Emergency Potable Water Planning at UBC: Increasing Our Resilience to Earthquakes

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EMERGENCY POTABLE WATER PLANNING AT UBC: INCREASING OUR RESILIENCE TO EARTHQUAKES

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EXECUTIVE SUMMARY

This report is the result of a collaboration between the School of Community and Regional Planning and Risk Management Services at the University of British Columbia (UBC), made possible through the SEEDS Sustainability Program. The overarching problem this report aims to address is how to get clean water into the hands of the UBC community following a significant earthquake that cuts off access to running piped water. It aims to build on existing emergency potable water planning for the campus through conversations with UBC faculty and staff, by examining the planning context at UBC, and by looking to emergency water planning frameworks and practices from other schools and communities. The main finding of this report is that UBC may not be meeting all of the critical needs for the UBC campus in an emergency. Water source redundancy is offered as a solution to improve the overall resilience of the school to an earthquake, with regard to water systems and supply.

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ACKNOWLEDGMENTS

Great thanks is owed to Danny Smutylo of UBC Risk Management Services, who has been an engaged and supportive partner throughout this project, as well as David Gill from the SEEDS Sustainability Program and Dr. Stephanie Chang, my supervisor at the School of Community and Regional Planning. I would also like to thank Arielle Dalley, who I shared this project with, for being a great friend and collaborator. Additional thanks is owed to all of the stakeholders that participated in this project from UBC Energy and Water Services, Building Operations, Campus and Community Planning, and Student Housing and Hospitality Services.

DISCLAIMER

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INTRODUCTION

INTRODUCTION

ABOUT THE REPORT

This document is the result of a four month collaboration between the School of Community and Regional Planning and Risk Management Services at the University of British Columbia (UBC), made possible through the SEEDS Sustainability Program. This report focuses on emergency potable water planning for the campus, exploring ways to improve the comprehensiveness of the current preparedness strategy through conversations with UBC faculty and staff, bolstered by best practices from emergency water planning frameworks and emergency water planning experiences and practices from other schools and communities. The main goal of this report is to investigate what the needs are for the UBC campus and how they are being met, and what opportunities and challenges there are for increasing resilience, particularly focusing on what possibilities there are for increasing redundancy of water sources.

This report was initiated because experience has shown that re-establishing potable water systems after an earthquake is a challenge, and a need was identified by UBC Risk Management Services to identify the best solutions to get clean water into the hands of the campus community. UBC has begun to make steps towards accomplishing this. In 2016, UBC acquired a water filtration trailer with the ability to filter 120,000 L per day from a local stream source, but planning for the trailer system was only completed up to the point of producing potable water. Additional planning for packaging, transportation, and distribution has been the focus of a complementary SEEDS project completed by another student at the School of Community and Regional Planning, which will be referenced in this report.

METHODOLOGY

This research relies on information from UBC documents and conversations with staff involved in planning, management, and operation of water and emergency services, as well as external resources related to planning for an emergency drinking water supply. This introductory section of the report provides context for the plan, including additional information on the background of the project, and information on the UBC context. The second section focuses on potable water needs, which is examined through establishing key assumptions about the planning scenario and looking at water consumption for the campus. The next section investigates the possible options for increasing resilience on campus with regard to water source redundancy, based on conversations with UBC staff with institutional knowledge related to the topic, supplementary research, and information from correspondence between the co-investigator on this project and schools on the Disaster Resilient Universities email listserv. Finally, the report closes with recommendations for future planning and next steps.

WHY PLAN AHEAD FOR POTABLE WATER?

The University of British Columbia is located in a region that is prone to a number of hazards, but earthquake risk is a particularly serious threat to the campus because of the potential for significant damage. High ground motion can cause direct damage due to vibration, but can also cause indirect effects such as liquefaction and landslides, all of which will have consequences for potable water provision systems above and below ground (Clague, 2002). Typical elements of the water system that are damaged include house service connections, power supplies, control systems, trunk mains, service reservoirs, pumps, and treatment plants (Wisner & Adams, 2002). Disruption in water provision could last for days and have adverse impacts on the population on campus, as well as the day-to-day functions of the campus that rely on potable water.

The 2011 earthquake that affected Christchurch, New Zealand provides a comparable example of what our region could expect from a major seismic event. Following the earthquake, 80% of water and sewerage systems were severely damaged, and main water was out completely for a couple of days. For that period of time, the city mainly relied on water that was trucked in via water tanker trucks and trucks carrying water from bottling companies, in addition to water produced by a desalination plant brought in by the army, and emergency supplies that were on-hand. The loss of water proved to be a significant issue for the central hospital in Christchurch, and despite having back-up supplies (<1 day's worth) on hand and access to artesian wells, the lack of water impaired its ability to function effectively and efficiently. After the event, the hospital installed a ½ million litre capacity tank to provide emergency water for crucial activities and needs, such as sanitation and drinking water (McIntosh et al, 2012; Johnston, 2012).

There are important lessons to be learned from the Christchurch example about water issues and needs in emergencies. In particular, it gives a glimpse into why preparing for a water outage ahead of time can enable supplies to be designed in a way that can increase resilience of critical services, and also improve the efficiency and effectiveness of the emergency response for residents and visitors to UBC.

