EMERGENCY WATER SERVICES PLANNING FOR WELLINGTON

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ABSTRACT

The supply of water to Wellington city is extremely vulnerable in a major earthquake. The bulk supply lines from the Hutt Valley cross the Wellington fault in five places and restoration of a limited bulk supply to Wellington city following a major rupture of this fault is estimated to take up to 55 days. Functional restoration of the local water network will take up to 30 days longer for the furthest points of the network as there will be limited water available to re-pressurise, test for and repair leaks.

Capacity has been working on earthquake preparedness since its inception in 2004 and has convened a Water Services Emergency Preparedness Group (WSEPG) including representatives from the four city councils WCC, PCC, HCC and UHCC, the Wellington region emergency management office and Greater Wellington regional council. The recent Canterbury earthquakes have increased the focus on this work.

As part of the planning activities this group commissioned MWH to investigate alternative water supply arrangements and to develop a plan for the supply of water following a major earthquake. This investigation covered surface water, groundwater, bottled water, portable desalination and rainwater in addition to the city reservoir storage.

KEYWORDS

Emergency preparedness, earthquake planning, seismic resilience

1 INTRODUCTION

Emergency management has taken renewed prominence in network planning since the earthquake events of September 2010 and February 2011 in Christchurch. These earthquakes have highlighted the vulnerability of Wellington City in the event of a significant earthquake, particularly as the roading network in Wellington is highly vulnerable to landslides and other access into the City will be severely limited.

The bulk water sources for the Wellington metropolitan region are concentrated to the north and east of the region. The location of the major fault lines means that there is a strong likelihood the reticulation for most urban areas would be separated from the treated water sources in the event of a major earthquake event.

The scenario used for Wellington region emergency management planning is a major earthquake of the Wellington Fault of magnitude 7.6 on the Richter scale, resulting in 4-5 metre horizontal and 1m vertical fault displacement and widespread disruption to the roading network. A rupture of the Wellington fault is acknowledged as "worst case" however is a realistic scenario for planning purposes. The *It's Our Fault* project (GNS, 2010) recently estimated the chance of a major rupture in the next 100 years as about a 11% probability.

As the reservoir storage is less than that required for the likely restoration times there is a potential gap between the available reservoir water running out and restoration of the reticulated supply. This study was focused on identifying supplementary sources of emergency water to fill this potential gap and consideration of the distribution of that emergency water.

2 BACKGROUND

2.1 ACCESS LIMITATIONS

Roading access both into and within the Wellington region is severely vulnerable to a major earthquake and has been the subject of numerous investigations and improvement projects. Landslides are expected to isolate the regional access roads and there will be considerable damage within the region from the fault movement and liquefaction. The current estimate for land access restoration to the region is 120 days. This will make the external supply of resources particularly difficult as sea and air access will also be disrupted.

2.2 VOLUME OF WATER TO BE SUPPLIED

The initial target for this study was to provide a minimum of 10 l/p/d of potable water for this population for a period of up to 90 days. This was revised to 20 l/p/d to meet the 15 l/p/d as used by international humanitarian guidelines and allowing for some inefficiency in distribution. Allowance has also been included for supply to the major hospitals.

The quantity of water required would be a total emergency supply daily volume of 8,000 m^3 for the region compared to the current average daily bulk supply of 150,000 m^3. It is acknowledged that 20 litres per person per day is a very minimal volume of water and overseas experience suggests that the general population will demand significantly more than this, particularly after an initial recovery period of around two weeks. Resumption of the reticulated water supply as soon as possible would be required for economic activity and daily life to resume.

2.3 BULK WATER SUPPLY VULNERABILITY

The Wellington bulk water network is operated and maintained by Greater Wellington Water (GWW), a division of Greater Wellington Regional Council (GWRC). The supply sources for the Wellington metropolitan area are concentrated to the north and east of the region. The location of the major fault lines means that there is a strong likelihood the reticulation for most urban areas would be separated from these sources in the event of a significant earthquake event.

