Rainwater Harvesting: An Investigation of the Current Use on Salt Spring Island

DROMEDARY ENVIRONMENTAL

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Executive Summary

Salt Spring Island (SSI) is the largest and most-populous Gulf Island located between southern Vancouver Island and Vancouver, British Columbia. The increasing population and popularity with tourists in the summer months strain the freshwater resources available for use. To exacerbate the issue, SSI is considered to have a sub-Mediterranean climate due to its location in the rain shadow of the Olympic Mountains. Based on these stressors and the limited sources of water, it is necessary to explore alternatives, including rainwater harvesting (RWH), to meet demands on water resources and their management.

The Salt Spring Island Watershed Protection Authority (SSIWPA) was formed in 2012 and is made up of representatives from local government, provincial government, and water service providers that together create and propose strategies for watershed management on SSI. SSIWPA requires data to provide a baseline on current RWH activities for residential, civic, and commercial land uses and has tasked Dromedary Environmental, a group of students from the Bachelor of Science in Environmental Science program at Royal Roads University, with the collection and analysis of this data. SSIWPA plans to use this data to make further recommendations within its integrated water management program.

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Acknowledgments

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Glossary

Case study	A more detailed examination of rainwater harvesting systems from specific locations on SSI
Category	A designation for the type of property used in the case studies
Conventional water sources	Ground or surface water
CRD	Capital Regional District
SSI	Salt Spring Island
SSIWPA	Salt Spring Island Watershed Protection Authority
RRU	Royal Roads University
RWH	Rainwater harvesting
Water districts	Districts responsible for supplying properties with water from groundwater and surface water sources, including community wells and piped water from lakes and other surface water sources

Introduction

Dromedary Environmental is a group of students from the Bachelor of Science in Environmental Science program at Royal Roads University. We are working in conjunction with the Salt Spring Island Watershed Protection Authority (SSIWPA) to acquire data on current rainwater harvesting (RWH) practices and use for residential, civic, and commercial Salt Spring Island (SSI) properties. This data will be important for future decision making regarding conservation and use of SSI water resources.

SSI is the largest, most populous island within the Gulf Islands with a landmass of approximately 194 km^2 (Statistics Canada, 2017). The island had a population of 10,557 people in 2016, with a median age of 53 (Statistics Canada, 2017). The largest age group on SSI includes people between the ages of 55 and 64 (Statistics Canada, 2016). The number of people on SSI increases in the summer months, as tourists, visitors, and seasonal residents flock to the island (Destination BC, 2017). The community on SSI is largely contained in the Ganges town center with two other residential areas located at Vesuvius Bay and Fulford Harbour, (Macpherson, n.d.) shown in Figure 1 (Nash, 2016).

Figure 1. *Salt Spring Island residential areas: Ganges, Fulford, and Vesuvius (Nash, 2016).*

Many residents make a living as entrepreneurs, either working out of their homes, or starting their own businesses in town. SSI is serviced by three BC Ferry terminals; Fulford, Vesuvius, and Long Harbour. SSI is located in the rain shadow of the Olympic Mountains to the south which creates a sub-Mediterranean climate. According to the Koppen Climate classification, a sub-Mediterranean climate is designated by less than a third of precipitation falling in the summer, compared to the wettest winter month (Weatherbase, n.d.). The annual rainfall is around 105 cm, with the majority of precipitation occurring between November and March (The Weather Network, 2017). The very low precipitation in the spring and summer often results in drought conditions, indicating the necessity for rainwater harvesting (RWH).

Many water districts are defined on SSI. These districts use community wells or water from one of the eight lakes on the island to supply nearby properties (Salt Spring Island, 2015). Depending on the service area for each district, the use and therefore the stress level on the water source varies. Based on stress and limited sources of water, RWH is strongly encouraged on SSI. Many properties obtain their water from community or private wells, which can become stressed through the long periods without rain (Cowan, 2017, personal communication). If residents and businesses supplement their water use with rainwater, the strain on water sources would be lessened.

Rebate programs, past and present, have existed on SSI as an incentive for properties to install RWH equipment. SSIWPA, SSI Water Council, and the Capital Regional District (CRD) have partnered to provide a rebate program to reduce the cost of purchasing and/or installing equipment related to RWH by 25% to a maximum rebate of $500 (SSIWPA, 2016). SSI and the Southern Gulf Islands are unincorporated and governed under the CRD and Islands Trust.

Salt Spring Island

Knowledge of local geology is useful for understanding the importance of RWH on SSI. Furthering the goal of this project, this information is vital in determining the need, motivation, and barriers involved in RWH system implementation. As well, potentials of RWH on SSI is dictated by the wide variation in rainy periods and overall groundwater vulnerability. The documented history of RWH on SSI indicates what great RWH potential exists for this area.

Geology. A thorough assessment of SSI's geology was conducted in 2014. The results of this study are useful in further justifying the need to search for alternative water sources on SSI. The most recent glaciation has left its mark on SSI, leaving primarily unconsolidated glacial till across the island (Larocque, Allen & Kirste, 2015). This till has been eroded from higher elevations and settled in the valleys to expose portions of bedrock. Much of the bedrock consists of layered sedimentary rock which is unconducive to the storage of water in aquifers (Larocque, Allen & Kirste, 2015).

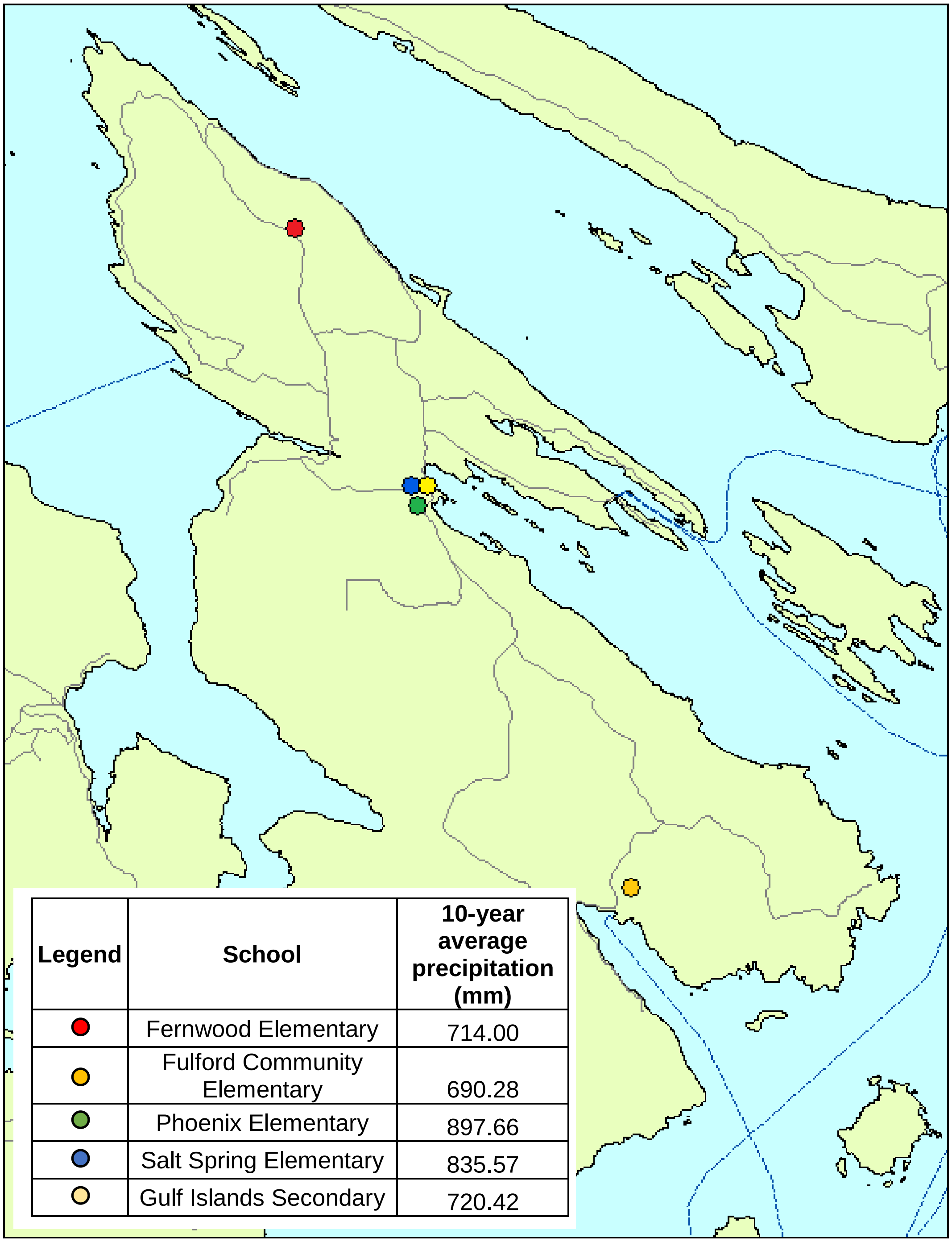
Rainwater harvesting potential and necessity. The potential for RWH on SSI exists because of its geology, climate, and groundwater vulnerability. Precipitation amounts vary month to month, as well as by location across the island. The variation between locations results in great potential for RWH on SSI as a whole. If rainwater is harvested in areas that receive high precipitation, this water could be supplied to many residents who may otherwise need to rely on an unsuitable or unreliable source. If a majority of the population collected rainwater which was then available for all residents' use, the benefits of areas that receive high precipitation could be extended across the island. The potential to work as an entire community to capture rainwater and ensure everyone has access to the amounts needed exists partially due to the culture of SSI; community engagement is strong and the residents are supportive of each other.

SSI is also a part of the Gulf Islands Coastal Douglas-fir ecosystem which often experiences low rainfall in the summer months (Islands Trust Fund, n.d.). Regular periods of drought increase the need and potential use of RWH. When groundwater levels run low due to increased stress on sources over drought-ridden summers, the stress on plants and animals that are dependent on these sources is also apparent (Islands Trust Fund, n.d.). As well, in more urban areas, harvesting rainwater reduces runoff and erosion, and reduces the amount of storm water that requires management. This results in lower costs for other infrastructure such as piping, along with the maintenance of this infrastructure (Islands Trust Fund, n.d.). Through this, the potential cost savings for residents of SSI due to better water management is also achieved. While it is important that many residents undertake RWH individually, working as a community will result in an overall benefit to the island and water resource scarcity.

Along with gaining a new source of water, those who harvest rainwater also develop an increased awareness of their water use, conservation practices, and rainfall patterns (Islands Trust Fund, n.d.). Harvesting rainwater protects surface and groundwater resources directly and indirectly by increasing awareness surrounding water use and conservation among water users. Water conservation and recognizing the need to consume less often leads to similar lifestyle changes relating to climate change and reduction of other consumables; lowering greenhouse gas emissions and making homeowners better environmental citizens (Islands Trust Fund, n.d.). According to information from World Climate, Victoria, BC receives an average of 845 mm of rain annually (2016). Comparatively, Victoria, Australia, receives an average of 625 mm of rain in a year (World Climate, 2016). Australia is harvesting more rainwater, despite receiving less precipitation, than BC; this highlights the current lack of awareness and use of rainwater as a viable source of clean water in BC.

To better understand local precipitation levels, rain gauges were installed at several school across SSI; this data is included below to indicate the range of precipitation across SSI (Victoria Weather, 2012). This rainfall data was collected as a part of a project done by University of Victoria students, in partnership with British Columbia school districts.

The variation in precipitation shown in Figure 2 demonstrates the benefit that could be obtained from understanding which areas of SSI have above average rainfall. Data was compiled using GIS mapping software, based on recorded rain gauge measurements (Weaver & Wiebe, 2012). The data was incomplete, as some monthly measurements were recorded as zero, indicating not that 0 mm of rainfall was recorded, but that the measurement for that month was missed (Weaver & Wiebe, 2012). This was because of a number of reasons, from random missed observations to a lack of personnel over the summer months. Due to the missing data points, this map only provides a rough estimate of the average annual precipitation. Information like this is useful in determining potential for RWH in different areas.



Legend	School	10-year average precipitation (mm)
	Fernwood Elementary	714.00
	Fulford Community Elementary	690.28
	Phoenix Elementary	897.66
	Salt Spring Elementary	835.57
	Gulf Islands Secondary	720.42

Figure 2. *10-year average precipitation data from rain gauge measurements made at five schools across SSI (ESRI, 2017; Weaver & Wiebe, 2012).*

Collected rainwater has been investigated as possibly reducing groundwater recharge (WaterAid, 2011). A study conducted by WaterAid in Nepal concluded that groundwater recharge is most strongly threatened because of increased development and the reduction in surface infiltration area due to the increase in impermeable surfaces (WaterAid, 2011). Aquifer systems are almost entirely limited in their recharge to precipitation percolating through the ground and saturating the area (WaterAid, 2011). While the potential exists to affect groundwater recharge because of RWH, the manner in which it is being done poses little to no threat. Most collection surfaces for RWH are already existing man-made structures. It is true that building a house, garage, and paved driveway on previously undeveloped terrain reduces the area available for percolation of rain; however, collecting rain that falls onto the roof instead of allowing it to runoff through gutters to the ground has a minimal effect.

