for the installation of rainwater tanks in critical areas in the Wellington Region before and after a damaging earthquake. The importance of securing emergency water after a large earthquake is indisputable and this study was especially concerned with the applicability of roof water harvesting as a sustainable alternative water supply option.

The study had the following specific objectives:

- To explore the benefits of installing rainwater tanks.
- Identify likely areas to site rainwater tanks.
- Identify logistical implications for transporting and installing rainwater tanks.
- Identify technical issues including cost estimates of tanks.
- To examine community needs, perceptions and expectations.
- To examine security of supply issues.
- Identify minimum water treatment requirements.

Roof-collected rainwater can contribute significantly to a sustainable water strategy in times of disasters like earthquake, when the lifelines of centralised water infrastructures are compromised. The strategic placement of rainwater tanks at accessible sites presents several advantages to affected communities – not least that the critical lifeline of water is immediately available for emergency response.

KEYWORDS:

Rainwater tanks, earthquakes, emergency management, sustainable water supplies, treatment options.

1 INTRODUCTION

Urban water infrastructure services include water supply, wastewater and stormwater drainage facilities (Parkinson, Goldenfum and Tucci, 2010). The goal for Porirua City Council's urban water supply activities for example, is that *all urban areas have access to a continuous supply of high quality drinking water and urban fire-fighting supply* (PCC, 2009:17). The Council aims to use its assets to *meet the required level of service in the most cost effective way (...) to provide for existing and future customers* (PCC, 2009:15).

While coping with too much water during some months of the year and too little during others is not an uncommon problem for New Zealand communities, a further pressing issue for urban areas is preserving supply lifelines in the wake of damage to water infrastructure from earthquake. There is strong convergence between areas vulnerable to damage by earthquake and areas where infrastructure concentrates (GNS draft discussion document, 2010).

For water and wastewater infrastructure in New Zealand, restoration delays of between 65 to 90 days are not unimaginable, following an earthquake of magnitude 7.6 + or – 0.3 (GNS draft discussion document, 2010). In the Wellington region, this magnitude earthquake is assumed at least 15% probable before 2060, and without such an event occurring by 2060, the risk increases in the 150 years following (*ibid*).

Under Civil Defence Emergency Management (CDEM) legislation (2002), New Zealand's local authorities must have mechanisms in place to cope with water related emergencies like drought and flood, and including earthquake and tsunami. The Civil Defence Emergency Management Act (CDEM Act) 2002 came into effect on 1 December 2002, replacing the Civil Defence Act 1983. Section 58 of the Act states that: '*government departments and others' including local authorities and lifeline utilities, must ensure that they are 'able to function to the fullest possible extent, even though this may be at a reduced level, during and after an emergency.' They 'must take all necessary steps' to 'perform their functions and duties'* (Section 59).

Thus, an ongoing challenge for local authorities and other lifeline utilities, as they manage water, wastewater and stormwater in their communities, is developing affordable, effective, response and recovery action plans, that ensure a temporary loss of normal water services affects as few people, for as short a time, as possible.

Lifelines such as water and power must be quickly restored to gain the best outcomes for affected communities, in terms of response to, and recovery from, a natural disaster or emergency (World Bank, 2010). Rainwater tanks are thus emerging as a potential solution to providing renewable supplies of reasonable quality emergency water for Civil Defence. The strategic placement of rainwater tanks at accessible sites may present several advantages – not least that the critical lifeline of water is immediately available to communities in the various stages of post emergency response and recovery, following earthquake

The October 2005 earthquake in Northern Pakistan was the most devastating natural disaster that Pakistan has ever faced. It has been estimated that more than 73,000 people lost their lives, 570,000 houses were damaged rendering 2.8 million people shelter-less, and over a million people lost sources of income, while around 70,000 were injured (Amin & Han, 2009). The earthquake caused severe damage to over 4000 community owned drinking water supply systems, 25 km of sewerage lines, as well as drains, street pavements, public toilets and solid waste management systems. Water and sanitation facilities in 420 health facilities, and 5857 educational institutions, were destroyed (*ibid*). Many small and simple, economically-feasible rainwater harvesting systems were installed in relief camps of the earthquake-affected areas in Pakistan. Further, a simple, locally-designed household sand-filter proved efficient in improving drinking water quality for illiterate communities, with a positive resultant impact on health effects and economic outcomes (Mahmood *et al.* 2011).

Rainwater harvesting (RWH) was encouraged as a sustainable alternative water supply in tsunami-hit Banda Aceh in 2007 (Song, Han, Kim and Song, 2008). From a technical perspective, the RWH was found to be particularly useful for the following reasons: (1) the materials used could be obtained easily and cheaply in the area; (2) its design and installation was simple and replicable, using locally available technology; (3) maintenance was easy; and (4) the expected volume of collected water was considerable (Han 2007; Song et al., 2008). In the 19 months since the earthquake and tsunami-hit Samoa in September 2009, the Samoa Red Cross Society procured and installed 350 rainwater tanks (Red Cross and Red Crescent Operations, 2010), providing inestimable social welfare benefits to affected communities.

Part of reducing vulnerability to hazard impacts is about increasing people's resilience through preserving or quickly restoring the services needed for relief and recovery (Cannon, 2008). Water supply, in particular, is a lifeline that can suffer only minor interruption, in the wake of a damaging earthquake or tsunami. Understanding and increasing a community's capacity to anticipate, cope with, resist, and recover from hazard impacts is an essential component of reducing vulnerability in the event of a disaster (World Bank, 2010). It is notable that among the most successful disaster reduction initiatives, local involvement, including work coordination and activity identification among schools and communities, as well as local 'political commitment' are fundamental (ISDR, 2007:45).

