THE WATER FOOTPRINT OF TOURISM FOR INDEPENDENT ISLANDS

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List of Abbreviations and Acronyms

cap	Capita
Catalina	Santa Catalina Island
CC	Cross-channel arrivals
CDWR	California Department of Water Resources
CICC	Catalina Island Chamber of Commerce
CICC & VB	Catalina Island Chamber of Commerce & Visitors Bureau
CS	Cruise ship arrivals
ECRI	EarthCheck Research Institute
ESRL	Earth System Research Laboratory
excl	Excluding
gal	Gallons
MPDE	Ministry of Physical Development and Environment
NASA	National Aeronautics and Space Administration
no	Number
pop	Population
RQ	Research question
SCE	Southern California Edison
SQ	Research sub question
sq ft	Square foot
SWF	Stay with friends
UN	United Nations
UNEP	United Nations Environment Programme
UNWTO	United Nations World Tourism Organization
USDE	United States Department of Energy
USGS	United States Geological Survey
VB	Visitor's Bureau
VR	Vacation rentals
WBCSD	World Business Council for Sustainable Development
WF	Water footprint
WTTC	World Travel and Tourism Council
WWF	World Wildlife Fund

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Abstract

The availability of fresh water is an increasing problem, the intensity of which is specific to locations and time of year. Many locations classified as water scarce, however, are also leading tourist destinations. This creates a problem as the increase in occupancy leads to increased water demand. Islands that are both self-reliant for their water supply and yet dependent on tourism economically provide an example of where economic stability and water availability can become dangerously intertwined. The aim of this research, therefore, is to investigate the impacts of tourism on water use for islands that are reliant on their own limited water resources. Using utility data, descriptive data, and water use standards, we have applied the water footprint to evaluate the situation at a case study location, Santa Catalina Island. Using these methods, we determined the general water footprint of tourists and compared this to the water use targets set for the island. Through the application of the water footprint we also identified which aspects of tourism were the most water intensive and recommend possible policy pathways that could address the issue of tourism water use. In the end, it was found that water rationing, though effective for residents, might not be appropriate for tourists. This is primarily because the number of tourists plays such a large role in the total water used for tourism. Additionally, water reduction measures could negatively impact the quality of a vacation, inherently reduce the number of tourists on the island, and have devastating impacts for the islands economy. Therefore, when attempting to address the water usage of tourists, it is recommended that economic impacts and tourism quality should also be considered.

1. Introduction

1.1 Background

Fresh water is essential for maintaining human life, which makes it one of the most important resources on Earth. However, variations in the climate, as well as other factors, have resulted in numerous effects to water supplies. Most recently, regions with marked wet and dry periods are further exacerbated by climate-driven changes in the hydrological cycle.This includes water scarcity, which has had a particularly large impact worldwide, as can be seen in Figure 1. In this figure, light orange represents areas that are vulnerable to water scarcity or are undergoing water stress. Meanwhile, dark orange signifies coutnries which cannot provide enough water for their occupants. These locations are then considred to be water scarce. As can be seen, water scarcity ranges by country, however, it also varies by region and season within each location. Because of this, countries which are recognized as having access to enough water for their occupants may still have areas within them that qualify as water scarce. Therefore, access to fresh water has very much become a local issue.

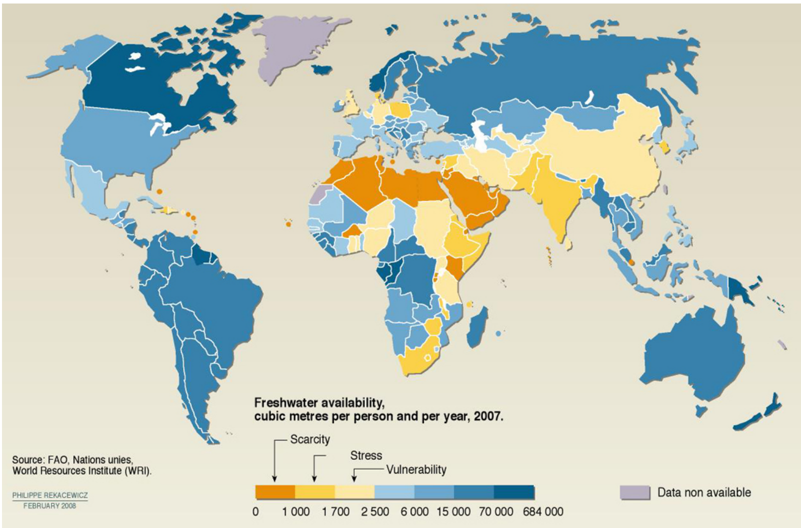


FIGURE 1: GLOBAL WATERSTRESS AND SCARCITY (UNEP, 2008)

Ironically, many of these water scarce locations are also leading tourist destinations. The popularity of these locations showcase the preference of tourists to visit dry locations during dry seasons (Gössling et al., 2012). Though not considered a major contributor on a global scale, the regional and seasonal impacts of tourism water use have shown to be significant (Gössling et al., 2012). This is impart a result of tourist consumption being as much as 8 times that of municipal users (Becken, 2014; Gössling et al., 2012). Islands which are self-reliant for their water supply while also economically dependent on tourism provide a clear example of where tourism and water demand can become dangerously intertwined. These islands cannot exist without the income brought by tourism, however, the increase in occupancy leads to increased water demand, threatening the available water supply (Lovett, 2014). Locations already experiencing water scarcity issues, therefore, have found the added demand of tourism water use problematic. This problem is increasing, however, as the World Tourism Organization (UNWTO) projects that tourism rates will double between 2010 and 2030. Unless conservation efforts are put into place, this increase in international arrivals will translate directly into an increase in local water consumption.