Security of supply has been a major focus of GWW staff over the years and efforts to reinforce the network for seismic response are an ongoing focus. Two main trunk lines feed Wellington city, of these the 26km Wainuiomata to Wellington pipeline runs along SH2 between Petone and Wellington, close to the Wellington fault, and is expected to be out of service following a Wellington fault earthquake of significant magnitude. The 56 km Te Marua to Wellington pipeline (which also feeds Porirua City Council's network) crosses the Wellington fault at Haywards but then moves away from the fault and does not pass over higher risk liquefaction areas. This line is of more modern welded steel construction and overall is more resilient.

Recent GWW reports have suggested that it could take 40 to 55 days to restore a 33% supply to Wellington City based on repair of the 56km Te Marua to Wellington pipeline. This time is potentially reduced by 15 to 20 days if a dam and treatment facility were to be constructed at Whakatikei. Wellington City is located furthest from water sources and will therefore have the longest time for restored supply. Upper Hutt supply could be resumed within one week, Hutt City within about 3 weeks and Porirua is expected to take a similar amount of time to Wellington. There is considerable uncertainty regarding these times due to the inherent uncertainties in quantifying the effect of earthquake damage on underground utilities, particularly where they cross known fault lines. Full supply is expected to take 60-80 days to restore the bulk system to the local network in Wellington city. Note that repair of the local networks will take additional time, which has been estimated as up to 30 days for the furthest points in the network, e.g. Miramar. An upper figure of 90 days requiring emergency water supply was used for the purposes of this study.

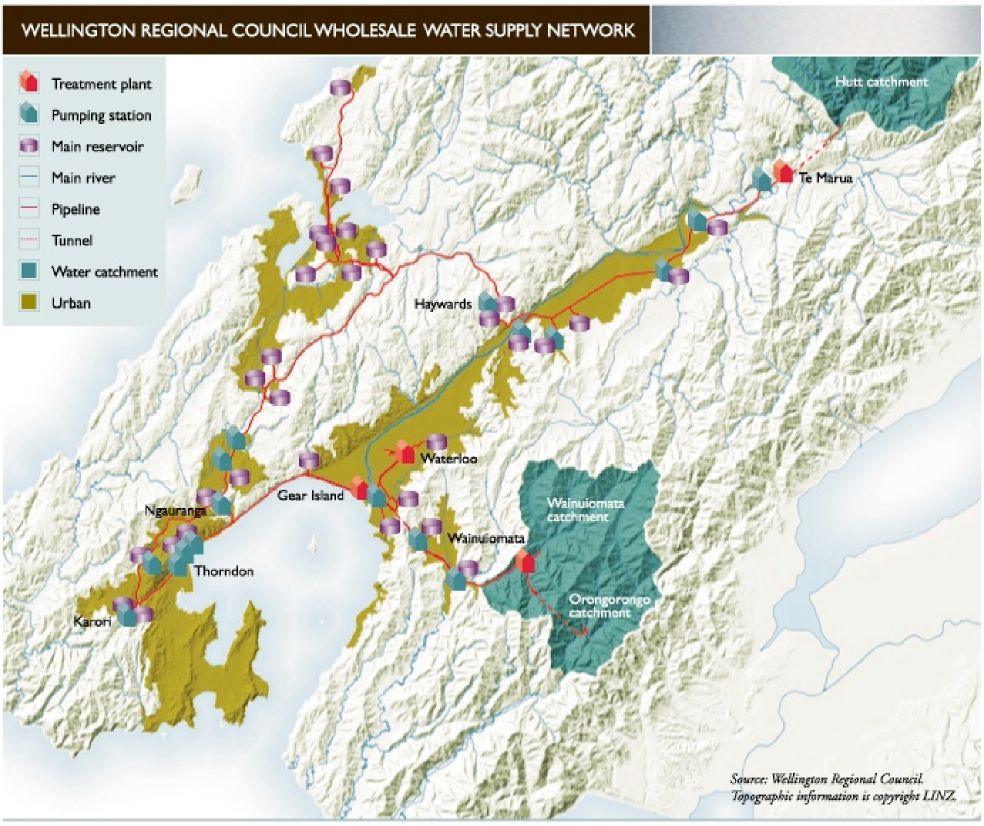

Figure 1: Greater Wellington Bulk Water Network

2.4 LOCAL WATER NETWORK MANAGEMENT

The GWW network delivers water to various points of supply in the four cities: Wellington City Council (WCC), Hutt City Council (HCC), Upper Hutt City Council (UHCC) and Porirua City Council (PCC). From the supply points, which are typically terminal reservoirs, pumping and storage is the responsibility of the city councils.