NZ Army Engineers working at New Brighton beach to provide desalinated water to residents following the Christchurch earthquake. Source: New Zealand Defence Forces

KEY TAKEAWAY: UBC is vulnerable to earthquake hazards that can disrupt critical water service on campus. Steps must be taken to protect and improve the resilience of water provision systems.

BACKGROUND AND CONTEXT

PROJECT BACKGROUND

As was previously mentioned, this report is the result of a collaborative effort with UBC Risk Management Services to address the need for a comprehensive emergency potable water plan. Part of this project includes completing the planning process for the water filtration trailer that was purchased in 2016, which has been taken on by another student at the School of Community and Regional Planning. During project scoping, the team found that more can be done to increase resilience of emergency water services to the UBC campus, both within the scope of planning for the new water filtration trailer, and more broadly. This report focuses on the case for why additional actions to increase resilience should be considered, and offers a suite of viable options for alternate water sources.

KEY RESOURCES

The following documents are key resources that were consulted in the production of this report, and may be helpful references for future decision-making and research in this area:

UBC Documents:

- *UBC Emergency Response Plan: Water Utility:* This is the existing plan for emergency water response on campus. It outlines different service disruption scenarios, along with associated actions and key contacts.
- *Filtration trailer manual*: This resource provides a guide on how to operate the water filtration trailer, in order to produce potable water.
- *Complementary SEEDS Report by Arielle Dalley*: This report discusses how water from the trailer can be packaged, transported, and distributed to people on campus.

External Documents:

- *Planning for an Emergency Drinking Water Supply (US EPA)*: This document provides a step-by-step framework for how to go about developing an emergency drinking water plan.
- *Environmental Health in Emergencies and Disasters (WHO)*: This book deals with measures designed to reduce the impact of disaster on environmental health infrastructure, including water supply.
- *Emergency Water Supply Planning Guide for Hospitals and Health Care Facilities (CDC)* : This handbook looks specifically at how to create an Emergency Water Supply Plan, in order to maintain daily operations and patient care services at health care facilities.

KEY TAKEAWAY: There have already been steps taken to plan for emergency drinking water on campus. This report attempts to identify additional actions that can be taken to further increase resilience to a major seismic event.

PLANNING CONTEXT

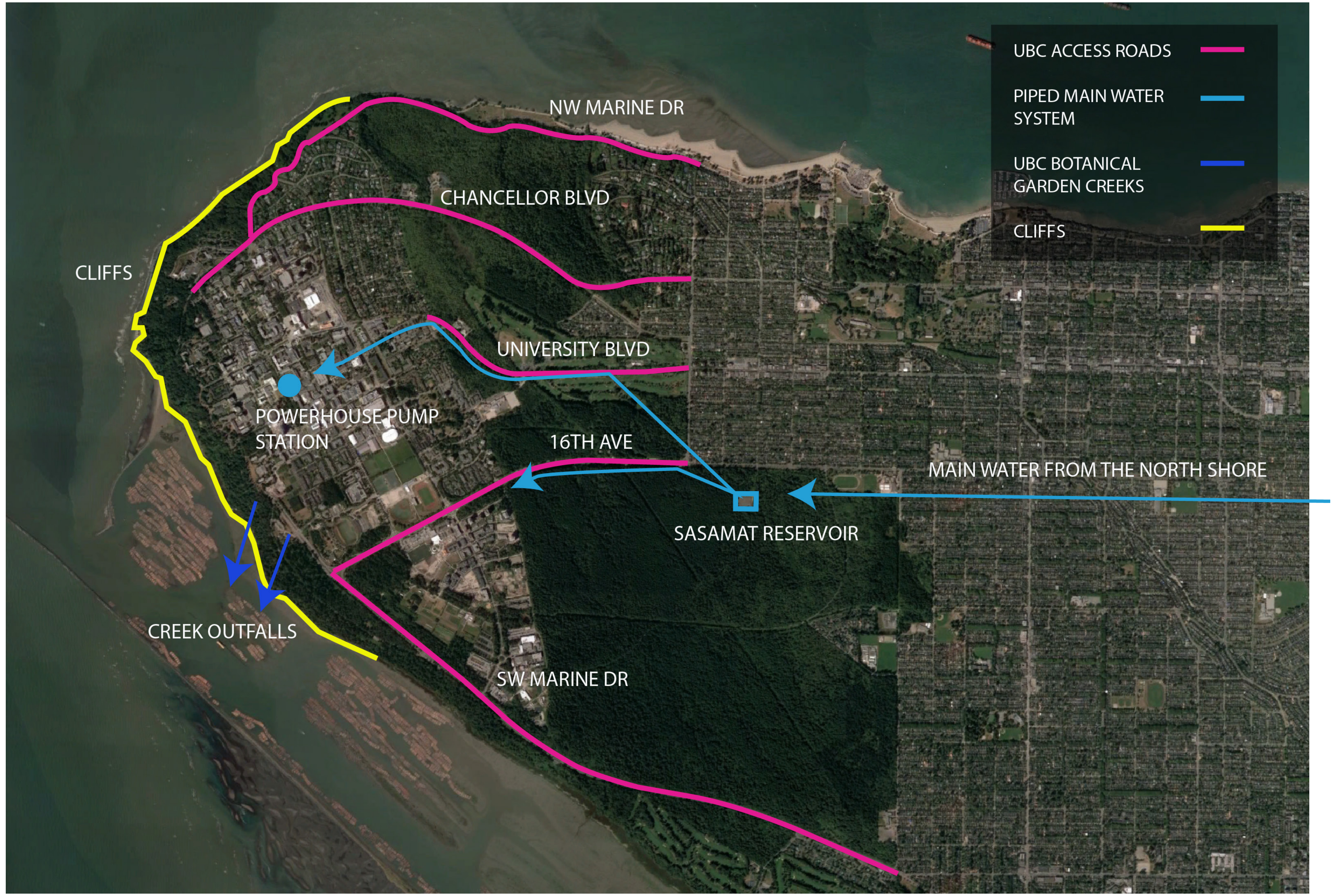
The university is a unique entity, as it has ownership over the land and buildings on the campus, and responsibilities similar to that of a municipality. This provides an opportunity in terms of the ease of implementation of strategic projects, but also presents some significant challenges. To begin, there is limited redundancy in the existing piped water supply system. The campus relies on water that from Metro Vancouver's three reservoirs on the North Shore: Capilano, Seymour, and Coquitlam, which is pumped through the City of Vancouver to the Sasamat Reservoir, an underground storage tank, which is then piped to the University Endowment Lands (UEL). The UEL then provides UBC with water that is purchased from the Greater Vancouver Water District, and once it reaches UBC, it is sent to Powerhouse Booster Pump Station on West Mall to distribute pressurized water, and to the 16th Ave lower pressure zone, which distributed non-pressurized water (Klein, D. et al, 2014)). In a significant earthquake scenario, the liquefaction of the soils will cause damage and breakage to pipes, and the lack of redundant piped supply could cause a water outage for the entire campus (see Figure 1).