Some of the issues with groundwater on SSI specifically include lack of availability, depth at which it is found, quality of the water, and feasibility of access. Another contributor to water scarcity is over extraction due to an inability to monitor usage and recharge rates. With this issue of over extraction in mind, the WaterAid group from Nepal conducted a study using RWH to recharge ground water (WaterAid, 2011). Infiltration rates and geological formations were characterized to determine how best to collect and reintroduce the water (WaterAid, 2011). The variations in sediments were a key aspect of groundwater retention, because of confined and unconfined aquifers (WaterAid, 2011). An unconfined aquifer is an aquifer that is exposed and influenced by atmospheric pressure, and is free filling and draining as it is in contact with the surface (USGS,2017). A confined aquifer is an aquifer that is placed under pressure by an impermeable layer (USGS, 2017). Recharge structures include ponds and wells used for shallow and deep aquifers, respectively (WaterAid, 2011).

Information from the Water Aid (2011) study relates to the water potential on SSI; some properties and situations are not well suited for RWH, but may have access to a well that would enhance water security through drought, if recharge was possible. Those sections of the island that receive higher amounts of precipitation, and have the ability to harvest more rainwater than is immediately required, could be used to refill aquifers. This goes back to the idea that SSI is a community that together can overcome the issues of water use and scarcity they are facing.

Another consideration for the possible issue of RWH affecting groundwater recharge is the use of rainwater. As rainwater is most commonly used for irrigation, the original destination of the water is maintained, just delayed by a few days or weeks (CRD, n.d.). With this in mind, the recharge of groundwater is not affected in a manner that is of concern. If harvested rainwater is to be used for potable systems, an issue may arise if the water continues its journey through sewer systems and does not return to the ground in the same area. Septic systems are common on SSI and, in this case, water is still returned to the ground in the area in which it fell. Another option for the management of groundwater recharge may be conducting a census of RWH systems. This would allow local authorities to get an understanding of the collected volumes and uses of harvested rainwater. As well, a census would provide benefits such as informing residents of the local geography and the frequency of RWH in their area, possibly leading to enhanced awareness in the community as a whole.

The issue of population growth also dictates the need to conserve water. As previously outlined, the vulnerability and lack of available groundwater on SSI is an issue. With a 6.2% population increase between the 2006 and 2011 census, and a further 3.2% increase from 2011 to 2016, stress on water resources is a mounting issue (Statistics Canada, 2012; Statistics Canada, 2017). As the population of SSI continues to grow, accessibility of water will become an issue that cannot be ignored if a solution is not put in place. This solution may include rainwater harvesting.

History of rainwater harvesting. RWH was documented on SSI as early as 1905 based on Reverend Wilson's Diary (Salt Spring Island Archives, n.d.). The family documented the quite rainy conditions on the island and decided it best to make use of the water falling from the sky, installing a large rainwater tank on Sept 26, 1905 (Salt Spring Island Archives, n.d.). Documentation from SSI's community newspaper, *The Driftwood*, showed a 175 gallon rainwater tank being offered for sale for $15 in 1965, with other inquiries for the purchase of a 300 gallon galvanized tank also appearing as a part of the classified ads (Salt Spring Island Archives, n.d.).

Such historical evidence indicates the long-term interest of SSI residents in collecting rainwater, recognizing the benefits of the climate in which they live, and taking full advantage of the free resource that is rain. The willingness of residents to participate in the initiatives being proposed will play a huge role in their success.

Rainwater Around the World

Many countries around the world harvest rainwater and have success for a variety of reasons. Success was determined by a large percentage of the population harvesting rainwater. RWH practices in Thailand, Australia, and Bermuda show examples of how RWH can improve in Canada. The low cost of RWH equipment in Thailand, and the cultural behaviour of its citizens have led to a high percentage of people harvesting rain. The Millennium Drought in Australia led to regulations that changed building codes to require RWH systems in new homes, and altered behaviour in residents when it became evident that all water sources became stressed. The lack of ground and surface water resources in Bermuda increased the need for RWH systems, and regulations were created that required cisterns in all houses on the island.

When considering how to encourage RWH in Canada, the relative cost of RWH equipment, the behaviour of citizens, regulations, and the need to start harvesting before a major drought occurs are all important.

Historical use of rainwater harvesting. One of the oldest methods of gathering water for domestic use is through RWH. RWH structures date back to the third millennium BC in India where stone structures were used to store rainwater. Rainwater was also harvested throughout the Middle East and Mediterranean areas where it was collected from roofs and hard surfaces and it was then stored in underground masonry dome cisterns. In Australia, Western Europe, and the Americas, drinking water was most often gathered by harvesting rain (Smet, 2003).

Rainwater harvesting in Thailand. Thailand currently has the highest percentage of the rural population in the world that relies on RWH, with 40% of people harvesting drinking water (Saladin, 2016). Rainwater has been harvested in Thailand for thousands of years with the primary purposes being for drinking water and domestic uses. Historically, water was collected in 50 to 300 liter earthenware jars (Saladin, 2016). In the 1980s when the United Nations declared the "International Water Decade" with the objective of providing all people, including the poor and less privileged, with safe water in adequate volumes, the Thai government launched a program to distribute RWH containers to each family in rural areas (Saladin, 2016). The distributed cement mortar containers (Thai Jars) usually could hold 1,000 to 2,000 liters (Saladin, 2016). By 2000, 21 million people in rural areas were using rainwater as their main source of drinking water (Saladin, 2016). The great success of harvesting rainwater in Thailand led the country to become one of the first low or middle-income countries to have full coverage and access to improved sources of drinking water. It is also important to note that the access crosses all income levels, with 100% of the richest and 97% of the poorest in the country having an improved drinking water source, which is one of the most equitable distributions on earth (Saladin, 2016). The low cost of RWH equipment in Thailand has been a great factor in the number of people who harvest rainwater. The relatively inexpensive nature of Thai Jars compared to alternative means of collecting water is of great benefit. As well, the high quality of mortar ensures a long-lasting product, and the low price of corrugated metal sheets, gutters, and plumbing materials facilitates initial system setup, making it possible for an overall low-cost harvesting system to spread to a wide sector of Thailand (Saladin, 2016). Since RWH has been a part of the Thai culture for centuries, there was no need for a behavioural change in the population, but rather there was a need for a new design to expand and increase collection volumes for RWH in Thailand (Saladin, 2016).

Rainwater harvesting in Australia. Between 1997 and 2009, Australia experienced a decade-long drought that was claimed by some to be the worst drought since European settlement, and was dubbed the Millennium Drought (Low et al., 2015). In June 2009, water storage volumes were at an historic low of 25.6% capacity (Low et al., 2015). Due to the intensity and length of the Millennium Drought, it impacted agriculture, ecosystems, residents, and the economy of Australia. During this time, the city of Melbourne, with a population of 4.3 million people, was able to reduce the per capita water demand by nearly 50% by implementing policy and innovative infrastructure, which included installation of rainwater tanks (Low et al., 2015). The installation and use of rainwater tanks to collect water from roofs increased during the Millennium Drought. Having a rainwater tank allowed residents to continue to water gardens and ornamental plants even during water restrictions, which made installing a rainwater tank desirable (Low et al., 2015). As of July 2005, the state of Victoria was the first to enact the 5 Star Building Standard that required all new homes and apartments to have a rainwater tank for toilet water or have a solar hot water heating system (Low et al., 2015). New homes that have a rainwater tank installed use 20% less piped municipal drinking water (Paltech, 2008). In the state of Victoria, the percentage of households with rainwater tanks increased from 16.7% in 2007 to 29.6% in 2010 (Low et al., 2015). The increased number of rainwater tanks may be because of Melbourne's Living Victoria Water Rebate Program, which provided $850 to $1,500 rebates for installing rainwater tanks (Low et al., 2015). In certain areas of Australia, rainwater is the main source of household water; however, in other areas it is used to supplement conventional water systems (Australian Bureau of Statistics, 2013). Rainwater tanks are common in Australia with exact frequencies depending on the area of the country: 86% of households outside of Adelaide in South Australia and 56% of households living outside of Melbourne in Victoria had rainwater tanks (Australian Bureau of Statistics, 2013). The impacts of the Millennium Drought caused the increased RWH systems in Australia, and were embraced by the public due to the positive effects on the water supply and the lower draw from the environment (Low et al., 2015).

Rainwater harvesting in Bermuda. Bermuda has an average annual rainfall of 1,458 mm that is evenly distributed throughout the year, and a total population of approximately 64,000 (Rowe, 2011). Since the rainfall is evenly distributed, it reduces the capacity required in water storage tanks to meet the needs of those who harvest (Rowe, 2011). In Bermuda, it is difficult to obtain freshwater as there are no permanent streams, lakes are brackish, and groundwater is in low supply (Low, 2016). All buildings in Bermuda are required to have catchment to collect rainwater and storage tanks, as stated by the Public Health Regulations, enacted in 1951 (Rowe, 2011). Rainwater that is harvested can meet all of the water supply needs, though the majority of people supplement with water from untreated private wells, treated commercial and government wells, and from desalination plants (Rowe, 2011). Supplementation of the harvested water is necessary where there is a small catchment (roof) area, higher demand, or lower than normal precipitation (Rowe, 2011). Of the residential buildings, 64% have neither water main connections nor a drilled well, and must rely solely on harvesting rainwater; however, there are supplementary water sources available such as "trucked" water that can be delivered when necessary (Rowe, 2011). According to the Public Health Regulations, it is mandatory that four-fifths of every building's roof be guttered such that 0.45 m^3 of storage capacity is collected for every 0.93 m^2 of roof (Rowe, 2011). Roofs are built from limestone slate tiles that are overlapped with a terraced appearance to more efficiently catch water. Gutter stones along the edges of roofs channel water into holding tanks that are built into the foundation underneath the house (Rowe, 2011). The tank walls are constructed from solid-filled concrete blocks on a concrete slab and waterproofed with a cement-and-sand-plaster. Although the Public Health Regulation states four-fifths of the roof be guttered, it is not enforced; however, those living in Bermuda are aware of the importance and necessity of RWH and have an average of 80% of their roof area guttered (Rowe, 2011). The regulations and requirements of installing RWH systems, along with the lack of ground and surface water resources in Bermuda, have resulted in increased awareness for RWH and raised the number of people who have RWH systems.

Sponsor Background Information

The sponsor for this project is SSIWPA. The membership is made up of representatives from local government, provincial government, and water service providers that together create and propose strategies for watershed management on SSI. The Technical Working Group and Public Advisory Committees support SSIWPA as they are working professionals educated on watershed management and other water related fields. These working professionals obtain and incorporate the perspectives of community members through their work. A sub-group, the Conservation and Efficiency Working Group, is focused on recommending appropriate efficiency and conservation measures to SSIWPA (SSIWPA, 2015).

SSIWPA was originally formed in 2012 working with their mandate "to cooperate on the development and implementation of policies and initiatives for improved raw water quality, and coordinated management of quantity of Salt Spring Island water sources", in conjunction with other SSI committees such as the Salt Spring Island Local Trust Committee (SSIWPA, 2015). SSIWPA has an integrated water management program, which aims to conserve and harvest rainwater in order to reduce infrastructure costs as well as to increase total useable water volumes (SSIWPA, 2015). SSIWPA requires data to provide a baseline on current RWH activities for residential, civic, and commercial land uses. Dromedary Environmental has been tasked with collection and analysis of this data. SSIWPA plans to use this data to make further recommendations within its integrated water management program.

Project Background Information

Water conservation is important because water systems on SSI become stressed due to summer droughts. RWH is an important alternative to supplement conventional water sources, including both ground and surface water sources.

Dromedary Environmental has created and administered a survey to determine water use, conservation methods that are in place, existing RWH infrastructure and use, and possible areas of improvement. Survey questions were posed to residents that already have RWH systems in place for comparison across water districts. As well, home-based businesses and commercial properties were queried to develop an understanding of the possible applications of RWH in a non-residential setting. In addition to those currently harvesting rainwater, the survey was also sent to willing participants on the island who do not have RWH equipment. Information from non-collectors was gathered to help identify barriers to RWH.

Those surveyed were grouped according to eight categories: bed & breakfast operations, small resorts, single family dwellings, multi-family dwellings, small businesses that require above average water supplies, civic buildings, hospital/clinics, and schools.

For commercial categories, the focus of the study was on water usage and possibilities for conservation, with the application of RWH as a possible solution to meet the water needs of the business. Survey data was compiled and analyzed to compare water districts, encompassing surface and groundwater sources.

Households were selected from those that harvest rainwater to investigate how RWH is used to offset water use. Case studies provide examples for those looking to install RWH systems, and provided more insight into barriers encountered for expansion and increased use.

Current Rainwater Harvesting Regulations

The regulations and guidelines are set to ensure that the physical RWH system is maintained and safe for its intended use. Use can be described with two generic categories: potable and non-potable water, each with different regulations. The BC Building Code does not have information specific to RWH, but there are several permits and inspections required for any construction or renovation project on a residential property. The following permits may be needed for a RWH system that is for potable and/or non-potable use: plumbing, electrical, and building. The plumbing permit is needed if the RWH system will be used to supply water in the building; electrical permits are needed for pumps or any other electrical controls the system might need; and footings for storage tanks, foundations, and collection surfaces may require building permits. Also, a grading and erosion control permit is required if the topography of the site is altered extensively.

The recommendations provided by Island Trust in Appendix A are not enforceable, other than the need for permits which are not RWH specific. The use of RWH as a source for residential buildings' water supply requires compliance to the plumbing code as described in Appendix B.