The tourism industry, however, is typically ignored or otherwise left out of water conservation plans. This is true even in areas where tourism water use is substantial because tourists are believed to have little interest or may even resist saving water, as it does not match their carefree, holiday mode (Becken, 2014; Gössling et al., 2012). As a result, destinations economically reliant on tourism fear the implimentation of conservation measures as it could result in negative market responses. These locations, therefore, tend to shy away from tourism-related water conservation, instead targeting residential, industrial, and agricultural water use (Agana et al., 2013; Barrington et al., 2013; CDWR, 2014; Mini et al., 2014; Tapper et al., 2011; Willis et al., 2010).

Water conservation measures targeting tourism, therefore, are urgently needed. In particular, initiatives that are beneficial or even neutral for competitiveness should be targeted. In other words: solutions should not only meet technical standards, but also have favorable effects on behavior and tourist satisfaction. In order to develop water conservation approaches that will target tourism water use, we must first have a solid understanding of exactly how much and in what context the water is being used. The quantity of water is needed in order for utilities and municipalities to identify problem areas and design effective water conservation measures. The context of the water use is needed so that it can be confirmed that the water conservation measures do not affect the quality of a tourist's experience. This is important to include, as negative impacts to the tourist could result in negative impacts to the local economy. Therefore, a water accounting method is needed that can both accurately quantify and depict tourism related water use.

Fortunately, knowledge about tourism water use is expanding. Indicators such as the water footprint (WF) have been applied to tourism in an effort to understand how much water is being consumed (Cazcarro et al., 2014; Hadjikakou et al., 2013; Yang et al., 2011). The WF method is preferred as it includes both direct and indirect water usage as well as the context that water is being consumed. However, the application of the WF to tourism is relatively new and the majority of publications using this method are focused on either global estimations or specific locations (Cazcarro et al., 2014; Hadjikakou et al., 2013; Yang et al., 2011). Additionally, the outcome of this methodology is typically not presented in a way that is helpful for policy design (Cazcarro et al., 2014). From the aforementioned literature, it appears that there is a gap between the use of empirical data to calculate the WF and the ability to present a method that can be applied to multiple locations. There is an additional disconnect between water consumption issues and how to apply conservation methods, specifically for tourists. Therefore, an approach to applying the WF is needed that is both broad enough to be applied to different locations, yet specific enough to provide useful information for water reduction measures.

1.2 Aim and scope

The primary aim of this research is to determine how the WF method can be applied in order to better support water conservation measures for tourism. We aim to build upon the existing applications of the WF to tourism by approaching the calculations from three different perspectives: general, specific, and target. It is intended that this approach will help identify the most water intensive aspects of tourism, therefore highlighting those that require the most attention.

1.3 Thesis objectives and structure

The main objective of this thesis is to answer the following research question (RQ) and additional sub-questions (SQ):

RQ: How can the water footprint of tourism be applied to support water conservation measures for water-independent islands?

SQ 1: What is the general WF of tourism and how does this compare with the target WF of tourism, as dictated by local needs?

The general WF, in this case, would be the average water used per tourist per day, while the target WF would be the locally determined maximum water use per tourist per day. Calculating the general WF will provide insight into exactly how much water is going towards the tourism industry. This profile will help clarify who the largest contributors to tourism-related water consumption are. By developing vacation 'packages' that are specific to the location and common tourist behavior, a better understanding of what types of travel are the biggest consumers should be made clear. The development of a target WF will allow for a standard to be set as to how much water should be consumed so as to meet local mandates or rations. By having all three types of WF calculated, aspects of high water use can be determined and the best path for water consumption reduction can be recommended.

SQ 2: What are the most water intensive aspects of tourism and who is responsible for each water source?

This information will help determine what the main sources of water consumption are and what sectors have the most impact. Once this is determined, more customized approaches to water conservation can be done on a per user / company / sector basis.

SQ 3: What policies can be recommended that will reduce the amount of water used by tourists while considering the effects on tourism rates and economic impacts?

As the point of this study is to reduce tourist related water usage, additional attention is needed to review the impacts on tourist experience and economic stability of the island. With this said, any policies that are recommended should also consider this and aim to have either a neutral or positive effect on the tourists activities.