In addition to the potential for a campus-wide water outage, UBC is also at risk of isolation from emergency water sources. There are five routes in and out of the campus through the Pacific Spirit Park (see Figure 1), all of which could be subject to road damage or blockage from fallen trees that could impede the movement of trucked water. There could also be damage to road and bridge infrastructure that connects the peninsula to the rest of the region, which could leave many people stranded on campus without access to shelter or running potable water. Additionally, the campus is surrounded by cliffs, which prevent water from being boated in. This potential for isolation, and UBC's responsibility under the *Safe Drinking Water Regulation* of the *BC Health Act* to undertake emergency water planning, is why actions have been taken to plan for water needs in an emergency, and look at how the campus can procure water from its own sources.

Following an emergency event, there is a process for re-establishing piped water on campus in the *UBC Emergency Response Plan: Water Utility*, which was enacted in 2002, and revised in 2004. This plan identifies specific emergency events and details a response plan, which includes required actions, such as water quality testing, and important contacts. Following from a need that was identified to produce alternative emergency water sources, the water filtration trailer was procured in 2016, which relies on West Creek and Rock Creek, which are located in the UBC Botanical Gardens area (see Figure 1). The UBC Emergency Response Plan: Water Utility has not yet been updated to include the creeks as an alternate source for water procurement. It should also be noted that there is limited (<3 years) monitoring data for the two streams that the trailer uses.

KEY TAKEAWAY: UBC relies on piped water from reservoirs outside of the campus. Due to its geography, UBC could become temporarily isolated from water sources, and people could be displaced from their homes. Though plans exist for re-establishing main water and procuring water from other sources, they have not been updated to include recent developments.

Figure 1: UBC Context Map



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WATER NEEDS

WATER NEEDS ON THE UBC-VANCOUVER CAMPUS

ASSUMPTIONS

When undertaking a planning process, it is imperative that those who are responsible for providing water supplies consider what assumptions are being made about the emergency scenario that the plan is attempting to address (USEPA, 2011). This can be challenging, due to the unpredictable nature of earthquakes and their effects. However, it is important that decision-makers are aware of the assumptions that are being made, and decide on a desired level of service that they wish to provide.

The following assumptions for emergency water planning have been developed through research and conversations with UBC faculty and staff:

Disaster and outage scenario: This report assumes that there is a campus-wide piped potable water supply outage due to a significant earthquake event.

Time scale of outages: 3-7 days. In a post-disaster situation, it is recommended to be prepared to survive for 72 hours (Government of Canada, 2015). After this, it is essential that potable water is supplied, although ideally water would be made available as soon as possible. Referring back to the Christchurch earthquake as an example, the piped water outage lasted for a week, with some functionality restored within three days.

Population considered: Based on information from Campus and Community Planning, there are about 68,000 people on the UBC campus every day. However, this varies seasonally, and between weekdays and weekends. It is also important to consider that the UBC and UNA residential population has been projected to grow by 13,000 people by 2028, so reviewing plans to determine whether they continue to meet the needs of the population will be essential to promoting resilience. These numbers do not include the population of the University Endowment Lands, as they are required to undertake their own emergency water planning (see Appendix).

Water use per capita : 2-4 L per person per day. There is a range of suggested amounts of water that should be allocated to each person per day, depending on whether hygiene and food preparation is included. A study of the minimum standards for post-disaster water needs reported ranges from 1.8 to 7 L for drinking, and ranges from 15-20 L for household needs such as sanitation and cooking (De Buck et al., 2015). In the immediate response period, the Government of Canada recommends 2 L to fulfill drinking water needs, and an additional 2 L for hygiene, food preparation, and dish washing. (Government of Canada, 2016).