Recent experience in earthquake-affected Christchurch suggests that current UN-based recommendations of 3 litres of water per person per day, to meet water needs in a disaster situation, may fall well below the actual needs of an urban population, and recent CDEM NZ guidelines now reflect this. The CDEM Wellington Emergency Preparedness guide (December, 2010) suggests 3 litres per person to meet daily drinking needs, and more for cooking, hygiene and pet care. In the aftermath of the two damaging Canterbury earthquakes on 4th September 2010 and 22nd February 2011, widespread liquefaction and damage to sewerage and water infrastructure put extraordinary pressure on Christchurch water supplies (canterburyearthquake.govt.nz; ccc.govt.nz 2011). Of eight main water reservoirs, seven had been damaged and/or emptied during the February 22nd event, and some of the structural damage to reservoirs and pipes was severe.

People required water, not only to drink, wash and cook with, but also to damp down choking dust and to use with temporary toilets. In the first days following the February 22 quake, people waited up to five hours for water at some welfare centres (Red Cross verbal briefing, 1 March 2011). Ten days after the February earthquake, queues of up to 50 people were still a common sight at some water distribution points, (Moore, personal observation, March 2011).

With relatively secure road routes in and out of Christchurch (rail was disrupted), water was able to be sourced from outside the affected regions via tankered water supplied by Fonterra milk tankers to welfare centres. With the vast majority of shops and businesses closed in the days following the February 22nd quake, and roads impassable or congested, sourcing bottled water was a challenging proposition for some residents. Volunteer response teams distributed bottles of potable water at welfare centres, food-banks and door-to-door, to meet a demand for 'ready to drink' water, Demand for 'ready to drink' water was particularly strong in suburbs like Aranui, where long-term power outages (and a significant elderly population with poor accessibility to gas camping stoves and barbeques) meant following the 'three minute boil rule' was a challenge, if not impossible.

While more than eighty percent of the Christchurch water supply was restored within two weeks of the February earthquake, *boil-water* notices remained in place city-wide until April 2011, due to the risk of cross-contamination from broken pipe works. Water infrastructure repairs and testing continue to interrupt supply (ccc.govt.nz/WaterServices 16 May 2011) and some communities in Christchurch are still without a mains water supply – more than 100 days after the February earthquake. Recent events have seen a return to the *boil-water* notice. A strong earthquake on June 13, 2011 ruptured pipework once again, risking sewage infiltration.

Wellington city's approach to emergency water supply is based on the objective to retain as much water as possible in storage and in reservoirs, within the boundaries of the city. This is in recognition that bulk water supply from the regional storage location is likely to be disrupted in the event of a significant earthquake. Wellington City Council have gradually installed seismic automatic shut-off valves on 58 reservoirs which currently contain about 92% of the total water storage capacity for the city. Of that capacity around 50% is located in reservoirs built post 1986 (Personal communication Stavros Michael, Wellington City Council, 5/04/2011). 1986 is used as the threshold point when the design standard NZS 3106:1986 *Code of Practice for Concrete Structures for the Storage of Liquid* was introduced. The 1986 standard included specific requirements for the seismic design of reservoirs. NZS3106 was last updated in 2009, with reservoirs now required to have a design life of 100 years to comply with loading as specified in AS/NZS 1170. Seismic assessment and upgrades of reservoirs are being programmed for pre 1986 reservoirs.

It is questionable whether Wellington's concrete reservoirs will retain their water storage capability after a major earthquake, bulk supply water pipelines will certainly be vulnerable, since they cross the faults at several places. Compared to Christchurch, Wellington is more isolated in terms of its supply lifelines, and road networks may be marginal at best, after a damaging earthquake. Moreover, as mentioned, it is predicted that restoration of mains water supply will take sixty to ninety days in some areas (Cousins *et al.* 2010). While it is possible that large tankers could distribute water sourced from outside of the city to areas of need, it appears there is a greater probability that damage to main trunk routes linking Wellington with other regions would prevent or hinder the passage of vehicles.

Given resilience in an emergency management context is a *capacity to cope with hazard impacts and quickly restore activities without significant damage* (Cannon, 2008), Wellington's resilience may not depend on trucks and tankers carrying water into the city, as it could be days before the required road networks are passable. Rather, in order to minimise losses and reduce vulnerability in hazard events like earthquake and tsunami, Wellington needs a practical and workable plan to provide water for people, from within its boundaries.

In light of predictions that the Wellington Region's mains water supply could be severely impacted in the wake of a large earthquake and that it may be two or three months to enact the majority of repairs (Cousins *et al.* 2010), consideration therefore must be given to alternative emergency water supplies that are practical, prudent, and possible.

2.1 BENEFITS OF INSTALLING RAINWATER TANKS

Rainwater tanks can provide a number of benefits to the householder and the community if properly installed and maintained. Rain tank water can be an invaluable alternative water supply in disasters such as earth quakes and fires (Abbott 2008; Male 2011). Currently more than 10% of New Zealanders rely solely on roof-collected rain water for their drinking water – especially in rural areas that are not served by municipal town supplies. However, even in urban areas some local authorities are now encouraging householders to install domestic rainwater tanks, not only as a mains-water saving measure but also to reduce the adverse effects of storm water runoff. In districts such as Kapiti, Waitakere, North Shore and Rodney, householders are offered rebates to install rainwater tanks to new or existing houses so that the rainwater can be used as a secondary source for toilet flushing, in washing machines, and outdoors for uses such as garden watering, car washing, and filling swimming pools.

Studies in Australia (Coombes and Kuczera, 2003; Lucas *et. al.*, 2006) on the performance of 1000 litre and 10,000 litre rainwater tanks have shown that depending on the roof area and number of occupants in a household, the use of rainwater tanks resulted in annual mains water savings ranging from 18,000 litres to 55,000 litres for 1,000 litre tanks and from 25,000 litres to 144,000 litres for 10,000 litre rainwater tanks. Coombes & Barry (2008) have also demonstrated that roof catchments systems supplying rainwater tanks were significantly more resilient to natural variations in climate and unexpected climate change than water supply catchments supplying dams. Furthermore, these authors showed that decentralised rainwater harvesting from roof catchments in cities has the potential to supplement centralised water supply strategies to create an overall more resilient urban water supply.