Capacity Infrastructure Services Ltd (Capacity) is a Council Controlled Organisation responsible for water supply for Wellington, Hutt and Upper Hutt City Councils. Porirua City Council currently manages their water supply directly.

Capacity has been working on earthquake preparedness since its inception in 2004 and has convened a Water Services Emergency Preparedness Group (WSEPG) including representatives from the four city councils WCC, PCC, HCC and UHCC, the Wellington region emergency management office and Greater Wellington regional council. The Canterbury earthquakes in September 2010 and February 2011 increased the focus on this work.

2.5 CIVIL DEFENCE MANAGEMENT

A major event such as the Wellington fault rupture considered in this report would be managed under Civil Defence legislation. The Civil Defence structure for such events includes National level, Group level and Local level. Since this study was completed the local Wellington emergency management offices (WEMO, HVEMO and PEMO) have restructured into the Wellington Region Emergency Management Office (WREMO).

3 SUPPLY SOURCES AND POTENTIAL RESOURCES

The first step following a major earthquake is reconnaissance to determine the damage to the network. Once reconnaissance is completed emergency water will need to be provided using the available resources with additional resources requested through WREMO. The emergency water sources will include two broad categories:

- **Stored water** from the existing reservoirs;
- **Alternative sources** to supplement the reservoir capacity.

These sources are described in the following sections.

3.1 STORED WATER

Council owned reservoirs are the primary resource for emergency water. Each of the Councils in this study has undertaken seismic assessments of the reservoirs and has a programme of upgrades underway. Substantial investment has been made in this programme however ongoing investment is required. For example, closer investigation by Capacity has found that only 45% of the 129,130 m^3 storage capacity in Wellington city is considered seismically secure to current standards. That volume could provide 14 days water supply for the planned emergency demand and ongoing strengthening and other improvements are planned to increase this figure.

Automatic shut-off valves are installed at most reservoirs and a programme to install these valves on the reservoirs with capacity of greater than $500m^3$ is ongoing for some of the Councils. Review of the inlet and outlet pipework has also resulted in seismic improvement works being required at some sites.

3.2 ALTERNATIVE EMERGENCY WATER SOURCES

3.2.1 GREATER WELLINGTON TREATMENT PLANT SITES

Assuming significant damage to the bulk water transmission network, the possibility of sourcing water directly from the treatment plant sites was investigated. Greater Wellington Water operate four treatment plant sites. A comprehensive seismic resilience review of all the GWW facilities was undertaken in 1993.

It was identified during this study that there were no specific provisions to fill water tankers or other mobile water equipment directly from the treatment plant sites. Additional hydrants in the adjacent road main and/or temporary hydrant points would most likely need to be used to fill tankers or other bulk water containers however these would be subject to the resilience of those pipelines. Capacity and GWW have subsequently developed a design for multiple tanker filling hydrants to be installed on a secure pipeline in Knights Road for the Waterloo treatment plant. This facility is planned for construction in late 2012.

Due to the long transmission lines and location of fault lines, GWW are also investigating storage "lakes" for treated water closer to Wellington city to enhance pipeline restoration times and/or provide water for re-treatment. This investigation is at an early stage and storage lakes between 10 and 500 ML size are being considered.

3.2.2 GROUNDWATER

The Hutt Valley has a significant number of groundwater bores, particularly from the artesian aquifer in the lower valley. Information from GWRC records regarding the location, ownership, diameter and permitted flow rate was reviewed to identify private bores. Capacity are currently making arrangements for possible emergency use with a number of these sites.

Very limited groundwater resource was identified in Porirua. Detailed investigation of additional sources was outside the scope of this study.

WCC had previously commissioned a desk top study of the potential for supplying a back-up water source to Wellington city from deep fractured rock aquifers (Beca, 2009). That assessment concluded that volumes potentially suitable for water supply could be produced from wells at 150m or more in depth. 15 sites were identified however none of these sites had been developed at the time of the MWH investigation.