The Water Act Section 12: Application and Decision Maker Initiative Procedures contains the rights of water license holders, and RWH could conflict with these rights which may lead to litigation (The Province of British Columbia, 2017). Licensing is required when diverting water, and applications may be rejected if diverting water from an aquifer or for agricultural use (The Province of British Columbia, 2017). The collection of rainwater is currently defined as a non-licensed water source. According to the water act, RWH could come into conflict with current rights or license holders, as well as environmental flow rates of the hydrogeological cycle. If conflicts are environmental in nature, issues would have to be researched further to create a report to assess the situation. Precedence has been set in the favour of the harvester, as in an 1856 case which ruled that as water falls onto one's property, the property owner's right to improve the land comes before the rights of the water licence/lease owner (Duke, 2014).

Further guidelines for RWH on SSI that are applicable include the *Canadian Guidelines for Domestic Reclaimed Water for Use in Toilet or Urinal Flushing*; this document advises how to use greywater for toilets in order to avoid any health risks and guides management of the system (Health Canada, 2010).

Overall, government intervention is minimal as it applies to RWH systems. Beyond common building codes for plumbing and electricity, the documents that are available are in the form of recommendations and guidelines for individuals to understand and apply, not steadfast regulations. For potable systems, regulations are in place for health and safety reasons.

As a part of the Southern Gulf Islands, SSI is governed by the CRD as an unincorporated entity. This indicates regulations imposed by this governing body must be adhered to by SSI residents. The CRD's major requirement is input and signoff from an engineer for any potable RWH systems (Janyck, 2017, personal communication).

Scope of the Project

The main focuses of this study are the results of an electronic survey, and the developed case studies of RWH systems from single family homes, businesses, and bed and breakfasts. These results will be used to determine existing system designs and uses for year-round occupants of SSI. Survey questions focus on property/business information, water consumption and conservation, and RWH system information including barriers and incentives surrounding

RWH. The survey and case study results provide baseline information on the current extent and use of RWH systems on SSI. SSIWPA will retain this report and compiled anonymized data for use in furthering future studies regarding water resources on SSI.

Objectives

The following objectives of this project were achieved:

- Objective 1: Conduct a survey of SSI residents and businesses to compile RWH information, which will be used by SSIWPA to guide further decision making.
- Objective 2: For three categories, develop case studies based on information provided by property owners currently harvesting rainwater. Make comparisons between water districts regarding RWH use. Survey response will dictate which properties are selected to be involved in case studies.
- Objective 3: Define a theoretically optimal RWH system that applies to each of the case studies representing three categories.

Approach and Methodology

Dromedary Environmental conducted a survey to gather information on the use of existing RWH systems. Convenience sampling was used to select survey recipients, and survey response rate was dependent upon their willingness to participate. Recruitment of participants was aided by attending Earth Day festivities and the Salt Spring Saturday Market. Criterion-based selection was used to determine case study participants based on presence of existing RWH systems and the water district in which they are found. To encourage maximum participation, a free site visit and consultation by Sandra Ungerson (Conservation and Efficiency

Working Group Chairperson) was offered to one random participant. The survey was distributed electronically, and case studies were developed. Based on the survey results, subjects for inclusion in the case studies were chosen. This study was governed by an approved ethical review obtained through RRU, with no additional process required by SSIWPA.

Statistics and the data analysis approach were developed with the help of Jennifer Lindquist. Microsoft Excel was used for data cleaning and management.

Results

Results gathered over the course of this project are included below. These include survey and case study results, as well as RWH and water usage information from residents of SSI.

Survey Results

Table 1 contains survey data for the purchase and need for supplemental water. Overall, supplementary water is not required for Salt Spring Island participants. Table 2 contains survey data for the use of harvested rainwater. The majority of harvested rainwater is used for landscaping and other household uses. Table 3 details the use of harvested rainwater in the landscape. Many gardens, large or small, are irrigated with rainwater, but there are few irrigated lawns. Table 4 displays the survey responses for methods of water conservation currently in use. Water conserving appliance and fixtures along with drought-tolerant landscaping are the most common water conservation methods used, green roofs were not in use. Table 5 contains survey data relating to the amount of time harvested rainwater will last before running dry. These responses show the wide variation in RWH systems used by survey participants. Table 6 details the volume of RWH systems used by survey participants. The majority of survey participants have a small to medium sized RWH storage capacity. Large systems over 10,001 gallons are less frequently used. Table 7 displays age range of survey participants, with the vast majority being over 51 years old. Table 8 contains survey response information on property sizes of survey participants. Properties between one and five acres are most common, with only a few larger than 10 acres. Table 9 details the material of the rainwater collection surface used by survey participants; nearly 50% of participants collect irrigation from an asphalt roof surface. Table 10 contains information provided by survey response on the colour of the RWH cistern. Black tanks are most common. Table 11 describes the storage tank location according to survey results. Above ground tanks are most common, with 89% of responses, while the use of ponds for storage are least common with only 3% of responses. Table 12 contains common filtration systems and UV disinfection used by survey participants. The majority of survey participants use some form of filtration, 16% use UV filtration and 47% use some mechanical form to filter rainwater.

Figure 3 contains data from responses to a survey question regarding the water source for a property. Survey participants use water from well, surface, and rainwater harvesting systems with relatively equal proportions, though surface water sources are used slightly less frequently. Figure 4 contains survey responses for a survey question asking if residents consider their water source to be stressed. Water sources were equally considered stressed and not stressed according to survey participants. Figure 5 is a pie chart showing the variety of water districts surveyed. Most participants were not located within a SSI water district, but seven of the 15 water districts were represented. Figure 6 is pie chart showing the proportion of survey participants that harvest rainwater. Of participants, 41 out of 84 harvest rainwater. Figure 7 contains data from responses regarding the category of a respondent. While the vast majority of survey participants were a part of the single-family category; multi-family, bed and breakfast, business, and resort were also represented. Figure 8 demonstrates the different installers of RWH systems, with 26 of 38 participants installing the system themselves, while the others have hired an experienced person, trades person, or a professional to handle their installation. Figure 9 indicates the barriers to establishing a RWH system. Finances and effort were the most prominent barriers, while time, lack of need, and regulations were also listed as barriers. Figure 10 represents the motivating factors that would encourage the installation of systems. Cost saving methods was listed as the most motivating factors, followed by education, and need. Figure 11 indicates survey responses relating to rebate application. Only eight out of 49 participants have applied to RWH rebates in the past. Figure 12 displays the proportion of survey participants which received a rebate, after application, for the installation of a RWH system. Six out of 44 participants had received a rebate. Figure 13 indicates the perceived usefulness of rebates, with 28 out of 30 survey participants believing a rebate would be useful in encouraging RWH system installations.

Table 1. *Purchase of supplemental water among Salt Spring Island survey participants. Results shown as percent total response for each question.*

Supplemental Water Purchased

No	70
Yes	28
Sometimes	2

Table 2. *Use of harvested rainwater among Salt Spring Island survey participants. Results shown as percent total response for each question.*

Use of Harvested Rainwater

Landscaping	49
Crop Irrigation	17
Livestock	6
Drinking	13
Washing Clothes	5
All Household Uses	6
Showers	3

Table 3. *Use of harvested rainwater for landscaping purposes among Salt Spring Island survey participants. Results shown as percent total response for each question.*

Landscaping Water Use

Regularly Watered Large Garden	39
Rarely Watered Large Garden	8
Regularly Watered Small Garden	20
Rarely Watered Small Garden	18
Regularly Watered Large Lawn	0
Rarely Watered Large Lawn	0
Regularly Watered Small Lawn	10
Rarely Watered Small Lawn	4

Table 4. *Water conservation methods used by participants in a Salt Spring Island survey. Results shown as percent total response for each question.*

Water Conservation Methods

If it's yellow, let it mellow	15
Landscaped Swales	4
Low-flow Showerhead	13
Low-flow Toilets	18
Greywater System	6
Composting Toilet	6
Drought-tolerant Landscaping	12
Efficient Washing Machine	10
Irrigation Ponds	5
Drip Irrigation	0
Low-flow Faucets	7
Green Roofs	0
Reduce Shower Times	1
Rain Gardens	1
Handwashing Clothes and/or Dishes	1
Point-Source Hot Water	1

Table 5. *How long harvested rainwater will last before running dry in collection systems of Salt Spring Island survey participants. Results shown as percent total response for each question.*

How Long Harvested Rainwater Will Last Until Running Out

A Week or Less	8
2 Weeks	21
1 Month	13
1.5 Months	4
2 Months	13
3 Months	8
4 Months	0
5 Months	8
6 Months	4
Never Runs Out	21

Table 6. *RWH collection volume based on Salt Spring Island survey responses, shown as percent total response for each question.*

Total Volume of Rainwater Collection (Imperial Gallons)

0 to 500	21
501 to 2,500	42
2,501 to 5,000	13
5,001 to 10,000	16
10,001+	8

Table 7. *Age range responses from Salt Spring Island survey results, with numbers showing percent total response from each question.*

Age Range

18 to 35	3
36 to 50	7
51 to 70	57
70+	33

Table 8. *Property sizes from Salt Spring Island survey responses, with numbers showing percent total response from each question.*

Property Size

Less than one acre	33
1 to 5 acres	40
6 to 10 acres	20
Greater than 10 acres	7

Table 9. *Material of rainwater collection surface among Salt Spring Island survey participants. Results shown as percent total response for each question.*

Rainwater Collection Material

Metal	24
Galvanized Roof	18
Ponds	6
Asphalt Shingles	47
Cedar Shingles	6

Table 10. *RWH storage tank colour among Salt Spring Island survey participants, shown as percent total response for each question.*

Storage Tank Colour

Black	39
Blue	5
Brown	11
Gravel	3
Green	18
Grey	5
Under-ground Tank	3
White	13
Wood	3

Table 11. *RWH storage tank location among Salt Spring Island survey participants, shown as percent total response for each question.*

Storage Tank Locations

Aboveground	89
Underground	8
Ponds	3

Table 12. *RWH filtration systems for Salt Spring Island Survey Recipients, shown as percent total response for each question.*

Filtration Systems

No	11
Yes	47
UV Light	16

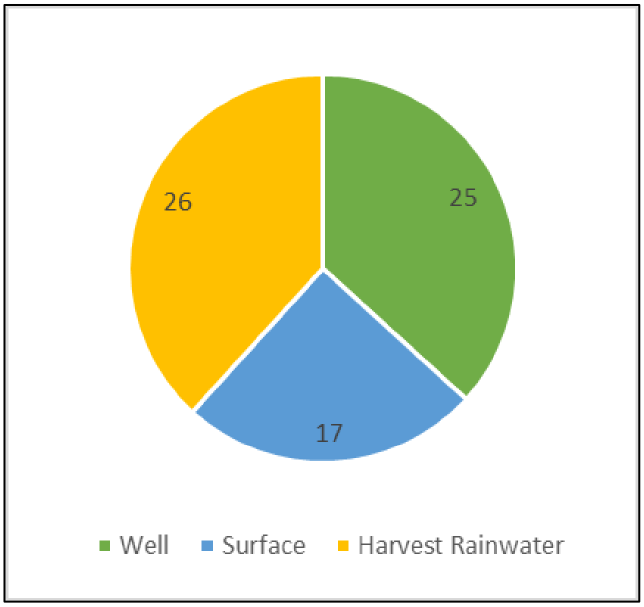


Figure 3. *What water sources apply to your property; well water, surface water, or harvested rainwater (n=68)?*