Rainfall frequency in a particular region, specific tank sizes and water demand will of course influence the total rainfall available for use. In some instances there will be overflow from the tanks during a rainfall event and in other cases the tank will be empty through lack of rainfall or overuse. Obviously the ideal situation for rainwater harvesting – even in emergencies - is consistent rainfall for dependable water usage, preferably higher usage only during times of higher rainfall.

Roof sizes across New Zealand vary considerably and are based on factors such as land availability and the size and layout of the dwelling. Unfortunately not all of a specific roof area will be available for use and will depend on the location of down pipes and the location of the tank. Ideally, the tank location and plumbing will be configured to ensure that all (or most) roof run-off is captured. However, considerations such as cost and site availability limit the actual roof area that can be used. Typically up to half of the roof area can be diverted into a rainwater tank.

A light rainfall event may not produce enough saturation of the roof to flush water into the tank. On the other hand, substantial rainfall events might result in overflow from the roof, particularly if debris has accumulated in gutters or screens. The proportion of rainfall run-off that can be captured ranges from 60% to over 90% depending on the condition of the gutters, since blocked gutters and downpipes can cause a reduction in water run-off through overflows. The losses due to evaporation from the roof and overflows from the gutters are referred to as coefficient runoff percentage from the catchment area. For example an impervious roof surface such as a metal or tiled roof has a higher coefficient runoff percentage than a roof made of less impervious material where a large percentage of the water would be absorbed. While an 80% (0.8) coefficient is often used in catchment calculations to account for loss through spillage, evaporation etc., a range of run-off percentage coefficients can be used in calculations depending on roofing materials, pre-treatment devices and climatic conditions. A simple formula for calculating the expected rainwater yield is:

Annual rainfall x catchment x coefficient x percentage of = maximum litres of rainfall (mm)

area (sq/m) runoff (%) diverted water (%) rainwater collected per year

For example, there is a metal roof on a dwelling in Wellington where 200 m^2 of roof area is draining into four downpipes from which the owners would like to capture and store the roof water in a rainwater tank linked to a 50 L first flush diverter. Rainfall for this region is 1270 mm/year; catchment size discharging to tank is 200 m^2 ; coefficient runoff percentage from catchment area of this metal roof is assumed to be 90% of coefficient rate for metal or tiled roof; pre-treatment device is a 50 L first flush diverter (assume 25 rainfall events – 1250 litres):

Yield: 1270 x 200 x 0.90 - 1250 = 227,350 litres of rainfall per year.

(Approximately 623 litres per day)

2.2 EXISTING AND POTENTIAL SITES FOR RAINWATER TANKS

Porirua City Council is implementing a strategy to ultimately have one million litres of water available in the community for disasters such as earthquake. Porirua is entirely dependent on water from the Hutt River system and in the case of any pipe failure from a large earthquake, the city could be without a proper water supply for weeks or in the worst case, months. Currently 41 rainwater tanks (mainly 25,000 litre capacities) have been installed at the locations shown in Table 1.

Rainwater Tank Locations				
Adventure School		Samuel Marsden Whitby		Porirua School
Aotea College		Seventh Day Adventist		Postgate School
Brandon Intermediate		St Pius School		Porirua College
Cannons Creek School		Tairangi School		Porirua East School
Discovery School		Takapuwahia Marae		Pukerua Bay RSA
Hongoeka Marae		The Anchor		Pukerua Bay School
Lakeside Baptist		Titahi Bay Fire Station		Rangikura School
Mana College		Titahi Bay Intermediate		Russell School
Masonic Hall		Titahi Bay North School		St Theresa's
Ngatitoa Hall		Ngatitoa School		Titahi Bay School
Papakowhai School		Viard College		Windley School

Paremata School		Plimmerton Pavilion		Plimmerton School	
Parish Plimmerton		Pauatahanui School			

Table 1: Rain water tank locations in Porirua and Pukerua Bay

To prevent vandalism and accidents, all the tanks have locked access covers and all the taps have been removed, so as to prevent accidental or unwanted draining of the water in the tanks. All the emergency rainwater tanks have "Boil for 1 to 5 minutes" labels clearly displayed (Figure 1).

Figure 1: Emergency rainwater tank with "boil water" sticker at Adventure School, Porirua

Wellington City Council (WCC) currently has seventeen 25,000 litre emergency tanks placed around the City. The WCC approach is to have these tanks in locations that can be easily modified instead of permanently fixed to ensure better flexibility. WCC are currently re-evaluating the locations and methods of filling them. These may be modified to be on line or via external supplies to enhance mobility. The locations of the 17 tanks are shown in Table 2.

Number	Rainwater Tank Locations
4	CitiOps Southern Landfill
1	Grenada North Reservoir
1	Johnsonville West Reservoir
1	Pembroke Road Reservoir
3	Raroa Yard
	Mains Water Storage Tanks
2	Karori Community Centre
2	Tawa Service Centre
1	Rural Fire Depot/Citiops yard
1	Khandallah Community Centre
1	Newlands Fire Station/Park

Table 2: Emergency water tank locations in Wellington City

At the Roof Water Research Centre at Massey University in Wellington, there are 16 rainwater tanks ranging in size from 1,000 litres to 25,000 litres. Although the rainwater is being used primarily for research purposes, it will be able to be used in emergencies given that provision has been made for shock dosing the water with disinfectants if, and when required.

As part of a sustainable water partnership initiative between Massey University and Wellington East Girls College, six rainwater tanks (5 X 1000 litres and 1 X 600 litres) were installed at the WEGC in 2008. Currently funding applications to NZ Trade and Enterprise are being prepared for two additional 25,000 litre tanks and five 1,000 litre tanks.