As part of this study the Institute for Geological and Nuclear Sciences Ltd (GNS Science) were commissioned to investigate the likely yield from wells in the Wellington CBD including Miramar Peninsula and Island Bay for the purpose of assessing the viability of groundwater as an option for emergency supply (GNS, 2010). GNS Science concluded that maximum well yield from any one well is likely to be between about 60 to $215m^3/d$. A target of 2,400 m^3/d was defined in their brief and this would require between 12 and 40 wells to provide an emergency supply. GNS Science recommended that groundwater be considered for at least a proportion of the emergency water supply and investigation well drilling and testing be undertaken to obtain more reliable well yield information. Capacity have subsequently identified a location in Miramar and this well was being drilled mid 2012.

In parallel to the GNS study, Ian Brown and Associates (IRBA) were commissioned to undertake a review of historical records of groundwater bores in the Wellington city area (IRBA, 2010). A number of semi-permanent springs were noted around Wellington city, including one in Thorndon and various springs in Kelburn. A number of groundwater bores were also identified. The Moore Wilsons bore in College Street / Tory Street is available to public access and is well known. This artesian well was drilled to 151 metres in 1927 to supply the former Thomson Lewis & Co drinks factory and has been regularly tested and confirmed as high quality water. This bore is under artesian pressure from the surrounding high ground. A plaque at the site stated that the production was 0.63 l/s (54 m^3/d) however the well is not currently configured to produce that volume. Records were found for a larger nearby well on the corner of Tory Street and Holland Street however that could not be physically located.

In addition to the constructed bores, IRBA were commissioned to review the numerous tunnels around the region, and in particular in Wellington city. Most of these tunnels have some level of groundwater seepage and this was identified as a potential resource. The most likely source of useful water in an emergency situation was the North Island Main Trunk Line Tawa No.2 railway tunnel. The outflow from that tunnel was monitored by Wellington Regional Council staff from 1977 and an average flow of 15 l/s (maximum 20 l/s) was noted in a 1986 investigation. Capacity has subsequently investigated this source and a sample collected was close to drinking water quality. This is considered a potentially viable water source for emergency use and Capacity are planning access improvements for emergency use.

3.2.3 SURFACE WATER SOURCES

Post major earthquake there will be severe damage to sewerage systems and any streams or rivers near urban areas may be contaminated with sewage. It was not considered likely any major surface water source in the urban areas would be of a reasonable quality to use without appropriate treatment.

There are a number of other small creeks and streams in Wellington above the "build line", which may be suitable for emergency supply, with treatment. It is also likely that untreated surface water supplies may be required for pressure testing local water reticulation to allow repair of water reticulation while the bulk supply lines are being repaired. Boil Water Notices would be required until the water supply could be tested and verified as safe for human consumption.

Capacity has progressed investigation of these surface water sources and is currently planning access improvements to the most viable sites.

3.2.4 DESALINATION / MEMBRANE TREATMENT

Desalination is a potential option for water supply in the Wellington region, with the extensive coast line available in many areas. Modern potable water desalination is typically undertaken using microfiltration then reverse osmosis membranes, often referred to as MF/RO. Either sea water or surface water can be treated using this technology. The throughput of sea water is considerably lower than clean fresh water, however surface water is subject to high turbidity during rain events and as noted above other pollutants could limit the use of surface water as a raw water source. The location for a desalination treatment plant for sea water use is also more flexible. Desalination does require significant electricity supply. For example, a single containerised RO unit of 1,000 m^3/day capacity from sea water would have five trains of membranes each with a 35kW electric pump. Raw water supply pumps would be additional to this.

The New Zealand Defence Force (NZDF) has three systems are based on this technology, using the PALL 1530 ROMM system. These can treat up to 5.5 m^3/hr from fresh water of turbity 50 to 500 NTU, but only 1.05 m^3/h of sea water with total dissolved solids (TDS) of up to 40,000 mg/l and turbidity up to 500 NTU.

Greater Wellington Water have subsequently commissioned a pre-feasibility study of a 10 MLD desalination plant for combined supplementary supply and emergency water use. The results from that study were not available at the time of writing.