Water quality: Water quality should comply with *Canadian Drinking Water Guidelines*.

Although these are the assumptions for water needs for the purposes of calculations in this report, it is essential that decision-makers at UBC review these assumptions to decide whether they are desirable and appropriate for the goals that they want to achieve.

WATER NEEDS ON THE UBC-VANCOUVER CAMPUS

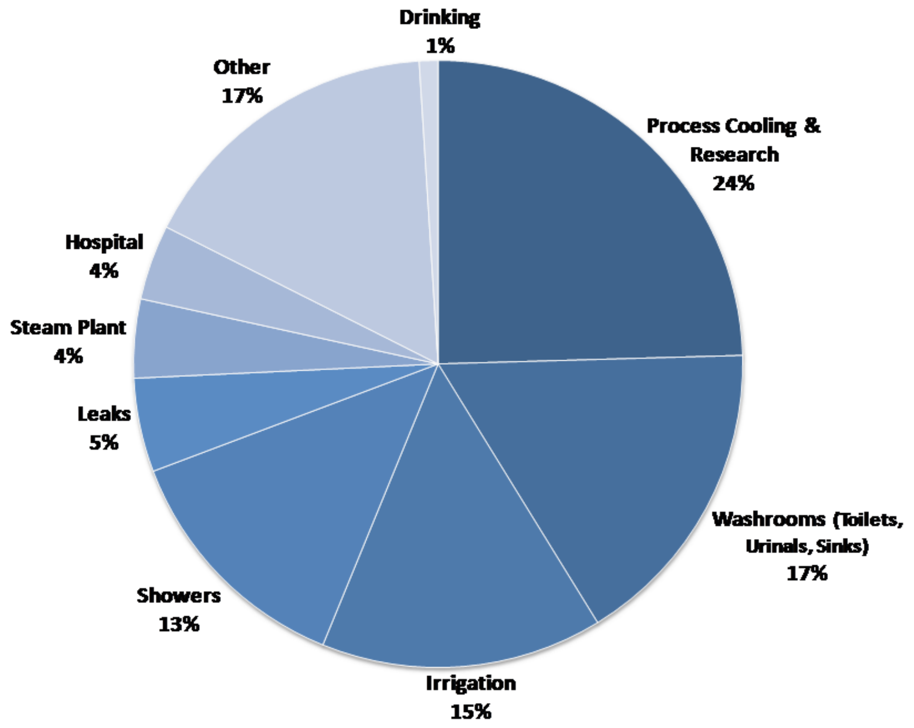
UBC WATER CONSUMPTION

In order to determine how needs will be met in an emergency scenario, normal water consumption on campus can give some direction. According to a water audit completed in 2011, the UBC campus consumes around four billion litres of water per year, This data was gleaned from water meters, which are installed on 80& of the buildings on campus (Klein, D. et al., 2014).

Four billion litres of water a year is roughly 10 million litres a day, of which 1%, or 100,000 litres, is used for drinking (see Figure 2). It is likely that total drinking water consumption on campus is even higher, as some drinking water could be attributed to buildings that are not metered, or to bottled water consumption. It is also important to consider the fact that many people bring bottled water from home to campus when considering these numbers in emergency planning.

Other important consumption considerations for emergency water planning is the UBC hospital, which uses 400,000 L a day, and process cooling and research, which uses 2.4 million L a day. The relevance of this will be discussed further below.

Figure 2. Breakdown of water consumption at UBC by end-use from 2011 water audit (Source: UBC, n.d.).



CHALLENGES

Under optimal conditions, the trailer can produce 120,000 litres of water per day, which is close to the amount of drinking water consumed from piped sources on campus per day. This source, in addition to bottled water on campus, might be enough water to supply people with a minimum amount of water, around 2 litres per day, which could be used for drinking for 3-7 days. However, needs and circumstances are subject to change in an emergency event, especially in scenarios where:

- people are stranded or displaced for more than a couple of days due to damaged transportation routes or buildings;
- an earthquake occurs at a time when the campus is very busy;
- an earthquake takes place during a drought, when the streams the trailer relies on could be dry or have very low flows; or
- an earthquake damages the stream source, the filtration trailer, or buildings that contain emergency water supplies.

It is possible that an earthquake event could result in a scenario when all four of these factors are an issue, which would mean that around 68,000 people might be on campus without access to running water or water from the stream sources. In this case, it would be necessary to seek alternative ways to procure at least 136,000 L of water to provide each person with 2 L of drinking water.

Beyond life-sustaining water for drinking, potable water is used for other critical functions on campus, which should be considered in emergency planning. The existing UBC Emergency Response Plan for water identifies four goals for emergency water response in descending priority:

1. Life Safety
2. Fire Suppression
3. Public Health
4. Commercial and Business Uses

Achieving all four goals will require more water than the trailer can produce in one day. Even though some of these critical areas could make use of non-potable water to regain some functionality, potable water is required for certain uses. For example, ensuring that there is enough water for the UBC Hospital to operate effectively and efficiently will be essential to the immediate response period (CDC, 2011).

Under normal conditions, the hospital uses 4% of the water supply, which allocates 400,000 L per day to critical functions that support public health and life safety (see Figure 2). From conversations with UBC staff, it is assumed that the hospital does have some basic supplies on each floor, in addition to a water filtration unit for dialysis, but it is understood that what is on hand may not meet all of the hospital's needs in an emergency.