Potential sites for locating additional large rainwater storage tanks (25,000 litres minimum) include the following:

- Westpac Stadium
- Wellington Railway Station
- Many schools and community/church halls in the Wellington area
- Supermarkets
- Sports fields /clubs
- Event centres or any location where large number of people are likely to congregate

While the storage tanks referred to in Tables 1 and 2 are essentially community emergency water supplies, there are a number of areas in the Wellington Region where the sole supply to private dwellings is roof-collected rainwater stored in either one or two 25,000 litre tanks. These areas are shown in Table 3.

Ohariu Valley	Makara	Horokiwi
Takapu Road	Whitemans Valley	Haywards
Judegeford	Mangaroa	Pauatahanui
Kaitoki	Pakuratahi	Cloustonville
Reikorangi	Te Horo Beach	Manakau

Table 3: Areas in the Wellington Region that rely exclusively rainwater

The catch cry "Store lots of water - the more you store, the longer you'll be self-sufficient" is very sensible, but drawing on recent events in Christchurch, more should be done by way of incentives to encourage householders in urban environments to install rainwater tanks or barrels, so that in emergencies they do not have to rely solely on community emergency supplies that will be available at relief / welfare centres.

2.3 TRANSPORTING AND INSTALLING RAINWATER TANKS

A wide range of tank sizes (1,000 – 35,000 litres) and shapes are now available in New Zealand and currently the variety of tank types include tanks made from polyethylene, corrugated iron, concrete, timber and fibreglass. Recently too, smaller rectangular and round slim line skinny tanks (ranging from 250 litres to 6,300 litres capacity) have also come on to the New Zealand market. These are especially useful in situations where available space for locating a large tank is a problem because these smaller tanks can be installed (even two or more in series) up against the wall of a dwelling under the eaves of the house. Bladder tanks of various sizes are also popular now and these are especially suited to placement under the dwelling or decking of a house.

Regarding installation of rainwater tanks post-earthquake it must be appreciated that the transportation of tanks by road may be challenging especially if there is severe damage to major road networks leading into Wellington. Although one of New Zealand's major tank manufacturers is based in Tauranga, the majority of tank manufacturers and suppliers are based in Auckland. Devan Plastics in Tauranga usually carry a stock of twenty 25,000 litre tanks, fifty 5,500 litre tanks and on hundred 1,000 litre tanks (Personal communication, Gail Swanepoel, Devan Plastics 07/05/2011). If required, they can manufacture up to five 10,000 litre and 25,000 litre per day. Devan Plastics have 5 reticulated trucks that could deliver twenty 25,000 litre tanks to Wellington every second day. The smaller 1,000 litre and 5,500 tanks are usually delivered via a freight company.

Galloway International (AquaTanks) in Auckland manufacture stackable rainwater tanks that range from 2,000 litres to 6,000 litres. These tanks have been designed for container shipping and are moulded as a single unit then the lids are trimmed off so the tanks stack inside each other in a shipping container with the lids packed around them (Personal communication, Martyn Jones, AquaTanks 03/06/2011). The lids simply sit on top and are fixed with some stainless screws and hence the tanks can be emptied and moved into storage to be re-used. Galloway International can place about 70 x 5000 litre tanks and lids in a 40-foot high cube container. They envisage a Hercules Transport plane could shift quite a number of these stackable rainwater tanks urgently from Auckland to Wellington immediately after an earthquake. Galloway International needs approximately 12 to 15 days to mould about 100 rainwater tanks. Last year they supplied 70 x 5000 litre stackable rainwater tanks to the International Red Cross for post earthquake purposes.

WaterGain (Auckland) manufacture 250 litre and 600 litre rain barrels – approximately 52 and 43 respectively can be manufactured daily if required (Personal communication, Tony Thorn, WaterGain, 05/06/2011). Currently they carry a stock of 300 of the 250 litre barrels. While manufacture of their 600 litre barrels has temporarily ceased they still have the rotational moulding machine for these tanks and could start production again at anytime depending on demand. WaterGain state that they can stack 87 of the 250 litre rain barrels in a 40-foot high cube container.

Rainline Water Solutions (Auckland) stock up to 500 units of a range of rainwater barrels from 210 litres to 510 litres. Since these are stackable barrels with separate lids, approximately 600 units can fit into a 40-foot high cube container (Personal communication, Byron Scott, Rainline Water Solutions, 23/09/2011).

Installation of a rainwater tank is relatively straightforward and simple if it is carried out by a competent plumber who has expertise in installing tanks. Positioning and installing a rainwater tank at a location can take on average up to two days according to Alec Ward (Ward Plumbing) who was responsible for installing a range of tanks at Massey University's Roof Water Research Centre. This time factor is the same regardless of the size of the tank that has to be installed but the installation time depends on whether additional components such as screened rainheads and / or first flush diverters are required to be installed as well. Time factors that also need to be considered are the preparation of a sand base, concrete slab and / or building a tank stand if any of these three are required.

Installation of a rain barrel is a straightforward process and can be done by a home handy man (or woman) within an hour. This includes the time necessary for cutting the down pipe, installing the water collector/diverter and linking the rain harvesting the system to the barrel (Figure 2).

Figure 2: 250 litre rain barrel connected to down pipe via water collectors/diverter

2.4 TECHNICAL ISSUES AND COST ESTIMATES

As shown above, the installation of a rainwater tank is relatively simple, if carried out by a competent person, and the installation of a rainwater barrel is even easier and does not require much technical skill. We have however observed some rather poor installations (and maintenance) of emergency rainwater in Porirua City. Deficiencies included:

- Capping off the first flush diverter (FFD), rendering them less than effective
- No primary 0.900 mm filters in the first flush diverters (only secondary 0.500 mm filters)
- Slow release valves missing from the FFD
- Leaf traps installed in the horizontal inflow pipes, instead of vertically in the down pipes where they should be situated for proper functionality
- No rubber seals at the inlet and outlet pipe connections on the tanks
- Overflow pipes not in position, leaving a 90 mm diameter hole where birds, rodents, insects and the like could gain easy access to the water in the tank, with subsequent contamination
- Completely blocked gutters (vegetation), so no water flowing into the tanks
- No standard scour valves and no standard tap spindles

At the time of writing, we are uncertain as to how many of these deficiencies have been rectified.