3.2.5 RAIN WATER COLLECTION

The Wellington region has a temperate climate with an average annual rainfall of 1,270mm, with a long term mean summer rainfall of around 60mm per month. Even a relatively small roof area of 125m^2 has the potential to collect an average 6,000 litres in a summer month assuming there is sufficient storage for this water. This amounts to 1,500 litres/head/month for a family of four people which is more than double the target supply of 20 L/h/d or 600 litres/head/month. It can be seen that roof water is potentially a very valuable emergency water resource, particularly for non-potable use such as washing. Toilet flushing may also be required, however the sewerage system is likely to be damaged beyond use in many areas.

Roof water can be collected on a 'jury rig' basis by carefully cutting downpipes in such a way that any sizable container (e.g. clean plastic rubbish bins, laundry containers, buckets, storage containers, plastic boxes etc) can be inserted to catch the roof run-off. Unfiltered and first flush roof water is likely to be contaminated by birds and vegetation in the gutters. Treatment with chlorination or boiling would be advisable before drinking.

Porirua City Council has an advanced programme for installing 25m^3 polyethylene water tanks at schools, connected to the roof spouting and including first flush diversion. As of early 2012, 42 tanks had been installed giving a total volume of 1,000 m^3. The rainwater connections will greatly reduce the amount of water cartage required, but will mean that water has to be boiled or otherwise treated before drinking. PCC have identified several stabilized hydrogen peroxide products (e.g. Pour N'Go) for this purpose.

Greater Wellington Regional Council has been encouraging home owner rain tank collection as part of the water conservation / emergency preparedness programmes currently in place. Some differing opinions on rain collection tanks being used for stormwater buffering have been noted in some areas and there is no consistent regional policy on this matter. One local example followed with interest is the Kapiti Coast District Council Plan Change 75 which was introduced in 2008, where all new dwellings constructed will be required to have either a 10,000 litre rainwater collection tank for toilet flushing and outdoor uses or a 4,500 litre water tank for toilet and outdoor use plus a greywater collection system for subsurface garden irrigation.

Household water tanks could reduce the emergency supply demand substantially. Several emergency management staff spoken to during this investigation strongly supported the requirement for new houses to install 600-2000 litre rain water tanks for emergency supply purposes.

3.2.6 BOTTLED WATER

Provision of bottled water is an established emergency supply option and is a preferred option as it can be transported in any type of vehicle, has its own container that is protected from contamination and can be reused. It is expected that distribution of bottled water will be a key part of the first response following a major earthquake, bearing in mind the access difficulties.

The Severn Trent (Gloucestershire) flood response in 2006 was reviewed as a case study. Extensive use of bottled water was made in that response, and initially 1 ML per day was requested, rising to 6 ML by the end of the first week. The British Army provided logistical support for this operation. This supply was in conjunction with other distribution of water.

It is likely that requests for bottled water would be made through WREMO as part of the response. This option is obviously dependent on both supply and transportation availability to get pallets of bottled water into the urban areas for distribution.

4 DISTRIBUTION OF EMERGENCY WATER

4.1 DISTRIBUTION OF STORED WATER

4.1.1 CRITICAL MAINS

Ageing pipes have been progressively replaced with PVC, polyethylene, ductile iron or steel pipe materials over the past 15 years. In the Wellington city network around 35% currently consists of these earthquake resilient pipes (Capacity, 2012). More targeted design is being employed in areas of known hazard. For example, critical pipelines in areas with a known liquefaction hazard are designed with axial restraint to reduce the potential for joint pull-out due to ground movement.

Two categories of critical water supply mains have been defined:

> **Priority One (P1)**: These mains are considered important in the distribution of the stored water during the recovery phase after an event. They will be responsible for distributing the water from the reservoirs to key points such as welfare centres, medical centres, water distribution points, etc.
>
> **Priority Two (P2)**: These are the mains that are considered essential to restore supply to the council's pumping stations and main storage tanks. Strengthening of these mains will reduce the recovery timeframes of operational storage, and therefore the recovery of the distribution as a whole.

P1 mains should be repaired and operational before P2 mains due to the limited volume of stored water available to be distributed. P2 mains would be repaired once the bulk supply lines to the primary reservoirs is restored.

The criticality, vulnerabilities and proposed remedial actions for the P1 mains are being identified by the asset management team at Capacity. All the mains require additional investigation to confirm the most appropriate treatment along with any other network considerations. In addition, the proposed treatments in the list need to be assessed alongside the network renewal and upgrade projects. As many of the high priority projects are for the larger mains specific funding cases may need to be developed.