The need for potable water to address sanitation more broadly should also be a consideration, in order to prevent the spread of disease. Additionally, it may be of interest to decision-makers at UBC to consider the needs of water-dependent research, such as research involving process cooling or lab animals.

WHAT NEEDS ARE BEING MET?

Using the assumptions that have been established, along with information about water consumption, it is possible to look at who are we supplying with water using existing plans, how much we are supplying, and for what purposes. Based on an optimal scenario, when the creek and trailer system have no issues, and back-up supplies are accessible, UBC is meeting minimum drinking water needs of 2 L per person per day for 3-7 days. If decision-makers have the desire to scale up to sanitation, they will require twice the amount required for drinking. If UBC wants to scale up further to address critical functions of the hospital and research, this could require much higher volumes of water than are currently planned for access. There is an opportunity for further research on these critical activities, as well as research on back-up bottled water supplies on campus, which could be coordinated with the upcoming Water Action Plan for UBC or further SEEDS program studies.

Figure 3 is based on 68,000 people consuming 2 L per day. It assumes the trailer produces 120,000 L, which is supplemented by an unknown amount of supplies on hand. For the purposes of this report, 16,000 litres has been used as an estimate of supplies on hand for 3-7 days. It should be noted that many of these supplies on hand, such as stored bottled water, are at risk of becoming inaccessible due to building damage and collapse.