First flush diverters are not essential for emergency rainwater harvesting. However, if they have been installed, it is imperative that they are installed correctly, since a mal-functioning first flush diverter can be worse than no first flush diverter. A mal-functioning diverter or capped diverter could in time act a reservoir and continuously inoculate the rainwater tank with organic nutrients and contaminants with every rainfall event. First flush diverters should have automated or semi-automated diversion and drainage systems (i.e. no manual diversion or drainage) so that the need for deliberate intervention and maintenance is diminished. Incorporating two filter screens (0.900 mm and 0.500 mm) in the diverter will enhance the automatic drainage function of the diverter because orifice blockage of the slow release valve is less likely to occur (Abbott *et al.* 2007). Aside from the obvious benefit to be gained from diverting organic matter from raintank water, a less obvious, but important benefit of a diverter following a Wellington fault earthquake, is that airborne dust, ash and debris would be prevented from entering the tank in the first instance.

As described in the benefits section, rainwater tanks can capture a considerable amount of water, depending on the roof catchment size and tank capacity. There may be situations or locations however when a roof catchment may not be available for collecting rainwater so that 'self harvesting' tanks needs to be considered. Rhino Tanks (Auckland) manufacture huge corrugated iron tanks (80,000 litres to 260,000 litres) that have special sloping corrugated tank tops with meshed rain caps for collecting the rainwater and hence obviate the need for a roof catchment.

Currently at Massey University's Roof Water Research Center, Franklin Golay, a Franco-Swiss research intern from the Swiss Federal Institute of Technology of Lausanne is designing a simple, but efficient *self-harvesting* rainwater tank system. The system uses a tarpaulin and poles, independent from the tank, and set up around the tank so that the collected rainwater flows down into the tank (Figure 3). This allows for a greater catchment area - the position of the poles on the ground will depend on its nature, with options possible for any type of location. Four metre long poles can be used along with different tarpaulin sizes, 8 metres being realistic and advantageous. This would give a catchment area of 64 m^2, which is enough to fill a 6000 litres tank with rainwater in an average Wellington month. This system has huge potential and is now being developed further with Devan Plastics in Tauranga.

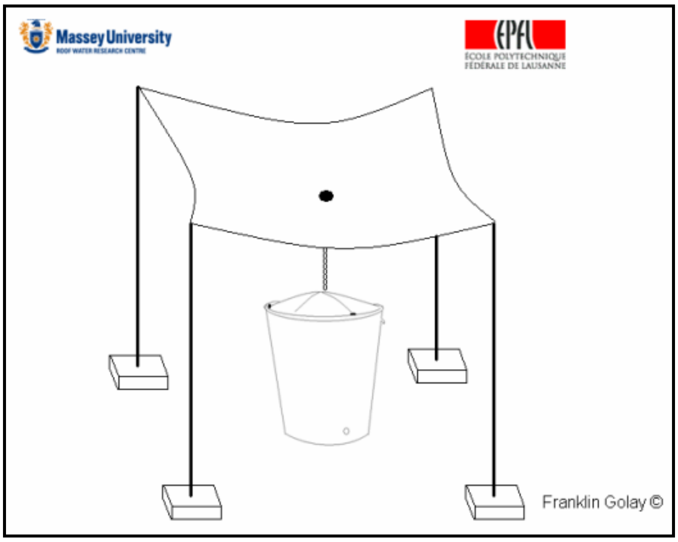

Figure 3: Schematic of a 'self-harvesting' rainwater tank currently under development.

There are a number of Australian and Australian/New Zealand Standards that apply to rainwater tanks and their associated fixtures and fittings and we believe that these standards should be applicable to emergency rain water supplies as well. All roofing, guttering, down-pipes and pipe work for the reticulation of drinking water must comply with AS/NZS 4020 - *Testing of products for use in contact with drinking water.* All rainwater-harvesting products (including polyethylene water storage tanks) must be certified to this standard if they are designed for drinking water applications.

The *Building Act 2004* states that no consent is needed for tanks:

- Not exceeding 35,000 litres and supported directly above the supporting ground

OR

- Not exceeding 2,000 litres and supported not more than two metres above the supporting ground

OR

- Not exceeding 500 litres and supported not more than four metres the supporting ground

Local conditions vary and all councils will have their own requirements; for example for tanks larger than 6,000 litres may need to meet certain criteria such as height in relation to boundaries. Kapiti District Council does not require a resource consent if the tank is lower than 2.4 metres, more than 1.0 metre off the boundary, 4.5 metres off the road margin, and the top area of the tank is less than 8 m^2.

All rainwater tanks should be placed on a 100 mm sand base, which should be boxed in to prevent erosion of the sand. Base isolation should be sufficient for tanks to withstand the stresses imposed on a tank during an earthquake and base isolation should neutralise tank sloshing (the wave velocity acceleration that causes the tanks to move around). Thus, we do not believe it practical or indeed necessary to put seismic restraints or bracings on large, wide rainwater tanks, but it may be prudent to do so on the smaller and thinner tanks.

Installation costs can vary considerably, and depends on the rainwater system required. The total cost (including the tank) could be anywhere between $1,600 for a small stand-alone system to $7000 for a large dual rainwater and mains water trickle top-up system. It cost $1,850 (including installation costs) in 2010 for a stand-alone (garden watering and emergency supply) system consisting of a 1,000 litre polyethylene tank, pump, first flush diverter, screened rainhead, tank taps, and scour valve (Figure 4).