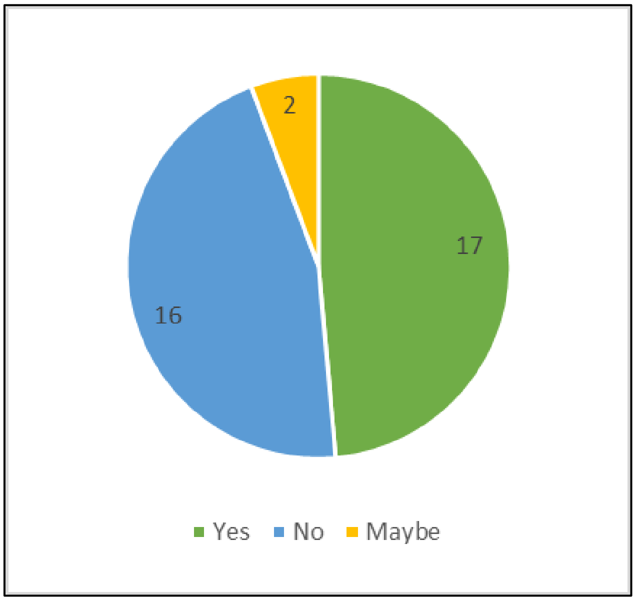


Figure 4. *Do you consider your water source(s) to be stressed (n=35)?*

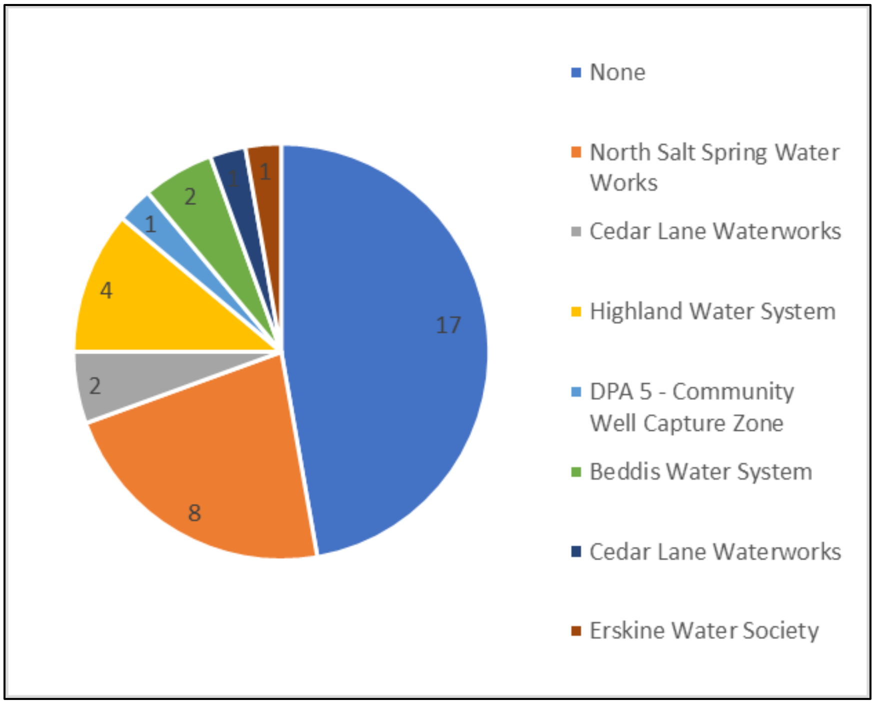


Figure 5. *What water district is your property located in (n=36)?*

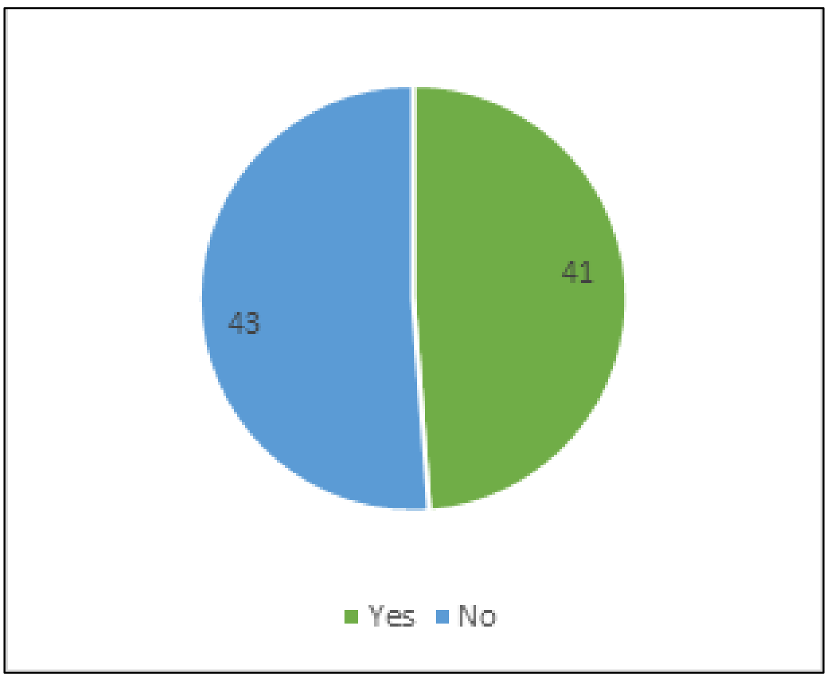


Figure 6. *Do you harvest rainwater (n=84)?*

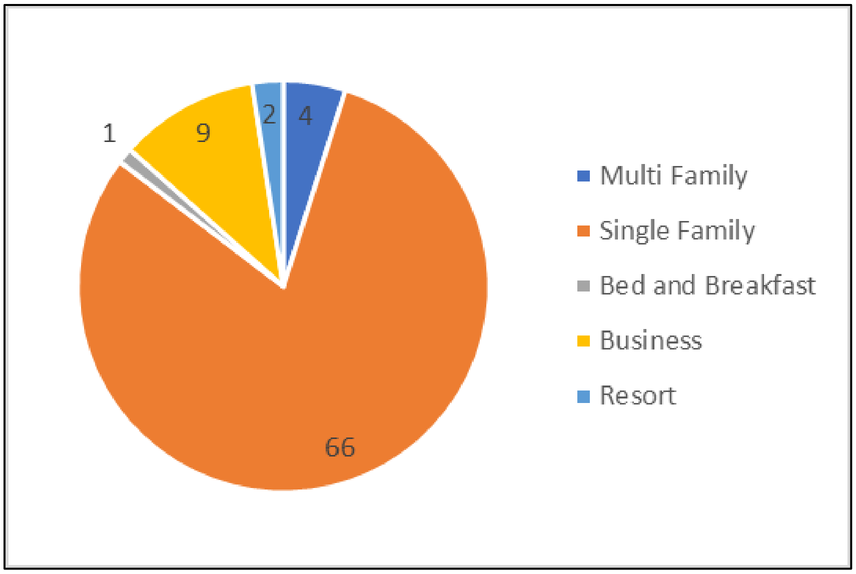


Figure 7. *What category do you belong to (n=82)?*

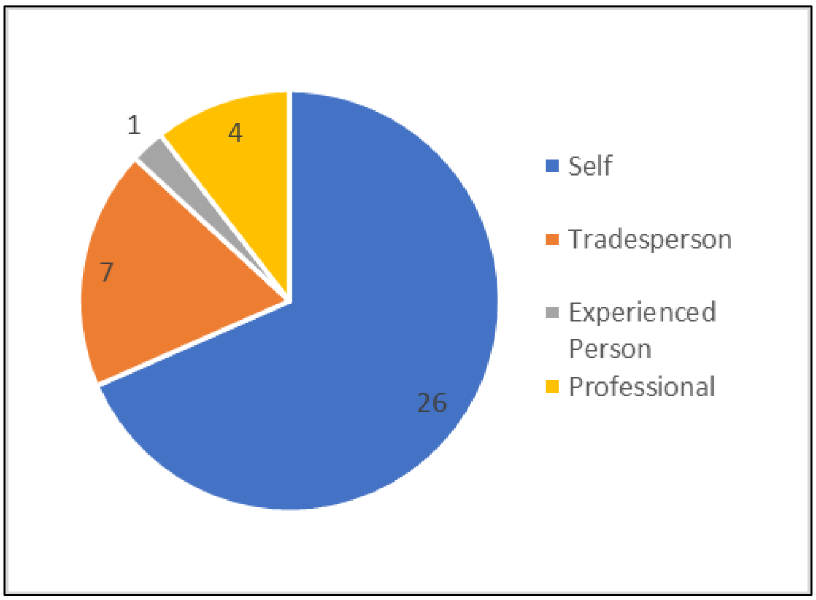


Figure 8. *Who installed your system (n=38)?*

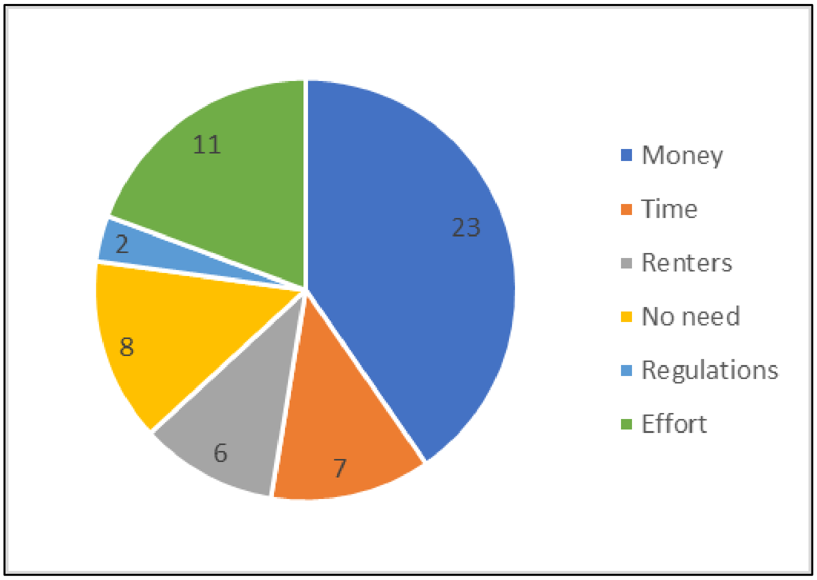


Figure 9. *What is preventing you from harvesting rainwater (n=57)?*

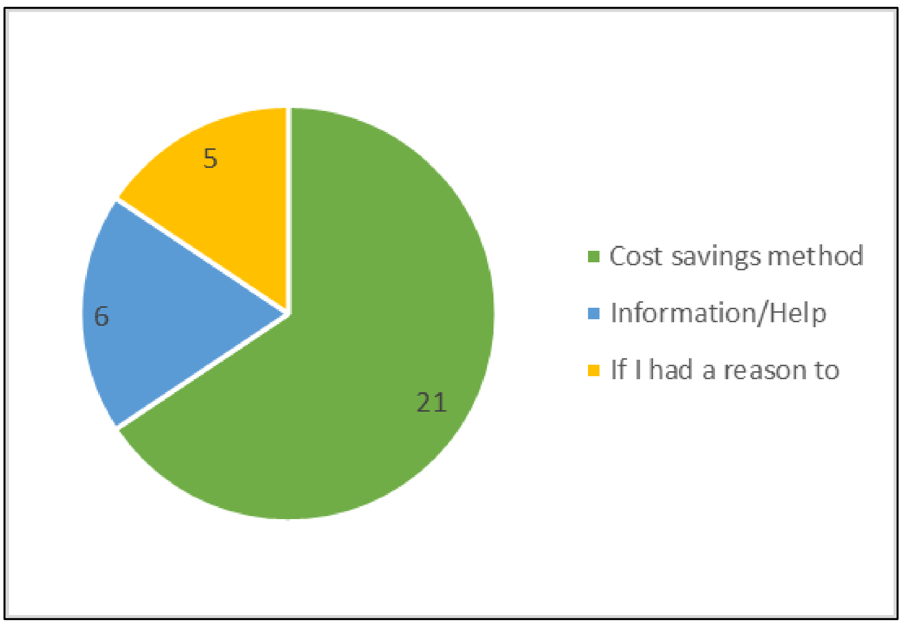


Figure 10. *What could motivate you to start harvesting rainwater (n=32)?*

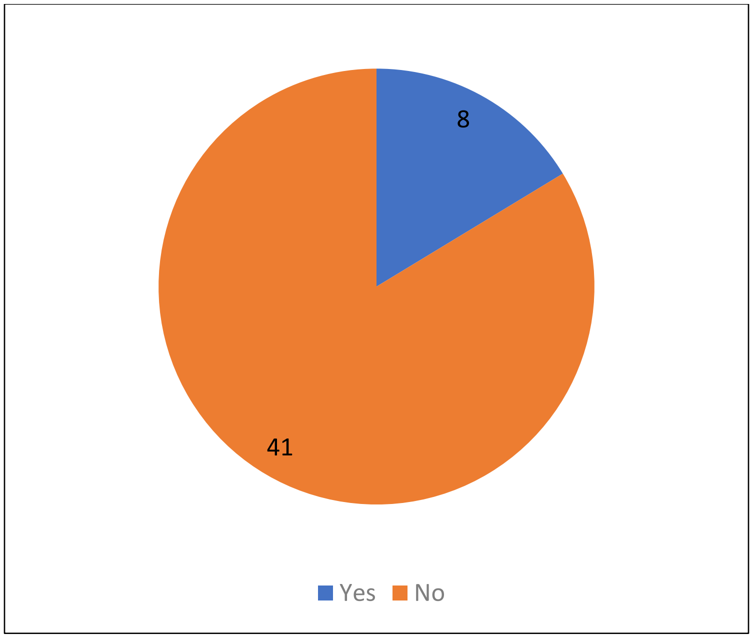


Figure 11. *Have you applied for any RWH rebates (n=49)?*

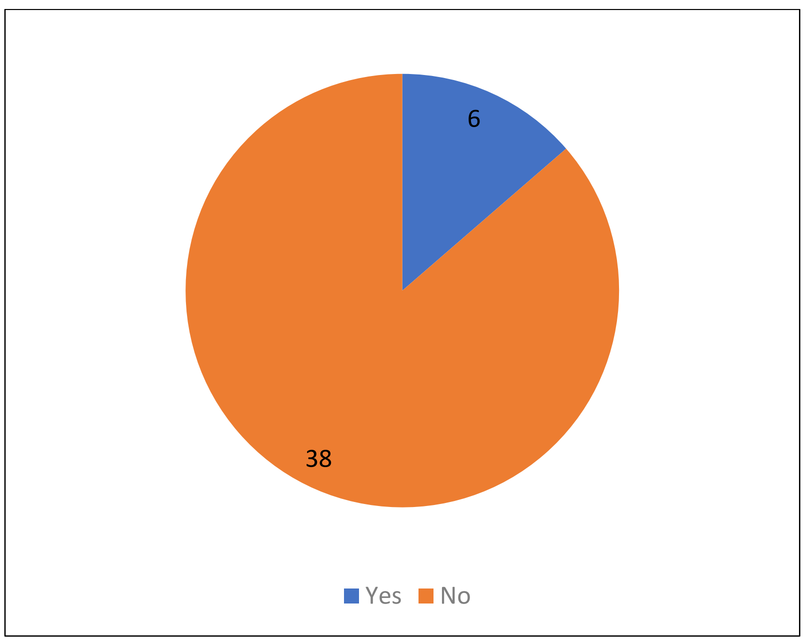


Figure 12. *Have you received any RWH rebates that you applied for (n=44)?*

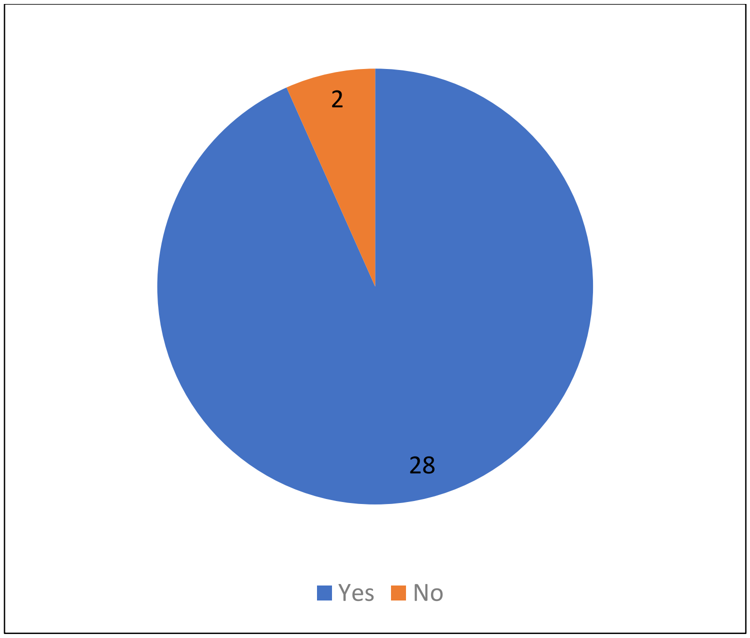


Figure 13. *Are rebates a useful method of encouraging you to install a RWH system (n=30)?*