These questions will be addressed by first exploring the topics of tourism and water in Chapter 2. In this chapter, we will discuss the interactions and overlaps of tourism and water, with a focus on the case for independent islands, and introduce the WF. In Chapter 3, the methodology for our research will be presented as well as how we propose to use the WF. The methodology will then be applied to a case study and the results will be compiled in Chapter 4. Chapter 5 will be comprised of a discussion of the results, including benchmarking outcomes of the WF of tourism in relation to sustainable usage (SQ 1), identification of the most water intensive aspects of tourism (SQ 2), and recommended water conservation measures (SQ 3). In the end, a summarization of findings will be presented in Chapter 6.

2. Water and Tourism

2.1 Water

Fresh water is essential for global vitality (ESRL, 2015). Its roll is irreplaceable within industry, agriculture, and domestic uses, therefore, a world without fresh water would be a world without business, food, or, most importantly, life (Postel, 2000; WBCSD, 2009). Though over 71% of the Earth's surface is covered in water, and this quantity of water has never changed in the history of the Earth, access to fresh water has become increasingly problematic (GrowingBlue, 2011; USGS, 2015). As shown in Figure 2, 97.5% of the water on Earth is salt. This means that only 2.5% of water is considered potable, however, the majority of this is unattainable, as it is either frozen in glaciers or trapped in unreachable areas. Therefore, it is calculated that less than 1% of water on Earth is both potable and physically attainable (USGS, 2015; WBCSD, 2009). Fresh water that is deemed attainable, however, still has complications, including accessibility and non-regenerating sources. Fortunately, there is more fresh water on Earth than is needed to support the existing population; however, fresh water is not always located where it is needed (Postel, 2000; WBCSD, 2009).

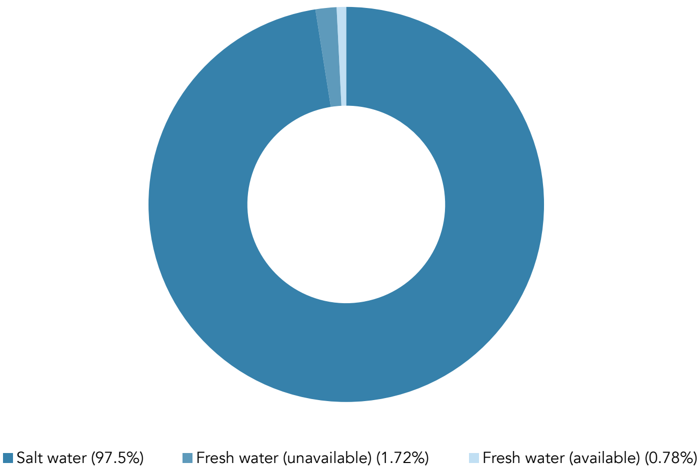


FIGURE 2: COMPOSITION OF TOTAL WATER ON EARTH (USGS, 2015)

Attainable fresh water, as depicted in Figure 3, is located in rainfall, lakes, man-made storage facilities, and rivers (WBCSD, 2009). Fresh water is also found in soil and plant life, however, water captured in these forms is not necessarily attainable for common uses (Postel et al., 1996). The majority of attainable fresh water, however, is sourced from underground aquifers. However, it must be noted that these aquifers are considered "non-regenerating" (Postel et al., 1996). This means that there is only a finite amount of water available and once this water is removed it is not replenished. This is concerning, as there has been an increased reliance on underground aquifers as sources for fresh water (WBCSD, 2009). Since 1950, underground aquifer exploitation has increased specifically for the application of agriculture, industry, and drinking. As such, underground aquifers are now responsible for 20% of irrigation, 40% of industrial uses, and 50% of all drinking water (WBCSD, 2009).

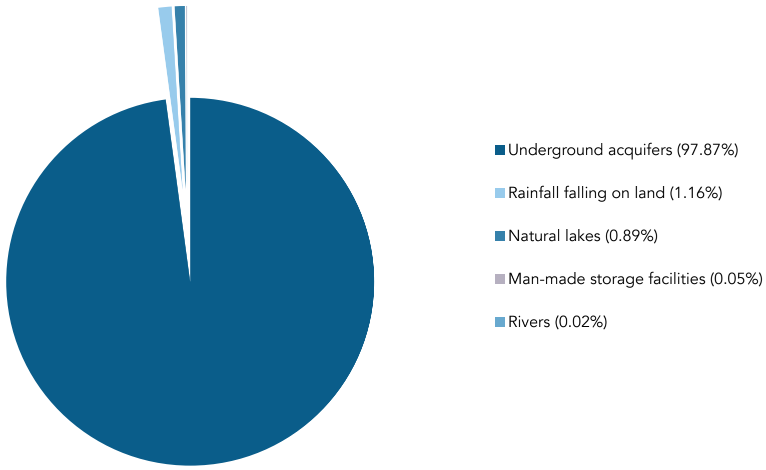


FIGURE 3: AMOUNT OF WATER ATTAINED FROM EACH SOURCE (WBCSD, 2009)

An additional issue surrounding fresh water availability is its geographical location. Over 60% of the Earth's attainable fresh water is located within just 10 countries, and water availability within these countries varies as well (WBCSD, 2009). This disparity of water availability has resulted in numerous locations experiencing water scarcity (Veldkamp et al., 2015). Though it can occur in many forms, the term water scarcity is typically used for when there is not enough water for all of the users within a given system. The quantitative definition for water scarcity, however, is when a given location has less than 1,000 m^3 of fresh water per capita per year (WBCSD, 2009). The impacts of water scarcity also vary in their effects and severity. However, according to the World Economic Forum (2015), water scarcity has been ranked the number one risk globally in terms of its potential impact.