Figure 4: A 1,000 litre rainwater tank with screened rainhead and first flush diverter installed at dwelling in Paekakariki

Costs for small rainwater barrels (210 litres to 600 litres) with rain water collector and diverter currently range from $135 to $250. A breakdown of current prices (includes GST and Delivery) for a selection of larger rainwater tank types and sizes are:

- $547 to $1,060 (1,000 litre polyethylene)
- $1890 to $2,187 (1,500 litre bladder))
- $1,333 to $2,057 (1,160 litre corrugated steel)
- $2,110 to $2,631 (3,000 litre corrugated steel)
- $2,140 to $2,335 (3,000 litre polyethylene)
- $2,151 to $2,660 (3,500 bladder)

- $2,231 to $2,635 (4,000 litre polyethylene)
- $3,120 to $3,649 (8,500 litre bladder)
- $1,897 to $2,475 (10,000 litre polyethylene)
- $2,947 to $3,150 (25,000 litre polyethylene)

The following is a summary of the findings of a cost survey of 32 rainwater tanks installed for emergency response and recovery in Porirua City. The project was to install forty 25,000 litre rainwater tanks over a period, agreed by Council in late 2008, with the survey commencing when slightly more than half the tanks had been installed. Costs for the tanks include GST and delivery and equated to $2,100 each. Installation was undertaken by one contractor and as at April 2011, the total project costs divided by the number of tanks installed show each tank, fully installed, and including GST, equated to $3500.00 per installed tank.

2.5 WATER TREATMENT REQUIREMENTS

Other than periodically checking and cleaning gutters and removing overhead branches, well designed and installed systems will generally require minimal ongoing maintenance. The results of the roof water sample tests of selected emergency rainwater tanks in April and May 2011 are shown in Tables 3 and 4.

Site	Total Coliforms	*E.coli*
Pukerua Bay School 23 (Sample 1)	613.1	0.0
Pukerua Bay School 23 (Sample 2)	547.5	1.0
Adventure School (Sample 1)	33.2	0.0
Adventure School (Sample 2)	15.6	0.0
Discovery School (Sample 1)	6.3	0.0
Discovery School (Sample 2)	6.3	0.0

Table 3: Roof water sample results 07/04/2011

Site	Total coliforms	*E.coli*
Pukerua Bay School (Sample 1)	2419.6	4.1
Pukerua Bay School (Sample 2)	2419.6	2.0
Tairangi School (Sample 1)	63.1	0.0
Tairangi School (Sample 2)	74.9	0.0
Adventure School (Sample 1)	88.4	1.0
Adventure School (Sample 2)	93.2	1.0
Postgate School (Sample 1)	2419.6	18.3
Postgate School (Sample 2)	727.0	9.6
Discovery School (Sample 1)	5.2	0.0
Discovery School (Sample 2)	8.6	0.0

Table 4: Roof water sample results 26/05/2011

Total coliforms are indicative of environmental contamination (e.g. soil and vegetation) and is indicative of faecal contamination. While these water quality results appear encouraging, especially regarding the low *E.coli* levels, it has to be appreciated that any repeat testing of water samples from these same sites could give widely different, and even alarming *E.coli* results, since microbial levels in the tanks are in a dynamic state and can fluctuate from day to day. Furthermore, since none of the rainwater supplies have the full gambit of physical measures to protect the water from contamination, the water would not be *fit for consumption*, regardless of past water testing results. Because these rainwater tanks are in fact emergency water supplies that will receive treatment (boiling or chemical disinfection) before consumption and use, we decided that there was little point in carrying out further testing of these rainwater samples.

While Christchurch has been advising its citizens to boil their drinking water for three to five minutes, due to cross contamination from sewage, the Ministry of Health (2008) advises that emergency water should be boiled for one minute, *as all biological and most gaseous contaminants will be removed or destroyed. Electric jugs with automatic cut-off are fine, especially if the water is left to cool for some minutes before use*. As discussed in the introduction, earthquakes can trigger power outages, meaning that alternative disinfection methods for the rainwater must be employed.

Sodium hypochlorite is widely available, cheap, and is used as a disinfectant in homes, schools, hospitals, swimming pools and in drinking water supplies. Sodium dichloroisocyanurate is another chlorine compound that is available in tablet form (*Puritabs, Aquatabs* from Global Hydration) and for water purification one tablet is added to each litre of water.

Sodium hypochlorite is commonly in liquid or powder form. According to the Ministry of Health (2008), hypochlorite is available under a number of brand names including: *No Frills Bleach*, *Janola*, *Brite Bleach*, *White Magic*, *Hypersol*.

Liquid household bleach is typically between 5% and 6% chlorine. Regarding the use of household bleach to treat water, The Ministry of Health (2008) advises that the water should be placed in a clean container and the bleach added according to the amounts shown in Table 5.

Volume of water Treated	**Clear Water (Add bleach as follows)**	**Cloudy Water (Add bleach as follows)**
1 litre	3 drops	5 drops
2 litres	5 drops	10 drops
5 litres	1/4 teaspoon	1/4 teaspoon
10 litres	1/2 teaspoon	1/2 teaspoon
20 litres	1 teaspoon	1 teaspoon
Mix thoroughly and allow to stand for at least 30 minutes before using (60 minutes if the water is cloudy or very cold).		

Table 5: Disinfecting water with 5 to 6% liquid chlorine bleach.

For the disinfection of water in the rainwater tank itself, the Ministry of Health (2008) advises about 333 ml of household bleach should be added per 1000 litres of water if the tank has lot of dirt, or half that (167 ml of bleach per 1000 ml water) if the tank is relatively clean. The water from the taps should be run for about 2 minutes or until there is a smell of chlorine before turning the tap off. The disinfected water should be left to stand for about 24 hours before drinking or using to for drinking. If the water has to be used before the 24 hours, then it should be boiled.

While we appreciate that sodium hypochlorite has long been recognised as having outstanding disinfection properties, it is toxic and can be dangerous if used in the wrong doses. There are now safer hydrogen peroxide products available commercially, for disinfecting raintank water quickly. These are relatively non-toxic, tasteless, odourless products that are also ecologically safe. Stabilised hydrogen peroxide products include Aquasafe™ (Davey Water Products), PourN'Go™ (WaterGain) and Geosil 150™ (Geosil Pacific). Accordingly, if raintank water cannot be boiled, we strongly recommend use of hydrogen peroxide to treat water to a safe standard, in preference to chlorine compounds.