4.1.2 CROSS CONNECTIONS

Restoration of the bulk water supply mains is the critical path to restore reticulated water supply to Wellington city. The reservoirs cannot be recommissioned onto the network without the ability to replenish them from the bulk network. As the bulk supply will be in service before the local reticulation, several cross connections are available between the bulk and local reticulations so that water can be supplied directly from the bulk supply pipelines without having to go through one of the terminal reservoirs.

4.1.3 MANIFOLDS

Manifold kits to supply water directly from the reservoirs after an event are currently held at key reservoir sites. These kits include a manifold with six faucets that has a stand, a hydrant connection, hose and a valve key and will enable water to be distributed to resident's containers from an in-ground hydrant or emergency distribution tank. Hydrants are located at all major reservoirs. A typical set-up is shown in Figure 1 below.

Distribution points around the city are to be implemented at key welfare, civil defence, and community centres. The identification of community distribution points is being finalised in conjunction with WREMO as part of the detailed planning for each city.

Figure 1: Capacity Emergency Manifold Stand at Reservoir

4.1.4 EMERGENCY TEMPORARY WATER STORAGE TANKS

Local distribution tanks will be necessary for the efficient distribution of emergency water to the community. Several of the Councils have commenced installing rain water tanks that could potentially provide the dual function of rain water collection and emergency temporary distribution of tankered water. The current status of these is noted below.

As described in section 3.2.5 PCC has already installed 42 25,000 litre tanks. Hutt City Council has been working on a programme to install tanks at key water distribution points including civil defence sites. About twenty 5,500 litre tanks had been installed at early 2012 and further 25,000 litre tanks are planned. These tanks have been connected to the potable water reticulation.

Wellington City Council has seventeen tanks of various sizes installed and in storage. A programme to install fifty $25m^3$ polyethylene water tanks has been developed by Capacity for installation from 2012 to 2015. These tanks will be connected to the potable water reticulation and also rain water capable where possible.

4.2 DISTRIBUTION OF ALTERNATIVE EMERGENCY WATER SOURCES

As noted in section 3 the stored water may need to be supplemented with alternative emergency water sources. As part of this study some consideration was made of the resources and logistics around moving substantial quantities of alternative emergency water within the region.

4.2.1 TANKERS

Water tankers will be required to resupply the emergency water distribution points to distribute the stored reservoir water to residents. There are very few suitable tankers currently located in the Wellington region and additional tankers will need to be bought in to assist. Request for water tankers will need to be made through WREMO.

Road tankers offer the great advantage of being able to deliver water to neighbourhood delivery points, such as emergency storage tanks and manifolds. They could be used to supply water to Wellington by road or by sea. Four types of water tankers were identified and considered in the study.

Potable water tankers were considered first. In the North Island there are approximately 150 potable water tankers owned by more than 100 contractors that are in the business of supplying drinking water. A list of these carriers was obtained for reference.

Milk tankers were considered next. Fonterra indicate that they would be both willing and able to help. They have a fleet of more than 500 milk tankers, with a typical capacity of 27,000 litres (27 m^3). The peak daily milk production experienced to date is more than 80,000 m^3, which provides perspective when compared to the Wellington region emergency supply volume of 8,000 m^3. The milk production peak occurs in the spring period (October/November) and Fonterra indicated a capacity to assist, with minimal milk spillage, with the proviso that they were not penalized for any spillage that did result.

Water tankers owned by civil engineering contractors were also considered. It is estimated that there are around 10 water tankers with an average capacity of 8,000 litres in the Hutt Valley/Porirua/Wellington area alone. In the North Island there are believed to be at least another 120 such earthwork contractor owned water tankers. These tankers typically have pumps which can be used for loading and unloading. The performance of the pumps is reported to be variable and would be a factor in selection for mobilization.

Concrete trucks had been identified as a potential resource to cart drinking water in an emergency in previous work undertaken by Iain McIntosh, working with Karori Civil Defence. There are nearly 50 concrete trucks in the greater Wellington/Porirua/Hutt Valley region. They would have to be cleaned to remove most of the alkaline cement residues. Concrete trucks have a capacity of around 6m^3 of concrete, however water alone would slop around in the bowl, reducing its capacity to around 4m^3.