Though water scarcity exists through hydrological cycle changes, it can also be created through overuse. Fresh water use is broken into three primary uses: agriculture (70%), industry (22%), and domestic purposes (8%) (WBCSD, 2009). Overuse is primarily a result of excessive withdrawal, pollution of resources, and inefficient consumption (WBCSD, 2009). To understand overuse, it is important to clarify the differences between water withdrawal and water consumption. According to Vickers (2001), water withdrawal is defined as the "water diverted or withdrawn from a surface water or groundwater source". Water consumption, on the other hand, is defined as water that is permanently withdrawn from a source, i.e. "water that is no longer available because it has evaporated, been transpired by plants, incorporated into products or crops, consumed by people or livestock, or otherwise removed from the immediate water environment" (Vickers, 2001). The primary difference between these two terms is that withdrawn water may eventually be returned to its source, while consumed water is removed permanently. An example of excess withdrawal can be seen in agriculture, where it has been estimated that 15-35% of agricultural related withdrawals from aquifers are deemed unsustainable (WBCSD, 2009). This means that there is not enough water in the aquifers to continue supplying at the current rate. The result of this high withdrawal has resulted in drops to underground aquifer levels of as much as 50 meters.

Inefficient consumption, as well as the other sources of overuse, are most commonly linked to the increase in fresh water demand which stems from population growth. Over the next 35 years, the human population is expected to increase by over 2.5 billion (UN, 2012). This growth in population has shown to increase migration towards urban cities; urbanization which has been argued to amplify fresh water demand as a result of increased distance between user and source as well as inefficient infrastructure (Srinivasan et al., 2013). Though efficiency upgrades are often looked to for reducing this impact, it is typical that the water saved in these upgrades is negated through the continuing increase in demand (Hoekstra, 2014). An example showcasing the issue of water scarcity can be found in the Colorado River Basin. This basin has experienced both rapid population growth and record-setting droughts (NASA, 2015). The result has been an overtaxing of the underground water supply and a draining of the area's aquifers and lakes (Wildman, Jr. & Forde, 2012). According to the National Aeronautics and Space Administration (NASA) reports, this combined impact of both population growth and declining reserves "will likely threaten the long-term ability of the basin to meet its water allocation commitments" (2015).

2.2 Water and tourism

Water scarce areas already do not have enough water to provide for those living in the region. Adding the characteristically high water use of tourists, therefore, can contribute significantly to water availability issues (Becken, 2014; Gössling et al., 2012). Becken (2014) concluded that tourists consume 3 to 8 times more fresh water than that of municipal users (see Figure 4). This was especially true for developing regions like Fiji, where municipal users consume less than 100 liters per person per day, while tourists use upwards of 700 liters per person per day. Further, other researchers have found these ratios between municipal and tourist water use to be even greater. One such case is that of Zanzibar, where the average freshwater consumption per tourist was found to be 15 times that of local residents (Gössling, 2001). This overuse was sited as a contributor to the salt-water intrusion of the Zanzibar water supply and the 2010 cholera outbreak which killed 3 people (Hickman, 2012). This high water consumption is partially explained by the tourism industry's aim to provide first-world amenities which are not common to the area and are often very water intensive (MPDE, 2001).

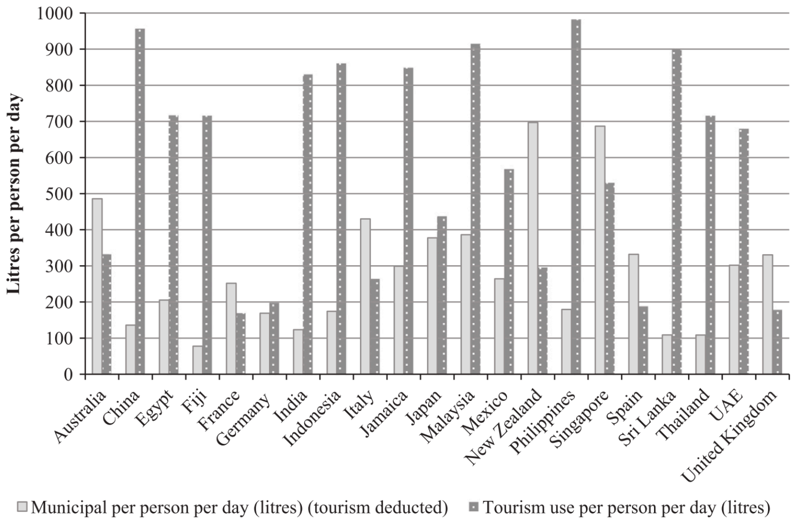


FIGURE 4: MUNICIPAL AND TOURISM WATER USE PER PERSON PER DAY (BECKEN, 2014).