Case Study Results

This section includes the results of the nine case studies that were developed. Bed and breakfast operations (designated B1, B2, and B3), businesses (designated C1, C2, and C3), and single-family dwellings (designated S1, S2, and S3) were the three categories that were selected for the completion of case studies. Phoenix Elementary school was also selected to represent the RWH potential for civic buildings, but will not be compared to other case studies. To maintain anonymity of participants, case study properties will be referred to by their case study numbers as noted above.

Case study B1 is located in the North Salt Spring Waterworks District and uses rainwater as their sole water source. Images of this case study are included in Appendix D, Figure D1. The water that is collected is used for the main residence and for the bed and breakfast guests on the property. The homeowner has been collecting water since 1997 when the home was constructed with the help of an engineer. Rainwater is collected from the metal roofs of all the buildings located on the property. The main water storage is a 40,000 gallon concrete tank built into the foundation of the main house. The dimensions of this tank are 20 feet x 45 feet x 7 feet, and it is divided into four sections. Water is passed through sand filters and a settling area before it enters the storage tanks; however, there is no first flush system. Before the water is used, it is passed through a UV filter to ensure its potability. Hot water passes underneath the house's concrete floor, which provides heat through conduction and lowers the heating energy costs. Since the main water storage tank is made from concrete, there are no concerns about UV degradation to the system. The system is typically filled to capacity around December. The homeowner is not overly water conscious in the winter due to high water availability, but becomes more water conscious during the summer when water is scarce. The homeowner has never bought bottled water or supplemented their water use with another water source.

Case Study B2 is not located within a SSI water district and relied on a well for water prior to installing their large pond which functions as a RWH system. Images of this case study are included in Appendix D, Figure D2. The pond was installed in 2011 to ensure well water would be sufficient for domestic use by guests and owners of the bed and breakfast. The pond is 10 feet at its deepest point, holds approximately 300,000 gallons, and is used to offset irrigation water consumption of the extensive gardens onsite. The pond receives rainwater collected from the metal roof of the main building as well as water runoff from higher elevations on the property. The collected water is run through a gravel filter before entering the pond where goldfish and pond plants create a no-fuss natural ecosystem that needs little maintenance. A pump in the pond drives the underground irrigation for the gardens and an overflow allows excess water to flow downhill from the pond and off the property. The pond can be topped up with the well water in the summer to prevent the liner from showing for aesthetic purposes. The cost of the installation for the system may be prohibitive for many individuals, but adds a lot of value for this bed and breakfast; not only does this provide peace of mind for the owners by ensuring sufficient well water for use, but it also adds to the beautiful setting of the bed and breakfast with an acre of gardens and a picturesque pond on the property.

Case study B3 is located in the North Salt Spring Waterworks district. Images of this case study are included in Appendix D, Figure D3. The homeowner has lived on this property for six years. This 5.2 acre property uses surface water as their main conventional water source and has a collection pond on the site. The collection pond is unlined but it has a clay bottom and a stream feeding the pond to replenish water. The property has as a fruit orchard and garden with cherry, fig, plum, and apple trees; tomatoes, blueberries, and vegetables. The pond has a two-horsepower pump with a hose and dripline used to water the plants close to the pond, which include the blueberries, tomatoes, and some fruit trees. The homeowner stated that the water level of the pond goes down 30 - 60% when using it for irrigation. The homeowner is considering using rainwater for the vegetable garden, which is further from the collection pond since there is another pond on the property near the vegetable garden.

Case Study C1 is a business property serviced by the North Salt Spring Waterworks which uses St. Mary's Lake along with community wells to supply properties. Images of this case study are included in Appendix D, Figure D4. This type of business typically uses upwards of 20 L/m^2 daily (Bilderback, Dole, Sneed, n.d., pp. 1). Water use at this site is considerably reduced, using only 3.6% of the water used by similar businesses, through the implementation of many water conservation techniques (Personal communication, 2017). The rainwater harvested on this property is used primarily for irrigation while also providing important habitat for local amphibian populations. Rainwater has been harvested on this property for over 40 years. The current system is composed of two large collection ponds capable of holding approximately 350,000 gallons, collected over eight months, and an above-ground pool for treating water with chlorine which is allowed to off-gas prior to use. Run-off from the property is directed towards surrounding native trees to support their health so they can continue providing shade to the site to reduce evaporation and the frequency of irrigation. Motivation for RWH in this setting was the limited supply of water through North Salt Spring Waterworks along with the desire as an environmentalist to support natural systems through alternative means.

Case study C2 was located within a Development Permit Area 5-Community Well Capture Zone. Images of this case study are included in Appendix D, Figure D5. The owner of this small business has lived on and owned the property for one year. The previous owner had set up the RWH system and was an employee of a local water works facility. The system includes a custom water sprinkler setup with a powered pump for irrigation and is supplied by three holding tanks with a total volume of 6,600 gallons. The dark green holding tanks are used to water the gardens every two days for 10 minutes, and the gardens are also mulched to increase water retention. The workshop is the only collection surface which has asphalt shingles. In the case of overflow and during pollen season the system has a diverter to direct water into the environment, mitigating any overflow or introduction of pollen into the storage system. The tanks are dug into the ground for structural support, and use a bucket with wire mesh and netting for large objects/particle removal. The small business owner says that collection is often stopped in February as the tanks are full. The business/property owner does not have any future plans to expand the system as of now because the current needs are met. The property is on a well which provides water for domestic use, and has not gone dry. The owner said that their water consumption awareness has increased due to the visible recognition of how much water is used to water the gardens. The owner is planning to grow a small plot of fruit on their land for use in the production of their product. The RWH system will be used specifically for this fruit crop. The owner said the largest barrier encountered was the learning curve as the system was inherited with the property purchase. It took some time to understand what cleaning and maintenance was needed for proper upkeep of the system.

Case study C3 is in not located within a designated Salt Spring water district and uses RWH for watering of their gardens, as the well water for that property is too hard and salty. Images of this case study are included in Appendix D, Figure D6. The system was installed by the property owners with input from contractors and volunteers. Rain is collected off a small metal roof which fills a 2,100 gallon black cistern. The tank was repurposed from a previous project, and fills over the winter. The only possible plan for expansion is the addition of tanks, should capacity run out. While harvested rainwater was not used for business purposes, it was used for irrigation which added to the atmosphere of the business.

Case study S1 represented one of the single-family dwellings on SSI. Images of this case study are included in Appendix D, Figure D7. It is located in the North Salt Spring Waterworks district and uses surface water from St. Mary’s Lake. The harvested rainwater is mainly used for irrigation purposes, though some water is used for drinking throughout the summer due to concerns of water quality deterioration in St. Mary’s Lake. This home has been harvesting rainwater for approximately 15 years. The RWH system consists of three 1,000 gallon black plastic tanks. Water is collected on the metal roof of the 1,000 square foot house and directed using five inch gutters with leaf guards to a first flush system followed by a sand filter and then into the tanks. The three tanks are set on a gravel base and enclosed on three sides by a sturdy wooden structure. The sand filter is cleaned out twice a year. Water flows into a sediment filter, which is changed four times a year, and then passes through UV light for disinfection. Water is then moved uphill using a small ¾ horsepower pump to the upper garden and house, or is fed to the lower garden by gravity. As mentioned by the homeowner, the tanks usually fill to capacity by Christmas, and at the time of our site visit in mid-April, the tanks were still at capacity. It was estimated that the water in the three tanks can supplement six months-worth of water use. The concerns of the homeowner were issues with lowered municipal water quality in the summer, including cyanobacteria contamination and a strong chlorine taste. High cost and regulations were identified as barriers to RWH systems. It was mentioned that it is difficult and expensive to have an engineered system, which would lower the draw for others to install RWH systems. Increasing parcel taxes were viewed as barriers to RWH, since everyone pays the same amount regardless of how much water the home uses.

Case study S2 is a residence within the Erskine Heights Water District located on the north-west side of SSI. Images of this case study are included in Appendix D, Figure D8. This system is currently a black single aboveground 1,100 gallon plastic cistern, with future plans to install a second container underground. The system is gravity driven and rainwater is collected off the glass conservatory roof, with future plans to collect off the main asphalt roof by installing a gutter system. The home owner is not concerned about any potential adverse health effects from the asphalt shingles as they believe that the roof has been sufficiently weathered of any possible contaminants. Although they would test the harvested water for any contamination collected from said asphalt shingles if any health issues arise with the plants that would be irrigated with the collected water. The homeowner's current harvesting use is purely irrigation for the vegetable garden, making the system non-potable with no plan of having a potable system in the future. The garden has been intentionally located in an area that gets shade during the hot afternoon sun. They have also built up the soil and added mulch for better water retention. This is all part of the homeowner's design to reduce the amount of water needed for the vegetable garden, which they say uses 50 gallons of water per day. The current system supplies irrigation water for two months during the summer before running dry. The barriers this homeowner perceives to be important regarding RWH on SSI are: cost, time, labour, and space. The homeowner feels that getting the water tested would be very expensive. A lot of time is required when designing and installing a system, as the homeowner performs all the labour for their system from the construction to the general maintenance. Any systems larger than the homeowner's current non-potable water system would take too long to build and maintain. The next barrier to expanding the current system is adding a new tank to uneven ground. The homeowner has purposely installed the current cistern concealed under the deck and behind plants and screening for aesthetics purposes. The homeowner's motivation for RWH is that they feel it is what a good ecological citizen should do and they are always encouraging others on SSI to start RWH. As well, the homeowner voiced that an incentive like a tax break would greatly help RWH on SSI, beyond the savings and gains when comparing RWH to purchasing water.

Case study S3 is a single-family dwelling found in the Highland Water district which uses St. Mary's Lake as their main water source. Images of this case study are included in Appendix D, Figure D9. The rainwater harvested on this property is used for irrigation and watering of the large vegetable gardens as well as fruit trees and some ornamental plants. The system is composed largely of repurposed materials; three large tanks are placed in front of the house, four medium sized rain barrels under the deck, seven rain barrels by the fence, and a food shipping container made of white plastic with a galvanized steel cage is used as a 1,000 liter cistern to collect rainwater off the small greenhouse roof. All other collection occurs off the main house's metal roof. Overall tank volume is estimated as 5,000 liters, with the entire system being gravity fed through PVC piping and silicon hosing. The motivation for this family to harvest rainwater included: resource conservation, savings as city water is not used as much, not wanting to put overly chlorinated water from the lake on plants, and the ability to steer water to specific areas of the property, with the overall motivation being a conservationist mentality.

Phoenix Elementary School on Salt Spring has been using a RWH system since April 2017, and staff was excited to share their successes with us. The school's system is shown in Appendix D, Figure D10. They are located in the North Salt Spring Water District. This system was set up to provide water for the school's garden to avoid the limitations from SSI water restrictions which limited watering to odd days only. The garden is accessible when volunteer parents can come to help with watering. Thanks to community volunteers and involvement, help from Windsor Plywood, and a grant from the SSI Foundation, this school was able to bring about this RWH project. Education is key, and this project emphasizes the importance of growing sustainable food, responsibility through setting up a watering roster, connection between the children (five to 11 years old) and the community through a market garden, and the development of business skills. As a result of the project, Phoenix students are learning a lot more than reading and writing. Limited rainwater collection occurs off the small roof used to provide shade for the two black 1,100 liters tanks, as the school's roof is asphalt and therefore not suited to RWH.