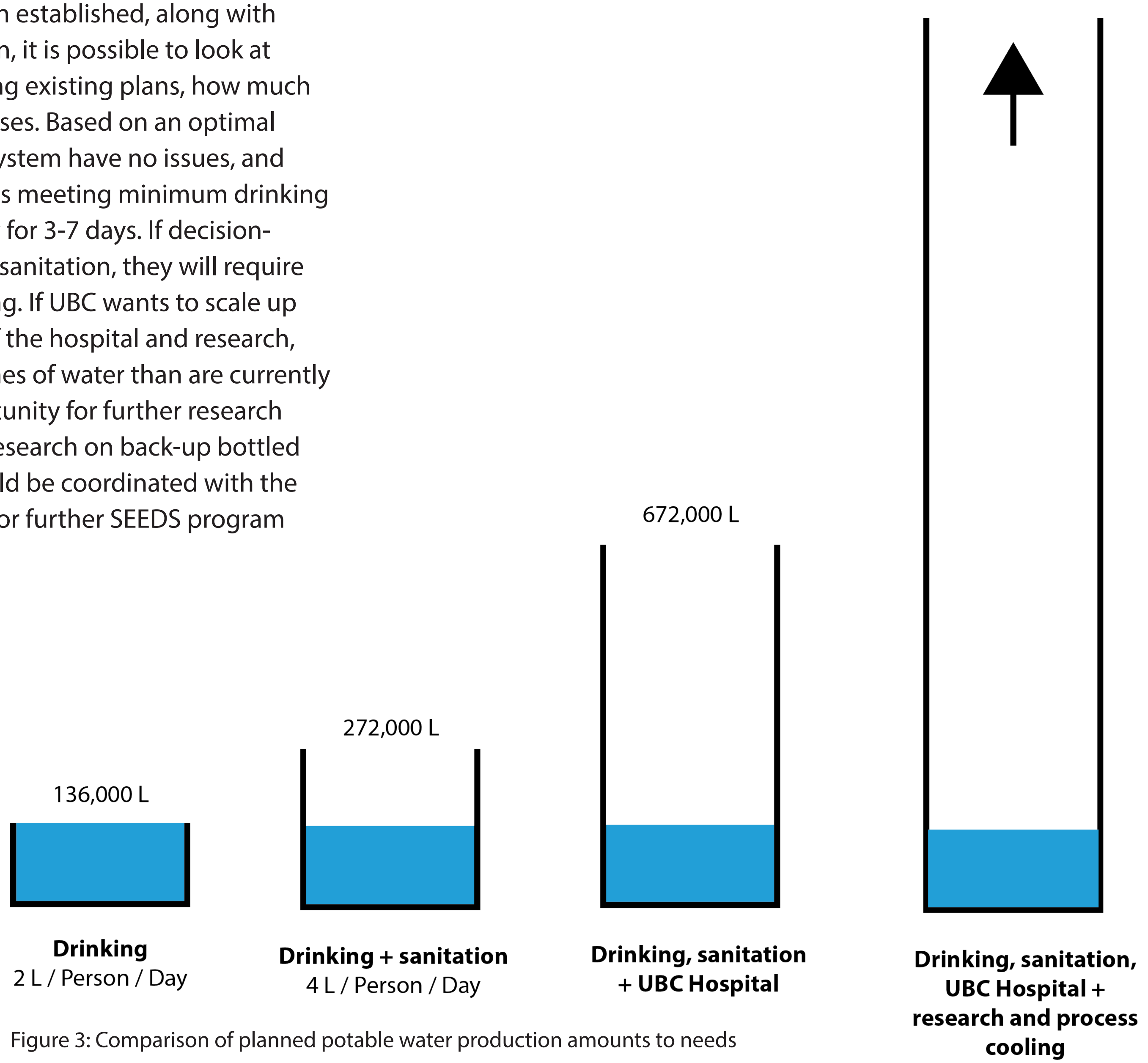


Figure 3: Comparison of planned potable water production amounts to needs

RELEVANCE OF UBC'S SUSTAINABILITY MISSION

Following from the desire to become a leader in sustainability among academic institutions, UBC created the University Sustainability Initiative in 2010. In addition to contributing to research on the topic of disaster resilience, the main objective of this project is to contribute to the goal of making UBC a leader in sustainability, which is commonly defined as "development that meets the needs of the present without compromising the needs of future generations to meet their own needs" (Brundtland et al., 1987). In the context of emergency planning, inaction can have significant costs to future generations. For this reason, sustainable development should also encompass considerations for reducing the impacts of disasters, if there is the capacity to do so. UBC does have the capacity to undertake such planning, and thus it is essential that decision-makers take steps to reduce the community's vulnerability to a disaster, and protect against irreversible social, environmental, and economic damage that could be caused by inadequate water supplies following an emergency.

UBC Campus. Source: UBC Public Affairs

KEY TAKEAWAY: Current emergency water supplies on campus may not sufficiently address all critical needs in particular emergency event scenarios. Being well-prepared to address these needs is well-aligned with UBC's sustainability mission.

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INCREASING RESILIENCE

INCREASING EMERGENCY WATER RESILIENCE

Based on the assumptions of this report, all of the critical needs for the campus may not be met by existing emergency water planning. This section identifies potential solutions and considerations for increasing resilience on the UBC campus, with particular attention to how this can be achieved by pursuing redundancy in water sources.

For each of the stages of the emergency water planning process (see Figure 4), it is necessary to determine roles and responsibilities in the process related to procurement, implementation, and operation. Procurement involves elements such as legal and regulatory issues, financial terms and coordination; implementation involves transportation, siting,equipment requirements and coordination; and operation includes staffing, maintenance, coordination, and demobilization (USEPA, 2011). It is important to note that for different water sources, there will be different roles and responsibilities. As the two creek sources in the UBC Botanical Gardens have already been identified as an emergency water source, roles and responsibilities in an emergency have mostly been clarified, and are further detailed in the complementary SEEDS report.

Figure 4: Steps of the emergency water planning process

IMPROVING RESILIENCE THROUGH SOURCE REDUNDANCY

As water sources on campus are subject to loss or damage in a disaster, it is crucial to look into ways to access new ones. Increasing redundancy in water sources can have benefits beyond functioning as an emergency source in a post-earthquake scenario, as they can be integrated into day-to day uses of buildings, provide social and environmental benefits, or serve as an emergency supply during a drought. Information for water sources identified has been collected mainly through conversations with UBC staff with institutional knowledge related to the topic, supplementary research, and information from correspondence between the co-investigator on this project and schools on the Disaster Resilient Universities email listserv.

Different sources of water have unique requirements, opportunities, and challenges for use in disaster response. The three main categories of viable alternative sources for UBC that have been identified are local untreated sources, bulk and pre-packed water from off-campus, and treated water on site (USEPA, 2011).

The table on the next page (see Figure 5) provides a basic evaluation of these sources using best key decision-making criteria that have come out of discussions with UBC staff. The criteria are:

- initial costs,
- maintenance costs,
- whether storage is required,
- control over the process, meaning no outside agreement is required,
- knowledge of systems and process required to access the source,
- the possibility of day to day use, and
- efficiency of delivery.

Scalability should also be a consideration, but would require additional information to evaluate the comparative scalability between different projects. Research on costs also warrants further investigation, as it is dependent on the type of project pursued and resource requirements. For example, in the treated water category, stockpiling bottled water is inexpensive, but building a dedicated bulk storage facility is very costly.

The purpose of the table (see Figure 5, next page) is not to bring the reader to a conclusion about what the best solution is for additional emergency sources on campus, as this is outside of the scope of this project. Rather, it is a tool that can help decision-makers consider some of the benefits and drawbacks when comparing different options, which can be taken to a more fine-grained level if specific projects are proposed. The overall message of this table is that local projects carry maintenance costs, storage requirements, and knowledge requirements, but they can be accessed at a low cost, could be used throughout the year, and could be delivered more efficiently to the UBC community. On the other hand, water that is trucked-in from elsewhere would have minimal ongoing commitments from UBC's end, but higher costs, and lower efficiency of delivery.

Figure 5: Comparison of alternative water sources.

Type	Comparative initial Cost	Maintenance Cost	Storage Required	Control (no outside agreement required)	Knowledge of systems and process required	Possibility of day-to-day use	Efficiency of delivery
Local Untreated Source	$ - $$	Maybe	Maybe	Yes	Yes	Yes	Medium
Bulk and pre-packaged water from off-campus	$$ - $$$	No	No	No	No	No	Medium-Low
Treated water on site	$ - $$$	Maybe	Yes	Yes	Yes	Yes	High

LOCAL UNTREATED SOURCES

Local untreated sources require prior planning for infrastructure, equipment, and personnel needed to treat the source, transport the water, and connect it to a distribution system. Opportunities: UBC can have complete control over the process of accessing the water; having the water on site means more efficient delivery of water to the community, although treatment could prolong the time period; and there is the possibility of using the source throughout the year for other activities or purposes (such as water features or irrigation). Challenges: There may be maintenance costs and storage required for equipment needed to treat the source; and it is essential that there are people with the expertise to procure the water available on site.