Though tourist consumption of water may account for less than 1% on a global scale, this percentage varies both regionally and seasonally (Gössling et al., 2012). It has been documented that typical tourist destinations are often already water stressed locations and tourism rates in these areas tend to increase with water scarcity and susceptibility to drought (Gössling et al., 2012). In these locations, the impact of tourism water use is considered substantial and continues to grow with the rise in tourism rates. International arrivals are already projected to increase from 980 million in 2010 to over 1.8 billion arrivals in 2020 as shown in Figure 5 (UNWTO, 2014). Though increases in tourism rates are often seen as a good thing for the local economy, this increase of inhabitants can also lead to detrimental effects on local water supply stability. To give a specific example, almost 50 million international tourists visited the US in 2000 and were estimated to have consumed a total of 120.05 million m^3 of water (Gössling et al., 2012). It is projected that US international visitor counts will increase to almost 100 million by 2020 which means that water usage by this group will easily double if conservation efforts are not put in place (Gössling et al., 2012). Therefore, as tourism rates continue to increase, conservation efforts aimed at tourism must be developed (UNWTO, 2014).

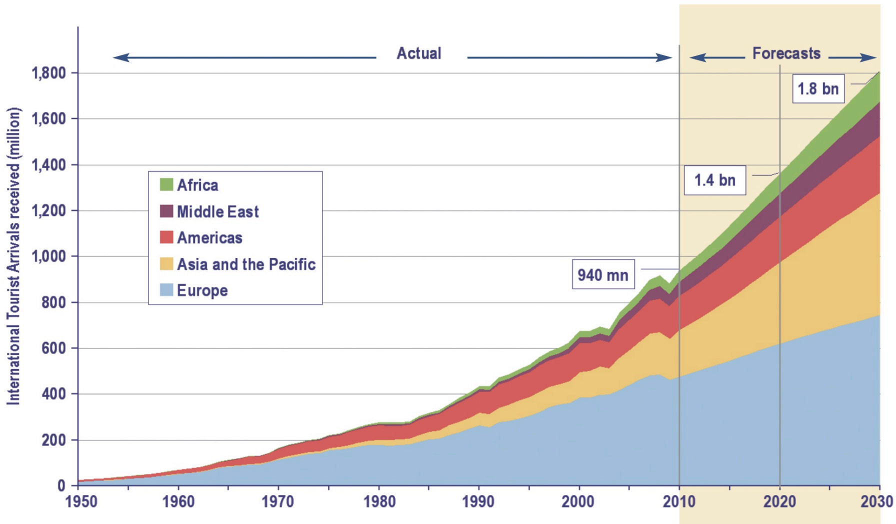


FIGURE 5: ACTUAL AND FORECASTED TOURISM GROWTH (1950-2030) (UNWTO, 2014)

Instead of conservation efforts, however, the typical response to this problem is to increase the water supply; an approach that is often not physically or financially possible (Lovett, 2014). As such, the next step is to decrease demand (Hadjikakou et al., 2013). This approach can often seem daunting, as not only do tourists have little accountability for their usage rates, but tracking their actual consumption can be quite complicated. In many places, the imposing threat of water scarcity has prompted initiatives targeted at reducing residential, industrial, and agricultural water use (Agana et al., 2013; Barrington et al., 2013; CDWR, 2014; Mini et al., 2014; Tapper et al., 2011; Willis et al., 2010). However, tourism remains overlooked since it is perceived that water conservation measures could affect tourism rates negatively and, in return, decrease local revenue (Gössling et al., 2012).

Additionally, it is unclear which stakeholders are responsible for this water use. This makes the development of effective conservation measures difficult to achieve (Cazcarro et al., 2014; Gössling, 2015; Hadjikakou et al., 2013). This is because the majority of the water consumed by tourists is actually "hidden" in indirect water use (Cazcarro et al., 2014). There are many direct and indirect ways that tourism consumes water. Luxury items such as swimming pools, golf courses, and spas receive most of the attention, however, indirect or unconscious water usage such as irrigation for landscapes, agricultural consumption in the form of specialty foods, and construction can have just as large of an impact (Gössling et al., 2012). In order to start understanding indirect water use, it is recommended to focus on areas where water inputs and outputs are clearly defined, a task made much simpler for the cases of water-independent islands.

2.3 Independent Islands

As stated before, the impacts and needs of tourism water use vary by location and time. Since the tourism industry is embedded within multiple industries, defining the boundaries of this group is quite complicated in and of itself. Mainland destinations further complicate these boundaries as their water sources are often shared with other locations and multiple utilities can be involved making it difficult to track the path and amount of water used specifically. Islands, on the other hand, provide a concentrated area where the confines of water use are clear because of the physical boundaries. Further, water independent islands simplify the approach to the problem as they are entirely self-contained. Islands are considered "water independent" when they rely solely on their own resources for providing fresh water. This means that all of the fresh water provided is in the form natural or man-made water sources that are located on, above, or beneath the island. Additionally, these resources are not shared with any other location.