If a North Island sourced fleet of potable water tankers, milk tankers, roading contractor tankers and concrete trucks was mobilized as shown in the table below it would be possible to move around 8,660m^3 of water daily from Waterloo to Porirua, Hutt City and Wellington. Note the tankers are reliant on road access and diesel refueling being available. A concept resource requirement was developed as shown in Table 1.

Table 1: Tanker Types and Potential Effective Volume

Type of Tanker	Number of tankers	Average volume / tanker m^3	Average Trips/day	Volume per day m^3
Potable	75	9	4	2,700
Milk	40	27	3	3,240
Roading	65	8	4	2,080
Concrete truck	40	4	4	640
Total	**220**	**-**	**-**	**8,660**

4.2.2 SEA TRANSPORTATION

The average number of tanker trips per day assumed that road access is possible, which is unlikely to be the case for at least the first week or so. In particular, SH2 alongside Wellington Harbour is located close to the Wellington Fault and access from the Hutt Valley was assumed to be unreliable. Wellington Region Civil Defence Emergency Management Group have made some consideration of shipping options including landing sites (WRCDEM, 2010) and the shipping options of specific relevance to bulk water or tanker transportation was considered in some detail.

Initially there will be a serious shortage of road tankers in Wellington and options for bringing them in were considered. Two suitable barges were identified in the Wellington/Marlborough Sounds area. Another possible option identified was the New Plymouth based oil rig supply ship Pacific Chieftain which can carry 279m^3 of potable water and 590m^3 of drilling water. Additional water could be carried as deck cargo, lifting the total potential capacity to around 1000m^3. Both Interislander and Bluebridge ferries could be very useful to transport tankers into the region.

The 9,000 tonne HMNZS Canterbury is a strategic lift vessel commissioned in June 2007 with excellent disaster relief capability. While its on-board potable water tanks amount to only 137m^3, it has two small RO de-salination plants each capable of producing 40m^3/day of potable water. The ship is basically a roll-on / roll-off ferry with a single vehicle deck. It was used to carry polyethylene water tanks to Samoa following the tsunami. It has cargo space of 1,451 m^2, which can be unloaded via two ramps, either from the starboard side or the stern, or with the help of two 60 tonne cranes lifting through the flight deck. There would obviously be multiple demands on this resource but it would be capable of carrying 30-40 10m^3 water tankers at a time.

4.2.3 RAILWAY

Several sources noted that railways are often quickly repaired following earthquake events. This was not investigated any further due to concern over the tunnel stability, however rail access could obviously be valuable in transportation of bulk materials including water post earthquake.

5 CONCLUSIONS

This paper describes the reduction, readiness and response aspects of Capacity's planning for the Wellington region metropolitan area. This planning is based on providing water for a nominal 20 litres per person per day (l/p/d) allowance as an initial target in an emergency.

The major available resource for emergency water supply is the water stored in the council reservoirs. Significant work has been undertaken to improve the security of this water, including seismic upgrades of the tanks, installation of automatic closing valves, installation of seismic triggers for those valves and improvements to the inlet and outlet pipework where required and this work is still in progress. Accessing that water can be achieved through the use of manifold kits. External water tankers will be required to distribute the stored water to publicly accessible emergency temporary water distribution points.

Critical pipelines have been identified and there is an ongoing programme of works to upgrade these pipelines with seismically resilient materials through the renewals programme. The most critical pipelines are the pipelines that supply the designated water distribution points. The second priority is the feed lines to and from the existing reservoirs. This work will assist recovery timelines and improve the distribution of water to the community post-event.

Stored water within each city will need to be supplemented by externally supplied water. This could be through bottled water or water tankered from the Hutt Valley, however severe access limitations are anticipated following a major earthquake. Other in-catchment surface water sources are being identified, however these require improvement works to be made accessible for ready use.

Emergency tanks are currently located at various locations in the region. Some additional tanks are held in storage and installation of further tanks located at welfare sites and civil defence centres is proposed over the next four years. These tanks will be maintained full with potable water and will have provision for rain water collection where possible, and tankered water distribution.

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