Optimal Rainwater Harvesting System

RWH systems can be customized to supply each site with rainwater to offset conventional water sources. Optimal systems will provide water for both potable and non-potable uses to the full extent that local precipitation allows. The actual components and design of the systems will vary based on specifications of the site. Optimal RWH systems should coincide with water conservation habits and practices such as: high efficiency appliances and fixtures, low-flow toilets, drought-tolerant landscaping, and grey water systems. Considerations affecting RWH system and design decisions include:

- Uses;
- System structure;
- Materials;
- Maintenance; and
- Conservation methods.

Many resources exist for design and use of RWH systems, such as *The Texas Manual on Rainwater Harvesting* (2005), Guelph's *Residential Rainwater Harvesting Design and Installation Best Practices Manual* (2014), and Nanaimo's *Rainwater Harvesting Best Practices Guidebook* (2012), therefore this report will only provide a brief overview of the system.

Rainwater use. The intended use of the rainwater will, in large part, determine the most suitable materials and system design. Harvested water can be non-potable for use outside for irrigation, outdoor chores, and fire protection, or inside for use in toilets and for laundry. Rainwater can also be made potable to supply drinking water and to fill water needs in the home.

Rainwater harvesting system structure. System structure includes considerations such as collection surface and conveyances systems, tank location, filter and flush system requirements, protection against pests, water treatment, tank overflows, rainwater distribution, and necessary redundancies (Texas Water Development Board, 2005, p. 5). Optimal systems will increase efficiency and simplicity by making use of gravity fed systems. The feasibility will depend on building construction and site slope, but storage tanks should ideally be located at an elevation higher than where the water will be used. If necessary, smaller storage tanks can be located at the collection site and a renewable energy pump can be used to move this water to the main storage tank. The benefit of this system is that the main source of water is available at all times, and pump failure will only result in a temporary loss of water collection.

Rainwater harvesting materials. Certain materials are better than others for RWH. The main concerns involve the leaching of harmful contaminants into the water and buildup of foreign materials on the surface. Water quality from RWH systems is affected by the climate and environment, catchment surface, storage tanks, as well as system filtration and overflow setup (CMHC, 2012, p. 30).

The rainwater collection surfaces are most often the roofs of buildings onsite. Ideally these surfaces, and all system components, will be made of materials that will not leach toxins into the water. Ideal materials include (RDN, 2012):

- For roof surfaces:
    - enamelled steel;
    - terracotta; and
    - slate.

- For gutters:
  - coated aluminum; and
  - vinyl.
- For storage tanks:
  - opaque high-density polyethylene;
  - metal; and
  - concrete.

Materials that contain potential toxins and/or the ability to alter water chemistry should be avoided, these include (RDN, 2012):

- cedar shingles;
- newer asphalt or fibreglass shingles;
- copper and lead roof and flashing materials; and
- composite roofing.

Longevity of materials can be improved by installing storage tanks and conveyance pipes underground to reduce UV and other environmental damage.

Rainwater harvesting system maintenance. RWH systems require some regular cleaning of the collection surfaces, filters, and screens. Regular cleanings and inspections will make sure the RWH system is fully functional, does not pose a health risk, and is not leaking; however, it is believed that the formation of biofilms in collection tanks could be useful in removing heavy metals and organics from collected water, and reducing the viability of potentially harmful organisms (Spinks, Coombes, Dunstan, and Kuczera, 2003). Having adequate filtration systems in place to remove particulates from rainwater before it enters storage tanks will reduce sediment buildup in the tanks. Diverting water from tanks during pollen season is necessary to prevent these small particles from clogging filters and entering storage tanks (RDN, 2012).

Water conservation methods. As noted by survey results, the most prevalent water conservation method is the use of high efficiency appliances. High-efficiency dishwashers and washing machines, along with low-flow toilets, faucets, and showerheads are common fixtures in people's homes. Adjusting daily habits can significantly decrease water use by reducing the length and frequency of showers, rarely washing vehicles, and following the "if it's yellow let it mellow" principle for toilet flushing.

Maintained gardens and yards require large amounts of water. This consumption can be reduced by employing many common practices:

- mulch gardens to prevent evaporation from soil and extend time between watering;
- plant and maintain trees around the property to provide shade during the hottest times of the day;
- convert turf grass to yarrow, clover, or moss, or allow lawns to go dormant in the summer by not watering;
- water deeply and less frequently to encourage deep root systems more capable of handling drought; and
- plant native and drought-tolerant gardens that require less water.

Grey water systems are also extremely useful for conserving water. Basic grey water systems could be as simple as keeping a bucket under the sink to collect water to use in the garden. More complex systems have additional plumbing to fill toilets and washing machines or direct water to gardens that has been filtered after use in kitchen and bathroom sinks. Grey water systems aim to reuse water multiple times before it is considered wastewater. Regulations are currently being developed by the BC Ministry of Health to guide grey water system and composting toilet installations in BC (Ralston, 2016).

Discussion

Below is a discussion of results gathered over the course of this project, including an interpretation of case study and survey results, as well as the major barriers and success factors regarding RWH systems.

Survey Interpretation

Due to the nature and scope of this project, data collected did not allow comparisons between those who harvest rainwater and those who do not. Due to the qualitative nature of data collected, statistical analysis is not an effective method for comparison. The interpretations below provide preliminary insights into water issues occurring on SSI.

As data indicates, of the residents that answered the survey, 70% did not need to purchase supplemental water (see Table 1). SSI has a total population of 10,557 people (Statistics Canada, 2017), and extrapolation of the survey results indicates that 3,167 people need to supplement their supply of water. This may be a biased extrapolation as survey results are only representative of those harvesting rainwater. Both bulk water and bottled water can be purchased from local sources, which may in fact be exacerbating the water issue on SSI (SSI Water Council, 2016). Purchasing local bulk water not only further disconnects users from the issue of water scarcity, but also strains the groundwater surrounding the bulk water collection site. The population of

SSI is restricted in their water use as evidenced by the need to purchase additional water and that no further water licenses are being allotted (Kerr Wood Liedal, 2015; North Salt Spring Waterworks, 2017). The limited water licenses can be seen as a problem from a community standpoint, as some people are paying the price for SSI's stressed water sources; those without a water license are unable to access local resources due to the overconsumption by some residents. Recent development and a population increase of 3.2% from 2011 to 2016 (Statistics Canada, 2017) have only reduced the availability of water, and could result in future friction between the haves and have nots. The population growth on SSI will likely continue based on recent census trends, providing water resources are available. Limited water resources mean that societal friction will likely result from differences in water consumption, where some residents are unconcerned with water conservation, while others ration every drop to ensure long-term water sustainability.

Of the survey participants that do harvest rainwater, 49% use it for landscaping needs (see Table 2). Through case studies, it was found that participants considered the lack of water throughout the summer in the development of their landscaping and gardens. Participants noted the use of mulch to reduce water evaporation and the planned placement of garden beds. The placement of garden beds has been used to reduce water loss due to overexposure to the midday sun, as this is usually the warmest part of the day, and subsequently causes the greatest water loss from the soil (Litvak & Pataki, 2016). Participants mainly use the harvested water for gardening purposes, with 86% having a garden, of which 47% are considered large (see Table 3). Of large gardens, 39% are regularly watered and 8% are rarely watered. Only 10% regularly water their lawns (small lawns), which is an indication that residents of SSI do not favor ornamental vegetation like lawns; furthermore, 17% use the harvested rainwater for direct irrigation of crops and 6% use it for livestock. Land and garden sizes were subjective as defined by the participant.

Survey response data shows that individuals are not only trying to conserve water outside of their home, but also inside. Many individuals have low flow toilets and showerheads, efficient washing machines, and flush their toilets less frequently (see Table 4). Some individuals also reported having greywater systems and composting toilets, which greatly reduce water use in the home. Many survey participants indicated a lack of knowledge regarding design and installation, as well as the need and application of RWH systems; more education may be needed to provide direction for design and installation of RWH systems and to encourage water conservation practices.

Table 5 indicated the storage capacity of harvested rainwater which ranged between a week or less to effectively indefinitely. 21% of participants indicated their supply would last two weeks, while an equal 21% suggested that their supply had never run out, with the remaining 58% stating their supply would last several months. These results show the variation in system size, with larger cisterns lasting longer, and smaller tanks inevitably running out sooner. Most residents use their water harvested supply for landscaping and irrigation, while individuals' yard and crop maintenance practices are specific to each person. Case study results show some people would water their property every two days as part of habitual property upkeep, while others would only water at the first sign of wilted plants which allowed the resident to extend their stored water supply. The water use practices for vegetation on a resident's property are important, but are ultimately limited by the volume of supply the individual has. Islanders that answered the survey had holding systems ranging between 500 gallons (21%), 501 to 2,500 gallons (42%), 2,501 to 5,000 gallons (13%), 5,001 to 10,000 gallons (16%), and greater than

10,001 gallons (8%) (see Table 6). The most frequently used collection vessels are in the 501 to 2,500 gallon range, which indicates that this size is optimal for meeting average SSI water needs, assuming no barriers prevent expansion of the system. The size of the storage system would vary based on occupancy, affordability, the average water consumption, and other factors which all contribute to uncertainty in an optimal system. The survey showed 57% of residents belonging to the 51-70 age range, and 33% in the over 70 age category, combined that is 90% of the survey participants (see Table 7). Older residents are equivalent to younger residents as described by water usage, with per person consumption acting as a better indicator of consumption than age (Koegst, Tranckner, Franz & Krebs, 2008).

The survey did not provide sufficient information to compare household income to RWH catchment volume, but in future studies this relationship would be interesting to explore since the largest barrier identified in this study was financial means. It is expected that a higher income would correlate to increased volume of harvested rainwater, but it is also possible that individuals with a lower income and a passion for conservation would find the means to increase storage despite financial barriers.

While properties of one to five acres represent 40% of participants, 33% of participants are living on less than one acre (see Table 8). Case study observations indicate that the level to which individual properties have their landscape altered is highly dependent on an individual owner's preferences. Some people have completely manicured properties, formal garden beds, and engineered ponds, while others let the natural vegetation and topography dictate their landscaping practices. The collection surface for RWH was predominantly asphalt shingle roofs (47%) (see Table 9). The use of asphalt shingles for non-potable use is acceptable for RWH, as any contaminants in the roof runoff are less likely to cause harm. Of collection vessels, 39%

were black cisterns (see Table 10). The black colour is effective at preventing the infiltration of sunlight which would otherwise allow photosynthetic microbes like algae to grow in the cistern (Texas Water Development Board, 2005). Most of these cisterns in this study are above ground, with 89% of residents opting for this method of storage (see Table 11). Above ground storage tanks are easier to install and are opaque, making burial unnecessary. No form of filter is used for 11% of participant's RWH system (see Table 12); this is likely due to the use of rainwater for landscaping purposes which do not require filtration.

The type of roofing material used a collection surface may impact the water quality of the harvested rainwater as metals, nutrients, and organic compounds may leach from these surfaces (Nicholson, Long, Clark, 2006). In the past, it was believed that as roofing ages, the amount of substances leaching decreases; however, that statement is not true. Pollutants can be released at any stage in the materials' lifespan, but studies suggest that there are two periods that pose a concern: the early and late stages (Nicholson, Long, Clark, 2006). When the roofing material is initially installed, sealants and other surface contamination will wash off when rainwater runs over the surface; however, this decreases over time (Nicholson, Long, Clark, 2006). As materials age and weather from fluctuating temperatures, UV-radiation, occasional storms, and interactions with the roofing materials and compounds in rain, newly exposed surfaces can be created (Nicholson, Long, Clark, 2006). These surfaces were not expected to be exposed and, therefore, may not be sealed to prevent degradation, which can lead to additional compounds leaching from the roofing material. Pollutants released from roofing material can pose a risk to ornamental plants, and fruits and vegetables, which may create a potential health risk. Some materials are more likely to release pollutants or are more susceptible to degradation (see Optimal Rainwater Harvesting System section above).

As shown in Figure 3, of the 68 responses to this question of our survey, 38% used harvested rainwater in some capacity; 25% use surface water, which can include lake licenses, direct piped water, or retrieval from lakes and streams; 37% indicated wells are their property's water source, which can include community or private wells. The majority of participants use rainwater, demonstrating its prevalence on SSI while illustrating the potential for improvement. From Figure 4, approximately 50% of survey participants believe their water source is stressed. This poses a problem, as many of the responses to the question of why RWH is not being done is the lack of requirement. There is a misunderstanding that water is plentiful and can be considered not stressed which may lead to issues in the future. Through research and sharing of these findings, the hope is to alleviate this information gap and help residents understand that, while their well may not run dry, water needs to be conserved at all costs. The chart in Figure 5 shows the variety of water districts which were surveyed. North Salt Spring Water Works covers much of SSI, which is in agreement with the observation that the majority of responses came from that district. Residents of SSI which harvest and do not harvest rainwater were surveyed to determine what barriers are present to setting up a system, as well as to understand details of what the current state of RWH is. The survey participants comprised approximately 50% harvesters and 50% non-harvesters, which is shown in Figure 6. As demonstrated in Figure 7, the majority of responses were from single family homes. This is likely due to the most common use of harvested rainwater being for irrigation. Businesses that harvest are likely doing so for use on their property and gardens, as opposed to for use in their business specifically. As illustrated in Figure 8, many of the RWH systems on SSI are self-installed. This is understandable based on the relative ease with which these systems can be set-up when used strictly for non-potable water needs. Some help from tradespeople or experienced persons was used, with very few professionals involved in RWH system setup.