An example of a water independent island is the island of Barbados, which receives all of its fresh water from underground aquifers (96.8%) and fresh water springs (3.2%) (MPDE, 2001). In addition, two desalination plants were installed, providing a combined capacity of up to 12% of the islands fresh water needs (MPDE, 2001). These 3 forms are the only sources of fresh water for the island which cannot be shared and assistance from the next nearest land mass is nearly impossible, as it is approximately 180 km away (DistanceFromTo.net, 2015). In contrast, the island of Texel is an example of a water dependent island. Located off the north coast of the Netherlands, Texel has incurred a variety of water availability issues. This is primarily a result of the salt water intrusion of its underground freshwater aquifers and the increased demand because of tourism and population growth (Oude Essink, 2001). A water pipeline was extended from the mainland to the island in order to bridge the gap between fresh water demand and availability (Schoeman, 2006). This pipeline now provides a significant amount of fresh-water to the island, making Texel reliant on the mainland for its water supply.

Islands that are self-reliant for their water supply and are also economically dependent on tourism provide a setting where water conservation is desperately needed. These islands cannot exist without the income brought by tourism, however, the increase in occupancy leads to increased water demand, threatening the available water supply (Lovett, 2014). An additional example of the intertwining of tourism water use and economy, is that of the

Maldives. 40% of this tropical nation's GDP is based in tourism. The Maldives are also identified as a "critical" water location as they currently predicted to run out of fresh water by 2050 (Earthcheck, 2013; Gössling et al., 2012; WTTC, 2014).

According to the UNEP, there are over 1,990 recognized islands in the world (UNEP, 1998). Per the World Resources Institute (2013), at least 574 islands are categorized as having high to extremely high risk of water stress. Further, over 50 of these water stressed islands have more than 7% of their business spending reliant on tourism (WTTC, 2014). To showcase this problem, the islands with both the highest water stress ratings (5 out of 5) and a tourism business spending of over 8% are listed in Table 1.

TABLE 1: TOP RANKED ISLANDS IN TERMS OF WATER STRESS AND TOURISM SPENDING (2014)

ISLAND	COUNTRY	LOCATION	BASELINE WATER STRESS	BUS. TOURISM SPENDING
Antigua	Antigua & Barbuda	Atlantic region	5.00	15.5%
Barbuda	Antigua & Barbuda	Atlantic region	5.00	15.5%
Redonda	Antigua & Barbuda	Atlantic region	5.00	15.5%
Gozo	Malta	Mediterranean region	5.00	14.7%
Malta	Malta	Mediterranean region	5.00	14.7%
St Lucia	St Lucia	Atlantic region	5.00	13.8%
Barbados	Barbados	Atlantic region	5.00	10.8%
Dominica	Dominica	Atlantic region	5.00	8.5%
Jamaica	Jamaica	Atlantic region	5.00	8.1%
Morant Cays	Jamaica	Atlantic region	5.00	8.1%
Pedro Cays	Jamaica	Atlantic region	5.00	8.1%

These islands are important to study, as the inhabitants must either provide enough water to remain on the island or relocate, an option many will not accept. It can be argued that these islands provide small sample areas where the effects of drought and water scarcity can be wintessed. The impacts and solutions for these areas become a representation of what cities and coutnries may need to adapt to or change in order for their locations to remain occupied as well. As such, this research will center on tourism water use for islands that are self-reliant on their water supply in order to develop a greater understanding of the impacts of water scarcity as brought on by tourism.

2.4 Water Footprint

Though water independent islands simplify the scope of the problem, a water accounting method that is effective at using this information is needed to provide support for conservation development. Though past applications of the WF have been successful in achieving their purpose of identifying water usage, the approach to applying this methodology requires more development to better assist in conservation measure design. A SWOT analyses categorizing the aspects of the WF in application to tourism are presented in Table 2.

TABLE 2: SWOT ANALYSES OF WF METHOD AS APPLIED TO TOURISM

STRENGTH	WEAKNESSES
• Able to be defined both spatially and temporally • Can be applied to various situations • Provides a profile of water usage • Includes direct and indirect water usage • Internationally accepted	• Requires more development to better assist in conservation measure design • Typically provides global estimations or specific product processes • As it is done currently, it does not provide specific enough information to assist in demand reduction
OPPORTUNITIES	**THREATS**
• Connect to water conservation policy formation • Relatively new topic • New approach	• Method is tied to a specific location • This approach has not been completed before • Reliant on utility provided data • Separation of tourism and municipality is vague

From this table, it can be concluded that, though the WF is easily adaptable and matches well with the situation of tourism, the exisiting research is limited. Therefore, in order to use the WF, attention to how to make it more specific for the case of tourism is needed. The WF is comprised of three footprint types: blue, green, and grey (Hoekstra et al., 2011). The blue WF refers to the water consumed from surface or underground aquifers, including lakes, rivers, and runoff. An important parameter of the blue WF is that it does not include water that returns to these sources, as shown in Figure 6. The green WF is water that is embedded in soils and plants and is typically consumed in the form of agriculture. The grey WF addresses the issue of pollution, as it is the volume of fresh water required to dilute pollutants to an acceptable level for release. In all of these cases, the term consumption is defined as water that is not returned to either blue or green water sources. Note that, for the purposes of this research, only blue will be considered.