2.6 TOPPING-UP OF RAINWATER TANKS FROM WATER CARRIERS

As stated in the introduction, while it is possible that large tankers could distribute water sourced from outside of the city to areas of need, it appears there is a greater probability that damage to main trunk routes linking Wellington with other regions may prevent or hinder the passage of vehicles. The same would apply to water tankers needed for replenishing rainwater tanks that have run out of water. In other words, if the water carrier can deliver water to relief centres for distribution there, then they could equally deliver water to the rainwater tanks for topping up or replenishing.

Although tankered drinking-water is covered in Section 11 of the *Drinking Water Standards for New Zealand (DWSNZ)* (MOH 2005), in times of emergency it may not be possible, for obvious reasons, to source the water from a registered drinking-water supplier whose supply complies with the *DWSNZ*. While the *DWSNZ* states that all water carriers who provide drinking-water to customers must be registered on the Ministry of Health's Register of Community Drinking-water Supplies and Suppliers, in post-disaster situations this can be waived, as was the situation in Christchurch recently, where Fonterra milk tankers were used to bring in water to communities who were without reticulated water supplies. Similarly, during emergencies, water may be abstracted from non-compliant water sources that are approved by a drinking water assessor (e.g. river water with partial treatment or no treatment).

2.7 SECURITY ISSUES

A chain of custody is essential, with agreement needed in terms of care and use of rainwater tanks. Custodians in Porirua's case includes school principals, school Civil Defence/Safety officers, and caretakers who also perform maintenance such as cleaning out gutters. Local community guardians such as Civil Defence Coordinators and Neighbourhood Support Coordinators should also be part of the chain of custody. In the case of Pukerua Bay School, their caretaker takes responsibility for all tank maintenance, and is one of the chain of five contacts with access to (and responsibility for) the spanner or tap spindle to release water from the tank, along with other requirements. In respect of one school in our survey, first in the chain is the school principal, second is the caretaker, third is the local coordinator, while fourth is the school safety officer, and the fifth is in the Civil Defence/Neighbourhood support team.

Pukerua Bay also has a chain of custody for water treatment if required: purification tabs (sodium dichloroisocyanurate or hypochlorite) to treat small quantities of water, and *Pour n Go*, or similar, for the whole tank. First in the chain in this instance is the Civil Defence Coordinator or Porirua Emergency Management staff. The area Civil Defence Coordinator and Porirua Emergency Management staff have custody of the keys to unlock the padlock for the tank cover. Although boiling the tankwater is recommended, if power has failed and heating water is problematic, it may be necessary to remove the cover to pour in a disinfectant such as the stabilised hydrogen peroxide products mentioned above.

The chain of custody is an important part of preparedness and must be agreed and understood. Custody details and other useful information can be registered with emergency preparedness network *Readynet* (Readynetinfo.co.nz)

We recommend there be a Council Officer trained to take responsibility for the care and maintenance of all rainwater tanks. The rainwater tank locations could be visited on a pro-rata system by allocating perhaps two full days every two to three months. Other than periodically checking and cleaning gutters, and removing overhead branches, well-designed systems will generally require minimal ongoing maintenance

3. DISCUSSION

Lifeline restoration advances through various levels or phases: Emergency – basic (survival) – functional (operational) – normal (full) levels of service (GNS DDD 2010:1). The World Bank (2010:77: Burton, 2010) represents the lifeline restoration sequence as a schematic of 'disaster risk reduction' to build resilient communities (Figure 5).

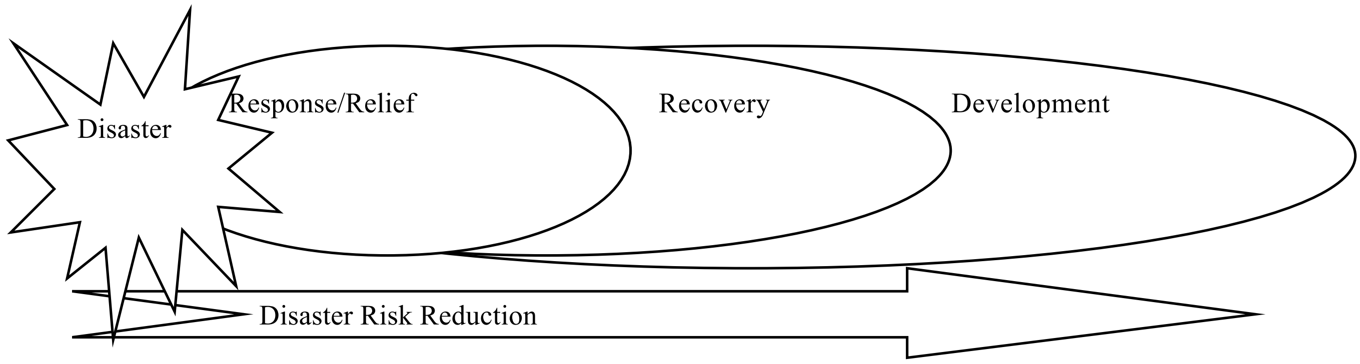

Figure 5: Response, recovery, development continuum (adapted from World Bank, 2010:77)

Rainwater tanks would conceivably be positioned across the spectrum of response, recovery, and development (basic, functional and normal), with critical benefits offered during the response/relief phase. Depending on the extent of lifeline restoration success, rainwater tanks could also provide significant benefits in the recovery phase. Moreover, in terms of their contribution to community resilience as alternative water supplies, and as stormwater detention mechanisms, strategically placed, suitably installed water tanks offer tangible benefits to communities undergoing the development phase.