A wide variety of barriers were identified for the establishment of a RWH system, and are shown in Figure 9. Many of the barriers were expected, such as money and time. It was communicated from case study participants that regulations were a large issue, with some people perceiving RWH as illegal. In contrast, according to survey responses, this does not appear to be the case, with regulations posing only a small hurdle. From communication with experts in the field, regulations should not pose an issue for RWH system installation. One surprising barrier was the understanding that there is no need to harvest rainwater. This may pose a greater issue to not only RWH but also water resources as a whole on SSI. Similar to the barriers to setting up a RWH system, motivating factors, shown in Figure 10, include providing money or information. Another key area that would motivate islanders to harvest rainwater was generically classed “if I had a reason to". This is somewhat worrisome as it highlights the lack of understanding of the need to protect the scarce water resources on SSI. Figure 11 indicates responses to questions about rebates that were offered in the past. Of the eight participants that applied for rebates, six received a rebate. It was also noted that 93% of participants would be encouraged to install a RWH system if rebates or incentive programs were offered.

This report established that the entire island is limited in its ability to meet the water demands of the population through surface and groundwater resources. This is demonstrated by water licenses no longer being issued, residents experiencing different degrees of water stress, and the variation in water quality and abundance within water districts considered to have unstressed water resources. SSI’s geology is not conducive to groundwater storage which further limits water availability. As such, water district comparisons can be used to indicate behavior changes or areas where education is needed. It fails to establish the storage capacities of each district as the survey was qualitative but this is something that could be pursued in future studies that may be undertaken based on the preliminary results provided by this study.

Case Study Interpretation

Within each category that was visited for case studies, water use and mentality of conservation varied. In most cases, rainwater was primarily used for irrigating vegetable or ornamental gardens. The second objective of the study was to compare case studies across water districts. This objective was not met as single water districts have variation throughout their boundaries, resulting in differences between properties located in the same district.

In the bed and breakfast category, all properties used rainwater mainly for garden irrigation, except for B1 where rainwater was the sole source of drinking water. Property owners all had a collection pond to store water, with some ponds also constructed for aesthetic purposes for the bed and breakfasts. Though the use of RWH reduces conventional water use and lessens the stress placed on wells and surface water, B3 did not install their system with a conservationist mentality or to save money. The collection pond already existed, and RWH was simple. B1 and B2 showed interest in conserving water, which was the main reason for installing their RWH system. Whether the system is preexisting or developed by the resident, the investment in RWH is subject to the individual. Inheriting a system may improve your awareness towards water conservation.

In the business category, only C1 used rainwater directly for the operation of the business. In all three cases, conventional water use was reduced, water consumption awareness was increased, and the use of conservation methods and practices, such as mulching, were increased.

In the residential category, all properties used rainwater mainly for garden irrigation, except for S1 where rainwater was also used for drinking. Drinking or applying chlorinated water to plants was a concern in S1 and S3, and was a driver for installing a RWH system. All homeowners stated the main reason for installing a system was to reduce water costs and lessen the stress on the conventional sources. The cost of installing their RWH system was identified as a barrier, and incentives such as tax breaks and parcel tax reductions were identified by S1 and S2. All property owners have become more conscious of water use and have increased water conservation methods.

All case study properties visited showed a variety of RWH systems and collection methods, and gave insight regarding how water was being used and the concerns of property owners.

The survey and case studies were successful in contrasting the perceptions of the residents, as some individuals contained within the same water district had different perceptions of the level of stress of their water source.

Limitations of the Study

Sources of error that occurred over the course of this project include errors relating to the survey and case studies. Firstly, the survey that was created was only available online; this posed a problem with survey accessibility. Potential survey participants with RWH systems were possibly missed because they did not have access to the internet. One of the case study participants was found via word-of-mouth and, when the homeowner was asked to complete the survey, they stated they did not have internet access. This case study participant would not have been located if it were not for the helpful contact who pointed out this property.

There were also possible errors in answers to the survey questions. Some questions had defined answers, such as a “yes/no” options or a “select all that apply”, which made analysis simpler; however, some questions had open-ended response options. There was error in turning written responses into defined categorical answers and, in a few cases, the responses to questions were vague or not completely understood. Using group discussion and best judgement, answers were separated into categories; nevertheless, responses may have been inaccurately categorized, which could have skewed response and analysis.

In addition, when participants answered questions regarding volumes of water, in some cases units were not included in their answers. This posed an issue as tank volumes are either measured in metric liters or imperial gallons, making it difficult to determine the correct volume. To correct this problem, all volumes without units were assumed to be imperial gallons, ensuring continuity of responses but possibly introducing errors. Imperial gallons were the assumed unit used as storage tanks volumes are commonly given in these units. Additional sources of error could arise from the participant’s subjectivity of what would be considered to be a small or large garden.

When creating the survey, questions might have been missed that would have provided a better understanding of systems located on SSI. As well, some questions may not have been clear to participants, and misunderstanding of the intent of a question may have occurred. Interpretation of the terms landscaping, gardening, and vegetable gardening may have also been confused, leading to errors when water use was described.

The survey design itself also posed errors in response. Depending on the answers received to particular questions, the respondent was directed to the next set of questions to streamline the process and to prevent answering questions that did not apply to their situation.

There was an error in either Google Forms or the survey options that prevented the survey from flowing properly, which caused an entire section (Business Information) to be skipped in the survey. This error was not discovered until survey responses were no longer being accepted. The "Business Information" section had specific questions related to the business property. Analysis comparing business and other property types could not be completed due to this error. This is a comparison that could be undertaken in a follow up project.

Furthermore, planned chi-squared statistical analysis could not be completed due to the design of the survey. To ensure that only SSI residents who harvested rainwater were surveyed, if the respondent answered that they do not harvest rainwater, they were directed to the barriers section at the end of the survey, completely skipping demographics and other such questions. Since this group did not complete the majority of the survey, there was no group to compare with the responses from those who do harvest rainwater; therefore, statistical analysis could not be completed due to the lack of a comparison group. This issue was overlooked at the beginning of the study when the online survey was designed, as there was a greater interest in collecting information pertaining to those who harvest rainwater, compared to those who do not.

The reach of the survey was also unknown. The Salt Spring Exchange website was used when advertising for the Saturday Market and Earth Day events on SSI, as well as to increase the reach of the survey. This website allows posts to be made for community engagement or outreach. The survey was also advertised using flyers with rip-tags placed around stores and other well-travelled areas, mainly concentrated in the Ganges town center. Advertising lead to an interview published in the Driftwood, the Gulf Island community newspaper. It was unclear how many people were aware of the survey compared to how many were actually completed and submitted. The survey was initially going to be used to determine resident's acknowledgment of the stressed water source but is limited in extrapolation due to the small sample size.

Case study participants may have incorrectly answered questions or exaggerated certain aspects about their systems or situations, which could potentially have led to inaccuracies in the results. Though there was a great effort in asking each case study participant the same questions, certain questions may have been forgotten for one case study versus other case studies due to the flow of the conversation. The willingness of participants and their specific interests also resulted in variation in data collection between case studies, leading to inconsistencies in comparisons. As well, while businesses were selected for case studies, the ability to draw comparisons between the three was difficult due to a lack of similarities. The uses for the harvested rainwater also varied, as the use was not specific to business uses but was used primarily for irrigation.

Regulations and Guidelines

A barrier that had not been accounted for until visiting SSI was the CRD regulations regarding RWH systems and practices. This barrier was not identified by the research team as a point of contention in the initial compilation of barriers to RWH through interaction with SSI residents and survey responses. As more residents of SSI were interviewed, the perception of CRD regulations inhibiting the development of RWH systems was communicated as an impactful barrier. The view points on this subject varied, as some residents would not discuss their RWH system for fear of repercussions from the government, while others felt regulations had not affected their RWH system at all. This variation in reported perceptions led us to clarify what regulations are required by the CRD for a RWH system by interviewing Mr. Darryl Janyck, a building inspector with the CRD.

Mr. Janyck explained that the CRD bylaws require approval by a certified engineer for all RWH systems intended to be used as a potable water source. The engineer deals with calculations for roof area, storage size to meet demand, treatment process, and maintenance practices. If the RWH system is to be used solely for irrigation, the engineering requirement does not apply, except where the storage tanks are greater than four feet tall, thus requiring sign off for seismic stability. The CRD is concerned about public understanding of the hazards associated with untreated water. The current CRD bylaw was developed from previous guidelines and recommendations from the region. The sizing of the RWH system is based on an average water consumption of 40 gallons per person per day, with a typical household requiring 30,000 gallons per year of cistern capacity, based on potable water requirements. At this size, the cost to residents comes in at about $1/gallon. According to Mr. Janyck this cost tends to come as a shock to residents but, as water consumption rates increase, these systems can recoup costs. These systems are designed to last decades or, in the case of a concrete cast cistern, hundreds of years. The CRD requires an engineer's signoff to ensure the system is designed, operated, and maintained properly to ensure the safety and health of residents.

An interview was also conducted with Gord Baird to gather a professional's perspective on CRD RWH regulations for SSI. Mr. Baird is an American Rainwater Catchment Systems Association Accredited Professional, sits as a Water Commissioner for both the CRD Regional Water Supply and the Juan de Fuca Water Supply, and is an elected municipal councillor for the District of Highlands. Mr. Baird helped in writing the new regulations and guidelines for the BC Ministry of Health for greywater and composting toilets. As an advocate for environmentally friendly practices, Mr. Baird teaches about RWH, installs systems, and believes that the CRD wants to encourage RWH but is disconnected from users. Mr. Baird indicated that requiring an engineer to design and sign off on a RWH system is made more difficult as small jobs are often not worth their time, and the requirement to travel to SSI further limits engineers' willingness to get involved. The need for an engineer is based on the requirement of the CRD to ensure liability coverage for the RWH system.

In his professional opinion, Mr. Baird believes that the CRD has underestimated the cistern sizes needed, as the bylaw is based on fire codes rather than on consumption and use. Fire codes establish a specified volume of water required for fire protection. Instead of requiring an engineer, Mr. Baird suggests that authorized professionals such as skilled trades people should be encouraged to become accredited; "get people who want to create RWH systems instead of engineers" said Baird.

The CRD supports the desire of residents to establish RWH systems, but their bylaws appear disconnected from the industry and those doing the work. The need for engineering sign off for residential use of RWH systems is not consistent with the requirements of other home renovations. Compliance with permits is required by the home owner, with a contractor being required to obtain the needed permits in most municipalities. The discrepancy between SSI and the other Gulf Islands, compared to the other CRD governed areas, is due to the lack of a local municipal government. Local governments are able to create bylaws to reflect the values and needs of their residents, such as making RWH more accessible. The current lack of incorporation of the Gulf Islands creates a void in the area of regulations and bylaws, which is filled by the CRD. The residents of SSI and the CRD need to increase communication on RWH. The CRD must acknowledge the commitment of SSI residents to RWH in order to reflect the needs and desires of residents by adjusting existing bylaws.

Success Factors

Through collection and analysis of survey data, and conversations with case study participants as well as other islanders, the overall success factor identified was the dedication of individuals. The best examples of systems had owners that were dedicated to water conservation, and were willing to put in the time and effort knowing the benefit would not be realized immediately. Effective use of the harvested rainwater is also a success factor, with some participants completely meeting their water needs with RWH. Even for those harvesting simply for irrigation purposes, successful RWH practices required continual monitoring of cistern levels and an ongoing awareness of water consumption levels.

Another success factor was the high participation rate. The electronic survey received 84 responses, and case study participants were more than willing to share details about their systems. Having access to this information and the varied perspectives made for a successful research project.

Barriers

Costs were one of the barriers outlined by SSI residents, yet rebates were not identified as a useful incentive for the development of RWH systems. Factors preventing the development of a RWH system were mainly cost, time and effort required for the set up, the inability to install a system as the property was not owned, or the perceived lack of a clear need to harvest rainwater. The overall barrier was lack of a motivating factor which would come from a better understanding of water resources on SSI.

Conclusions

Dedicated individuals are striving to develop and promote the use of RWH. SSI is an ideal location to encourage RWH at a broad scale because of the supportive and environmentally conscious community. Overall, residents expressed concern surrounding the costs associated with RWH systems. Additionally, existing regulations are affecting public perceptions regarding the accessibility and ease of installing these systems. Education on water conservation and the benefits of RWH is clearly lacking for those that are not experiencing water shortages. Phoenix Elementary School is an important example of how civic buildings increase community awareness and can help to educate the public on the need and use of RWH systems; also, educating younger generations is a step in the right direction for water conservation. Water resource management is an important issue, especially on SSI where water is scarce. RWH is a proven solution and, based on the findings of this project and many other studies, further development of this technology will be a benefit to the island and its residents.

Recommendations

With the high interest level, dedication to water conservation, and desire to take action, the recommendations that are made below have the real potential to have a positive effect on SSI as a whole.

- Adjust water fee structures on SSI to make the development of RWH systems more feasible and desirable as an alternative water source. Parcel fees should be reduced while the cost of water use is increased. This will provide an incentive that will offset and reduce water costs in the future.

- Amend CRD bylaws so RWH systems can be designed and installed by skilled tradespeople instead of engineers. This should make RWH more accessible to residents and potentially reduce costs associated with design and installation.
- Develop a rebate program which incentivises installation of systems, is promoted effectively to all residents, and is at a level that provides a significant offset of costs compared to cistern size.
- Educate SSI residents on the need and potential uses of RWH locally including design, maintenance, and benefits even with access to a reliable well or municipal water source.
- Public buildings can be used as demonstration sites for the installation of RWH systems and as a means of public access and education; a residential example, the Ruby Alton Nature Reserve, has been a successful installation that allows public tours increasing public awareness and knowledge (Islands Trust Fund, 2016).
- Conduct additional studies to obtain more information regarding public views on barriers and motivation for RWH development.