CREEKS

In order to reduce the vulnerability of the current emergency creek sources, they should continue to be monitored, and staff should be trained to deal with operational issues that the filtration trailer might encounter, such as turbidity levels that are higher than 5 NTU (Wisner & Adams, 2002). The second creek has more water in it (approximately 2 L/minute, but will need to be tapped, and requires a permit for dropping a barrel in for the intake system to pump water from the second creek to the first. To round out the planning process for these creeks, decision-makers should consider recommendations from the complementary report.

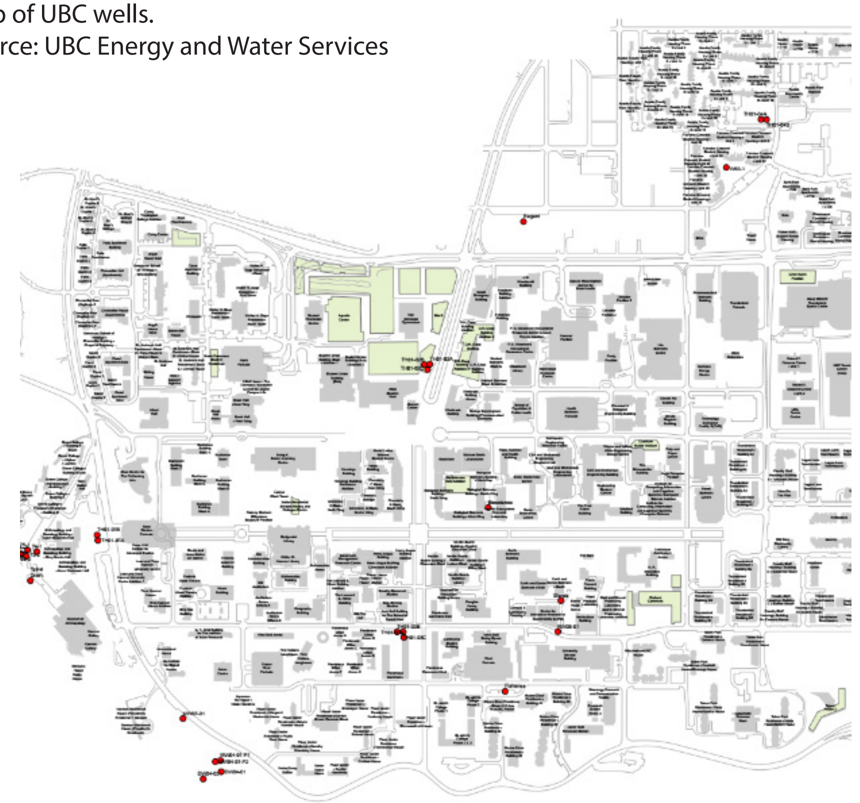
UBC Botanical Garden Creek used by the filtration trailer. Source: Arielle Dalley

SWIMMING POOL

The new UBC aquatic centre holds 4.9 million L of water that is cleaned using a state-of the art filtration system(UBC, 2017). This amount of water could support all regular functions on the campus for five days, meaning that in an emergency when there are less critical systems to run, it could support the campus for an even longer period. Sources have said that this water may be reserved for fire suppression, but it should be considered for drinking water access as well if life safety is the first priority for the campus. Chlorine levels in UBC pool are usually within 1-3 PPM, but to ensure it is safe to drink, it could require dechlorination if levels are above 4 PPM. A backup power source may be required to enable the filtration system to continue to function normally.

UBC Aquatic Centre. Source: UBC Public Affairs

Map of UBC wells.
Source: UBC Energy and Water Services



GROUNDWATER

On campus we have a perched aquifer 15 m below grade, which is 10-30 m thick and fairly impermeable, with a second aquifer at about 50 m. There are 30 wells on campus, however most of them are monitoring wells that are not designed for water production. They allow monitoring of the water table levels in the upper aquifer, so could potentially be used to test the drawdown, and water quality. There is a concern that iron and manganese levels are quite high, so chemical flushing may be required. One source believed that there was a productive well on campus, but it has since been decommissioned, and there is no indication that it could be put to use again.

LOCAL UNTREATED SOURCES

BLUE INFRASTRUCTURE

On the campus, there are a few different ways that water is captured and stored, which could potentially be used in an emergency. There are cisterns, such as the one underneath CIRS which holds 107,000 L, and the cistern underneath the new aquatic centre, which harvest rainwater from buildings. There are also ponds such as those in Wesbrook Place, behind the Museum of Anthropology, and in Nitobe Gardens. However, for much of this infrastructure accessing the water is a challenge, and water quality would pose more of an issue than other sources. A possible consideration for buildings that will be using cisterns in the future would be to look into building them in ways so that water could be easily accessed in an emergency, which would also require them to be able to withstand a significant earthquake.

Nitobe Gardens pond. Source: Jennifer C.