Rainwater tanks are an aid to communities, particularly in the event of a rapid-onset disaster like earthquake. The water they can provide may assist *the most vulnerable people in the shortest possible time* (Red Cross mission, Red Cross, 2011). When a 7.6 magnitude earthquake struck near the Indonesian island of Sumatra on 30 September, 2009, aside from the destruction of houses, contamination of waterways was a serious concern (Oxfam, 2010a). Left unresolved, communities would face the risk of diarrhoea and other sanitation-related illnesses, compounding their issues and impeding recovery and development. Immediately after the Sumatran earthquake, Oxfam arrived in affected areas to provide emergency response and relief. In Ajung village, there were 50 elderly women who had no adequate water supply. Nor did they have adult males to help them. Many women also were heading their households, while ill or injured, and while taking care of young children (Oxfam, 2010).

Oxfam responded by installing 50 rainwater tanks to support 208 people (Oxfam, 2010). Thus, connected to a section of rooftop over the largely crumbled cement structure that is the damaged home of Nona and her grandchild, is a bright orange water tank. "We're very happy to have this rainwater catchment tank. We will no longer have to walk for three kilometres to get water and then another three kilometres back," (Oxfam, 2010).

Quickly restoring water supplies following interruption due to earthquake has obvious implications for enhancing community recovery. By comparison, communities that do not have accessibility to lifelines like water in the aftermath of disaster, appear to suffer reduced recovery. Haiti's communities are suffering cholera in epidemic proportions thought to be due to river contamination initially (Bertuzzo e al., 2011), following the 7.1 earthquake in January, 2010.

Disaster reduction begins at home, in our schools, places of work and worship, and throughout our local communities (ISDR, 2007: iii). Reports from the World Bank and stories like the one above from Oxfam, are evidence that empowering people by giving them the means to look after themselves and others, raises levels of community solidarity and resilience.

The installation of rainwater tanks at Porirua schools, in particular, has appeared to have had an impact on community solidarity, and thereby resilience. There is evidence of raised awareness and interest in emergency preparedness in general, with positive instances of contact with CDEM increasing once the tanks were in (Personal communication, Trevor Farmer, 05/05/2011). Some schools have sought help from Civil Defence to complete Emergency Preparedness plans and have also communicated with parents about these. Classes are using the rainwater tanks for study purposes. A group of Year 7 and 8 students from Pukerua Bay School have taken an active and keen part in water sampling (Figures 6 & 7) and a follow-up school visit to the laboratories at Massey University is planned. Moreover, children in all classes have taken home the Civil Defence household planner *It's easy – get prepared* (2010).

Figures 6 & 7: Year 7/8 children taking water samples from the emergency water tank at Pukerua Bay School

In respect of the programme to provide one million litres of emergency water, the authors' general observations of social responses, as well as the water quality survey results, suggest an overwhelmingly positive outcome for the people of Porirua city, not only in the event of an emergency that interrupts mains water supply, but also in terms of the rain water tank programme's contribution to community goals of social, economic and environmental sustainability.

A follow-up survey would be useful to substantiate the broad observation that preparedness awareness has been raised by the school's more visible link with emergency management. It would be useful to capture the degree of significance of the Christchurch earthquakes, given they intervened during the survey period of this report.

Reducing people's vulnerability through building the resilience of people in communities has the potential to save lives and have a positive impact on all three phases of community-based response, recovery and development (World Bank, 2010:45). As a result, the authors recommend maintaining modularity (Moore, 2009) and to accrue the benefits of rainwater tanks as one of a number of measures towards securing water supplies for emergencies.

Porirua's investment in (modular) rainwater systems for emergency management is to be applauded. Despite the initial design flaws indicated, one million litres of replenishable water storage is a complement to the seismic strengthening and other strategies, including infrastructure upgrades and community water-conservation education. These measures combine to mitigate impending risks to water supplies from a Wellington fault earthquake, providing increased resilience, minimising our vulnerability, and aiding response and recovery

4 CONCLUSIONS

Roof-collected rainwater from a properly designed and maintained system can contribute significantly to a sustainable water strategy in times of disasters like earthquake, when the lifelines of centralised water infrastructures are compromised. The strategic placement of rainwater tanks at accessible sites presents several advantages to affected communities – not least that the critical lifeline of water is immediately available for emergency response.

Moreover, as a renewable resource, rain water tanks can continue to contribute to recovery, while mains water supplies remain interrupted. It is of particular significance that due to the succession of damaging earthquakes in Christchurch (most recently on 13th June, 2011), centralised water and wastewater infrastructure remain compromised (with tapwater again non-potable) in parts of the city. It is more than nine months days after the initial September 4, 2010 event.

The findings of this study show that rainwater harvesting, accompanied by proper education, can be a realistic option for a safe water supply, in terms of costs, simplicity of installation and maintenance. For use as emergency water supplies, roof-collected rainwater can be easily disinfected or boiled, so that there is minimum health risk when using the water for drinking, food preparation and washing.

Rainwater harvesting technologies are flexible and can be modified for the location concerned. The need for costly treatment and distribution systems is eliminated. We therefore strongly recommend that emergency rainwater tanks be installed at strategic locations across the entire Wellington Region to mitigate the devastating effects of water infrastructure interruptions that are inevitable after an earthquake. Further, we recommend that the Councils collaborate to take a more proactive approach to encourage householders and businesses to install their own rainwater tanks, and thereby reduce their reliance on mains water during emergencies. Financial and other incentives for ratepayers are a possibility to explore with the community. Alternatively or additionally, there may be benefits to be gained from negotiating a generous discount with tank and plumbing suppliers to provide a suitably designed system that can be easily self-installed, and catering to a range of property types and household configurations.

The recent Canterbury earthquakes, including June's serious aftershocks, the Japanese tsunami, and tornadoes in Auckland, New Plymouth and the US, graphically underline that disasters can strike at any time, and the impact they can have on society. The situation in Christchurch has demonstrated just how important it is to be prepared and to manage the response and recovery phases of disasters, so that communities can develop resilience and *get through*. Plans and strategies are in place for helping New Zealand communities affected by disasters to help themselves, so people can get back on their feet as soon as possible. Rainwater tanks must be part of the planning and be in place – before a disaster strikes.

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