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Appendix A

Island Trust Recommendations for the Gulf Islands

The following are the materials and system components recommendations that the Island Trust suggests for the Gulf Islands (Stubbs, 2006).

- Roof: Potable - painted galvanized metal, slate, terracotta, or concrete tiles. Not recommended for either potable or non-potable uses- asphalt shingles.
- Gutter systems: PVC and aluminum downspouts with sizes calculated from plumbing code, with a continuous downward slope of minimum 1:500.
- Conveyance piping: all systems should be fitted with filters to trap or collect debris. If the system is for potable use, the conveyance system should be CSA approved. If water is being held, measures to impede biological diseases or toxic vectors (mice, rats, and lizards) should be in place. First flush systems should be in place for either potable or non-potable uses to divert 0.02 inches of the beginning of each rain event.
- Storage system: rain barrels are not included in these suggestions. Cistern sizing is not an aspect of these guidelines, as it is determined by roof area, rainfall amount, length of the dry season, uses and volume loss during storage. The cisterns can be comprised of polyethylene, galvanized steel (with or without a coating), concrete, fiberglass, ferrocement, brick or wood. Liners are suggested to reach the National Science Foundation 61 standard. Cisterns should be Canadian Standards Association/National Science Foundation approved and installed to the manufacturer's specifications, unless it is concrete which requires a professional engineer to design. All cisterns must limit exposure of sunlight to the stored water and be marked "Danger-Confined Space". The outlet must be no longer than 0.25 inches and drain into an area that is erosion resistant.

- Pressure system: pump should have a minimum specification of 25 psi of residual pressure for or at the highest outlet. A pressure relief valve is needed if pressure exceeds 80 psi.
- Treatment system: if used for drinking, cooking, or hand washing/bathing, filtration and disinfection are required. Screened or filtered water can be used for urinals, irrigation, laundry, and other outdoor uses. Potable water is to be treated after it leaves the cistern as close to the out flow as possible. Filtration is required to be no greater than five microns, be changed every several months, and be a system recognized by Health Canada. Filters are installed before the disinfection system, which can be chlorination, ozonation, and/or UV. Testing for bacteria is required to be completed at an accredited lab as needed.

Appendix B

Plumbing Code for Residential Buildings

Plumbing code of Canada has mandatory specifications that need to be adhered to when completing any home plumbing modifications. RWH systems can be used to supplement or replace traditional water sources in residential and commercial buildings. Any additions to a building's water system must adhere to the *National Plumbing Code of Canada 2010* and *2005*. The plumbing compliance codes that are applicable to RWH systems as stated by *Canada Mortgage and Housing Corporation (CMHC)* are:

2.2.5.10. Plastic Pipe, Fittings and Solvent Cement Used Underground - Compliance list of plastic pipe, fittings and solvent cement for underground use.

2.2.5.12. Plastic Pipe, Fittings and Solvent Cement Used in Buildings - Compliance list of plastic pipe, fittings and solvent cements for venting systems in or under a building.

2.3.4.5. Support for Horizontal Piping - Compliance for bracing of horizontal pipe to control movement inside of the building, including support procedures for different pipe materials as well as hanger attachment and material.

2.3.4.6. Support for Underground Horizontal Piping - Firm base support for pipe length and hanger provisional information if needed.

2.3.5.1. Backfill of Pipe Trench - Outlines compliance for backfill material and mandatory depth.

2.3.5.4. Protection from Frost - Mandates frost protection for exposed pipes where applicable.

2.4.7. Cleanouts - Provides specifications for sanitary drainage system and storm water drainage.

2.4.10.4. Hydraulic Loads from Roofs or Paved Surfaces- Discusses the hydraulic load limit for a surface in liters of a maximum of 15 minutes of rain as not to exceed 24 hours of drain down from surface.

2.4.10.9. Hydraulic Loads on Storm or Combined Building Drains or Sewers - Has tabulated the gutter dimensions to hydraulic load of draining storm water to the buildings storm or sewer drain.

The plumbing code has a section (Section 2.6 Potable Water Systems) that outlines regulations for potable water that the CMHC does not make reference to (British Columbia Plumbing Code 2012, 2014; Canada Mortgage and Housing Corporation (CMHC), 2012).

Appendix C

Survey Questions

Rainwater System information:

1. Do you collect rainwater? *(yes/no)*
2. Was there a pre-existing rainwater system?
    a. Was it operational
    b. Were modifications made
    c. If yes, please explain (ie. non-potable to non-potable, more capacity, etc)
3. Did you install your system yourself or have a professional install it? *(installed by self, experienced individual, certified rainwater contractor, etc.)*
4. What is the rainwater collection surface:
    a. Material *(metal roof, shingles, etc.)*
    b. Approximate size *(options)*
5. In regards to the holding tank,
    a. What volume of water can it hold? *(on average what is the level, is it ever full/overflowing, and is it every empty)*
    b. What material is it made of? *(list)*
    c. Is the storage tank located above or below ground? *Systems in place – runoff pollution protection)*
6. Are there any filtration practices involved in your rainwater collection?
    a. First flush (pre-filter) to collect residue prior to the water entering your storage tank? *(check all that apply)*
    b. Large material filtration screens? (*material)*

7. What materials comprise the transfer of rainwater from collection surface to tank:
    a. What is the flashing made of?
    b. Gutters?
    c. Pipes?
    d. Joints?
8. How often is your rainwater collection vessel cleaned? *(filters, etc)*
9. Once collected, what is the rainwater used for? *(Gardening, washing clothes, toilets, drinking, livestock)*

Water Use and Conservation Practices:

1. What methods, if any, do you use to reduce your household water use? *(only washing full loads of laundry and dishwasher, "if it's yellow let it mellow", composting toilet, low flow/ultra-low flow/ standard toilet/showerhead, top/front loading/ high efficiency washer, point-source water heater, etc.)*
2. What methods of water conservation does your household practice? *(rain garden, collection ponds, grey water system, landscaped swales, green roofs)*
3. During handwashing, tooth brushing and shaving, is the faucet left on or turned off?
4. Carwashing - how many vehicles in your household, and how often do you wash them? (*never, monthly, twice a month, daily)*
5. How many loads of laundry per week?
6. How many baths per week? How many showers per week? How long? *(bathe pets)*
7. Gardening - no garden, small garden rarely watered, regularly watered small garden, large garden rarely watered, large garden watered regularly, water garden and lawn regularly, water lawn, plants around the house?

Property Information:

1. What water district are you in? (*North Salt Spring Water District, Fernwood Highland, Beddis, Fulford, Cedar Lane, Cedars of Tuam, Erskine Water Board, Harbour View Improvement District, High Hill Baker Rd, Maracaibo Estates, Maracaibo Estates, Mt. Belcher Improvement District, Reginald Hill, Scott Point, Swan Point, Merchant Mews)*
2. What sources of water are used on your property? *(private well, community well, municipal water, community lakes - Cusheon, Ford, St. Mary, Blackburn, Stowell, Bullocks, Weston, Roberts, Maxwell)*
3. If private or community well:
    a. Is there variation in water quality through the seasons? *(no, yes - the water quality decreases, yes - the water quality increases, etc.)* – subjective… smell, taste, appearance, etc.
    b. At what point in the year does the water quality deteriorate? *(June, July, August, September, etc.)*
    c. Does your well run dry? *(no, yes - during high drought years, yes - every year by the end of the summer, etc.)*
    d. Do you purchase water to supplement well usage? *(no, yes - bottled water is purchased for drinking, yes - water deliveries fill up an additional storage tank, etc.)*
4. What type of residence to you live in? *(Detached single family, townhouse, apartment, condo, etc.)*
5. What out buildings, if any, are present on your property? *(detached garage, greenhouse, shed, workshop, barn, studio, other)*

6. What area of land so you have? *(less than one acre, one to five acres, more than five to ten acres, more than ten)*
7. What land use takes place on your property? (*Maintained lawn, Irrigated lawn, farm animals, vegetable gardens, ornamental gardens, natural area, pond, hardscaping (paved areas, decks), softscaping (water permeable gravel, mulched paths, etc.))*
8. Do you have a home based business? *(yes/no)*
9. What type of home based business? (*Exercise/yoga, hair dressing/salon/spa/nails, massage/acupuncture/chiropractor, dentist, doctor, lawyer/consulting, counselling, day care, nursery, art studio, other)*
10. Would you consider your business to be an intensive water user? *(yes/no)*
11. What percentage of household water use is estimated as business use? *(Dropdown options)*
12. Have you heard of past water harvesting rebate programs in your area?
    a. Yes
        i. Did you apply for a rebate?
        ii. Did you received a rebate?
        iii. Are you more likely to expand your capabilities if there’s an incentive program?
    b. No
        i. Will you collect rainwater now that you know there is an incentive?
        ii. What could be done to get you to collect?

Business Information:

1. Do you own/lease your business?

2. Building type? *(Detached unit, shared complex, other)*
3. Building size? (*estimate square footage)*
4. Business type? *(Studio, retail, personal services, medical, health/wellness, etc)*
5. Number of staff working at one time? *(none, 1, 2, 3…)*
6. Land space? *(none, parking area, patio, garden)*
7. Land area? *(estimate square feet)* – land/building
8. Public washrooms available?

Demographic Information

1. How old are you? *(prefer not to answer, 18 to 35, 36 to 50, 51 to 70, 71+)*
2. What is the annual net income of your household? *(prefer not to answer, less than $30,000, $30,000 to $59,999, $60,000 to $89,999, $90,000+)*
3. What is your educational background? *(Prefer not to answer, no formal education, did not graduate from high school, high school education, post-secondary education, university degree, PHD, or other)*
4. How long have you lived on SSI?
5. Address (zoning), prefer not to answer

Barriers

1. What is preventing you from expanding the rainwater harvesting system?
    a. Money
    b. Knowledge
    c. Time Effort
    d. Regulations

   e. Material availability

2. What prevents you from using harvested rainwater for other purposes? (Toilet, washing machine, and potable)
   a. Money
   b. Knowledge
   c. Time
   d. Effort
   e. Regulations
   f. Material availability
3. What would encourage you to expand your system and/or add uses?

Additional contact

Are you interested in contributing more to our research project? This could involve more questions regarding your rainwater harvesting practices as well as a potential site visit - Is it acceptable to contact you for further details, more in depth questions, etc.?

Yes - Please include contact information

No thank you

To be entered to win a free inspection and consultation of rainwater harvesting infrastructure will be offered by Sandra Ungerson (Conservation and Efficiency Working Group Chairperson), please leave your name and contact information below.

Appendix D

Case Study Images

Figure D1. *Case study B1 images taken by Kendra Anderson during site visit on April 22, 2017 to gather further details on RWH systems that exist on SSI. Collection of rainwater occurred off all roofs on the property, which are linked and controlled via piping and valves.*

Figure D2. *Case study B2 images taken by Kendra Anderson during site visit on May 30, 2017 to gather further details on RWH systems that exist on SSI. Rainwater is collected in the $170,000 pond which has a capacity of 300,000 gallons. This harvested rainwater is used for irrigation of gardens and the property.*

Figure D3. *Case study B3 images taken by Kendra Anderson during site visit April 23, 2017 to gather further details on RWH systems that exist on SSI. The unlined pond collects rainwater to irrigate the fruits grown on the property such as blueberries and apple trees.*

Figure D4. *Case study C1 images taken by Kendra Anderson during site visit on April 22, 2017 to gather further details on RWH systems that exist on SSI. Rainwater is collected and stored in the 250,000 gallon lined pond, with the above ground pool used for chlorination and off-gassing for disinfection.*

Figure D5. *Case study C2 images taken by Kendra Anderson during site visit May 29, 2017 to gather further details on RWH systems that exist on SSI. Water is collected off the workshop roof and held in three cisterns with a combined volume of 6,600 gallons, used to water the garden area.*

Figure D6. *Case study C3 images taken by Kendra Anderson during site visit May 30, 2017 to gather further details on RWH systems that exist on SSI. A 2,100 gallon black cistern is filled from collection off the metal roof and pumped for use in irrigation. The tank was repurposed from previous projects.*

Figure D7. *Case study S1 images taken by Kendra Anderson during site visits to gather further details on RWH systems that exist on SSI. A UV filter is used to bring water up to potable quality, and a pump transports water from the three large 3,000 gallon tanks to the house for use.*

Figure D8. *Case study S2 images taken by Kendra Anderson during site visit on April 21, 2017 to gather further details on RWH systems that exist on SSI. Rainwater is collected off the conservatory roof and used on the garden area which is shaded through the afternoon to minimize water use. A 1,100 gallon is used for storage.*

Figure D9. *Case study S3 images taken by Kendra Anderson during site visit on April 23, 2017 to gather further details on RWH systems that exist on SSI. A variety of tanks are used to store rainwater, including a 1,000 liter food shipping container, for a combined 5,000 liter storage capacity.*

Figure D10. *Case study on Phoenix elementary school image taken by Kendra Anderson during site visit on May 30, 2017 to gather further details on RWH systems that exist on SSI. A 2,200 liter tank is filled off the roof of a structure built specifically for the purpose of RWH.*