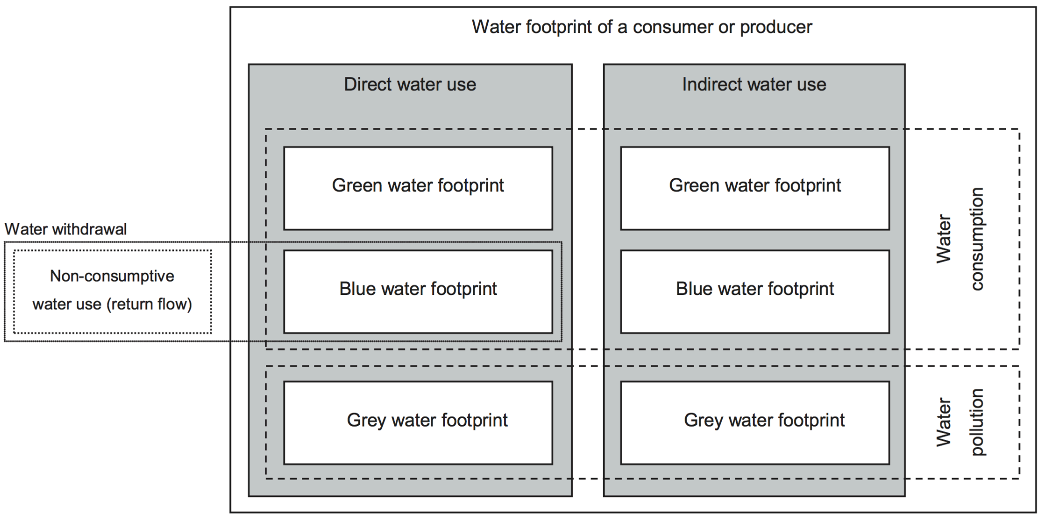


FIGURE 6: SCHEMATIC REPRESENTATION OF THE COMPONENTS OF A WF (HOEKSTRA ET AL., 2011).

The Water Footprint Assessment Manual (2011) notes that the key to the WF approach is that all components are defined both spatially and temporally. This allows the WF method to address issues such as water scarcity, as water scarcity is also dictated by location and time. Though there are several approaches to using the WF, the situation that best suits the industry of tourism is the 'group of consumers' approach. This tactic is defined as the summation of the operational WF ($\mathrm{WF_{direct}}$) and the virtual WF ($\mathrm{WF_{indirect}}$). In this case, the $\mathrm{WF_{Direct}}$ is water that has been directly used by tourists for items such as washing and drinking, while the $\mathrm{WF_{Indirect}}$ is water that is consumed in the process of producing goods or services for use by tourists (e.g. landscaping, embedded water in agriculture, etc.) (Hoekstra et al., 2011).

Though most commonly used to evaluate the WF of products, the WF can also be applied to various situations such as diets, international trade, national consumption, and tourism (Cazcarro et al., 2014; Gerbens-Leenes et al., 2013; Hadjikakou, 2014; Vanham et al., 2013; Wichelns, 2015; WWF, 2014; Yang et al., 2011). The pairing of the WF method with tourism water usage, however, is relatively new. Though numerous articles have been published on the application of the WF method, the majority are focused on global estimations or specific product processes (Ercin & Hoekstra, 2014; Gerbens-Leenes et al., 2013; Gerbens-Leenes & Hoekstra, 2012; Vanham et al., 2013). To date, however, there are three articles that apply the WF approach to tourism specifically, though all three approach the topic differently (Yang et al., 2011; Cazcarro et al., 2014; Hadjikakou et al., 2013). Cazcarro et al. (2014) evaluates the tourism WF for the country of Spain at a very high level, which, as the paper notes, does not provide specific enough information to assist in demand reduction. Yang et al. (2011) is more finite in their analyses, focusing on a single mountain area in the northwest of China. However, this narrow focus limits the understanding of how to apply the footprint to other areas of tourism. Hadjikakou et al. (2013), on the other hand, is able to take a more general approach to the topic, focusing on several types of tourism (e.g. budget, luxury, etc.). Hadjikakou (2013) elaborates on this approach by breaking the direct and indirect WF into sub-categories; the $\mathrm{WF_{direct}}$ is comprised of the accommodation footprint ($\mathrm{WF_{accom}}$) and activity footprint ($\mathrm{WF_{act}}$). Additionally, the $\mathrm{WF_{indirect}}$ is broken into the diet footprint ($\mathrm{WF_{diet}}$) and the fuel footprint ($\mathrm{WF_{fuel}}$). The relation between these categories is shown in Equation 1.