BULK AND PRE-PACKAGED WATER FROM OFF-CAMPUS

BULK HAULING

Bulk hauling involves transportation of treated water, from treated reservoirs, treatment plants, or nearby utilities. It may be a good option if UBC is willing to put up the costs in exchange for minimal dedicated resources and space beyond an initial investment. The investment in bulk hauled water could be significant- a business owner in Tofino spent $50,000 for a 10 day supply of water for the population (around 18,000 in the summer) during a drought (CBC News, 2006). Comparatively, UBC's daytime population is three times this, so costs could be upwards of $1 million. An addition consideration for hauled water is that in a scenario when roads are blocked or damaged, they might not be able to access the campus. If this is a desired route, it would be advantageous to attain contracts with hauling companies ahead of time, to prevent double counting and competition with other areas requiring emergency supplies (Wisner & Adams, 2002).

TREATED WATER ON-SITE

PRE-PACKAGED WATER

Like other universities, UBC has a stock of bottled water supplies for emergencies. However, other universities continuously cycle through their stockpiles, rather than having to replace them after they expire. If UBC wishes to do this, it would require storage facilities close to food and water distribution site, and coordination with Food Services. The main challenges with this option are that access to stockpiled supplies could be challenging if buildings are damaged or collapsed, and that it is not in line with the sustainability mission of the school, which involves reducing bottled water consumption supplies (Wisner & Adams, 2002).

Bottled water stockpiles. Source: Pennsylvania National Guard

A residential hot water tank. Source: I am I.A.M.

WATER TANKS

Using potable water left in water tanks in residences and in the food trucks on campus could be an easy way to quickly access water. This source would mainly be beneficial to those that can access the hot water and toilet tanks in undamaged residential buildings, however there would need to be some communication around how to access the water, ensuring that people let their hot water tanks cool before draining them, and water is taken from the back tanks of toilets, rather than the bowls. This messaging could be part of a larger post-earthquake communications plan, which would require coordination between SHHS and Risk Management Services.

TREATED WATER ON-SITE

DEDICATED BULK STORAGE

This option would require building a storage tank on campus that would have the ability to withstand an earthquake. It is an option that another school has implemented on a smaller scale, using a tank with 20,000 L capacity. It may be a good option for facilities that would require dedicated water that could feed into their systems right awa, such as hospitals. As was previously mentioned, following the earthquake in Christchurch, the hospital installed large water tanks on its roof as an emergency supply, to ensure they would not encournter the same issues if they were to experience another earthquake in the future. One of the advantages of bulk storage, if it is built above ground, is that it could use gravity to fill containers rather than requiring pumps. The main issues with dedicated storage are that it would need to be accessible for maintenance, built to withstand a seismic event, and would require real estate on campus.

Bulk storage in a water tower Source: Steven Tyler PJS

CONCLUSION AND FUTURE CONSIDERATIONS

One of the greatest products of this project has been that it has brought together all of the people that have a stake in the emergency water planning process on the campus. One of the main issues that seemed to be stalling the planning process was the lack of clarity around roles and responsibilities, what needs to be done to complete existing plans, and whether or not that will get the UBC to where it would want to be in a disaster response scenario. With that, the most important recommendation coming out of this project would be that **all of the groups and individuals involved in this project continue to communicate with one another, and continue to coordinate planning for emergency response**.

RECOMMENDATIONS

Some general recommendations for the group moving forward are:

- Decide on what the desired level of service is that UBC wants to provide following an earthquake with regard to water needs, and how much scaling up is required to do this. Once this decision is made, it should be communicated to the UBC community.
- Determine the critical water needs for the hospital and research in an emergency, and confirm what supplies are on hand. This could include looking at how much bottled water is available on campus.
- Update the UBC Emergency Response Plan to include the creeks as an alternate source, and any other sources that are planned for access.

Some recommendations specifically related to increasing resilience and redundancy of water sources are:

- Continue to monitor the streams to ensure that they continue to be a reliable source in an emergency.
- Consider the options for alternate sources that have been presented, and determine what the priorities are for choosing a project.
- If multiple projects are being considered, consider undertaking a multiple account analysis to determine which best fits the needs of the school and its population.

Emergency water planning can be a challenging and complex task to undertake for a place like UBC, with so many moving parts requiring coordination. However, it is also very important to do, as we depend on water to sustain ourselves and many of the things that we do on this campus. Even though there is much uncertainty about when we will have an earthquake and what will be affected, continuing to plan for these scenarios is essential, as the stakes of failing to do so are high.

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APPENDIX

POPULATION DATA FROM CAMPUS AND COMMUNITY PLANNING

Total number of people on campus everyday (as of Nov 2016 unless otherwise noted; data from UBC-PAIR).
o Staff: 9,250
o Faculty: 3,396
o Students: 54,232 (note: this is headcount rather than FTE; I assume that's more relevant for emergency planning)
o Visitors: N/A (in 2013, calculated 630,000+ annually: 160k Chan Centre; 120k MoA; 40k Dental Clinic; 31k UBC hospital; 30k conferences; 250k Pacific Spirit Park, including the beach)
o Other N/A (no numbers for other campus employers like UBC hospital or TRIUMF)

Population Projections (estimates only):

Population Projections (estimates only)			
	Current	2017-2022	2023-2028
UNA	~10,000	~14,000	~18,000
Student Residents*	12,869	14,778 (12,947 SHHS beds)	17,813 (15,982 SHHS beds)
UEL**	4,000	5,000	6,500

*Existing SHHS population + future SHHS beds + existing non-SHHS beds
**Based on Block F development projections