EQUATION 1: $$\mathrm{WF} = \mathrm{WF_{direct}} + \mathrm{WF_{indirect}} = (\mathrm{WF_{accom}} + \mathrm{WF_{act}}) + (\mathrm{WF_{diet}} + \mathrm{WF_{fuel}})$$

However, this approach is tied to a specific location: the Mediterranean. Additionally, the sources of Hadijkakou's calculations are slightly generic. The outcome is an approach that is specific to a location, but broad in its findings. However, the general approach of Hadijkakou is a logical first step in the direction of quantifying tourism water consumption in a way that can be applied to multiple locations and with policy worthy outputs. Therefore, we used this research as the starting point for our own, but depart from this approach ever so slightly by also calculating the WF from three unique perspectives. The purpose of doing so is to provide a more customized WF per tourist, identify the differences between current water usage and the target usage, and finally apply this information in a way that help reduce water consumption by this user group. In the end, we plan to expand upon Hadjikakou's approach to provide a WF that can better connect to water conservation policy formation.

3. Method

The intent of our research was to identify how tourism water use could be reduced through identification of water use context and quantity. To do so, we began with location selection, the process of which is described in Section 3.1. We then collected data from utlities, municipalities, and literature reviews, detail in Section 3.2. In Section 3.3, our approach to organizing the data is presented. After this was completed, we began the application of the WF method. Note that the details of the WF method calculations were specific to the descriptive categories and are detailed in Appendix B, C, D, and E. We then calculated the general WF, the specific WF, and the target WF, detailed in Sections 3.4, 3.5, and 3.6, respectively. This approach was considered to be a new step in the WF and tourism studies, as the breakout of the three WF had not been completed before. This information was then used to identify which tourism categories were the most water intensive. Using this information, we prepared policy recommendations for how this water consumption could be reduced (Section 3.7).

3.1 Location selection

The first step in this process was selecting a location. The criteria included that the location must have heavy economic reliance on tourism and was impacted by water stress or scarcity. Additionally, the location was limited to islands that were self-reliant for their water supply (water-independent). This was done because the physical boundaries of an island helped simplify where water was being sourced from and where water was being used. For this research, the case study of Santa Catalina Island (Catalina) was used. A more thorough discussion on Catalina's situation and its applicability to this research is presented in Section 4.1.

3.2 Data collection

Before addressing the actual data collected, it was important to define the titles and terms that would be used throughout the research. These terms and their definitions are present in Table 3.

TABLE 3: DEFINITION OF TERMS

TERM	DEFINITION
Municipality	The location, its cities, and its residents
Resident	Those living in the location
Tourism	Tourists, relevant businesses, and associated impacts
Tourist	A person visiting a selected location who does not reside in that location
Visitor	A person going to an activity, location, hotel, etc. *Note: this is not the same as a tourist*
WF	Water used per consumer, typically gal/cap or gal/cap/day
Water use	Total gallons consumed by a user or group

Data was then sourced from utilities, literature reviews, visitor bureaus, and municipalities. As a result of the varying sources and types of data, the types of data and how they were later divided were also defined in to category types, as shown in Table 4.

TABLE 4: DEFINITION OF CATEGORIES

TERM	DEFINITION
Utility categories	Breakout of water use into groups defined by utilities
Descriptive categories	Break out of water use into context groups which describe the situation of water use
Municipal categories	Break out of water use into context groups that are relevant to residents and the municipality
Tourism categories	Break out of water use into context groups that are relevant to tourists

3.2.1 Utility data

The participating utility for our case study was the manager of Catalina's water supply, Southern California Edison (SCE). The utility provided data that was in aggregated, monthly form and presented three ways: water produced, water delivered, and water sold. The definition of these terms can be found in Table 5.

TABLE 5: DEFINITION OF UTILITY DATA FORMS

UTILITY DATA TYPE	DEFINITION
Water produced	The amount of water removed from each water source (e.g. reservoirs, wells, and desalination plants).
Water delivered	The amount of water supplied to customers, broken into utility categories.
Water sold	The amount of water billed to customers, broken into utility categories.

For this research, we primarily used the water delivered data as it was already broken down into utility categories and was considered more reliable than the water sold data. The water sold was considered less reliable as it included billing errors and accounting corrections. In addition to water usage data, the utility data also included the number of accounts and population served.

3.2.2 Literature review data

The purpose of the literature review was to obtain standard water usage values, census data, activity specific information, and business information. Standard water usage values were collected for both commercial and residential users and were later used to convert utility categories (i.e. commercial usage) into descriptive categories (i.e. restaurant usage, hotel usage, etc.). Census data provided general information such as population statistics and household size, while activity specific information included typical water usage for water intensive activities (i.e. golfing, wineries, etc.). Business information was collected through online business and tourism websites (e.g. Yelp and Trip Advisor). Information such as business type, rating, and the presence of water intensive amenities were also collected. For this, several sources were used, as there were questions of accuracy. Therefore, the multiple sources were continually crosschecked to confirm the validity of the recorded information.

3.2.3 Visitor bureau and municipality data

Catalina Island Chamber of Commerce & Visitors Bureau (CICC & VB) and the City of Avalon (municipality) provided the bulk of the needed data for this research. This included data such as monthly tourist arrival numbers, rate of accommodation use, and stay durations. The monthly visitor counts were broken into cross-channel arrivals (CC) and cruise ship arrivals (CS). This breakout was necessary, as CS tourists typically do not use on island accommodations. Rate of accommodation use was used to estimate how many tourists stayed at the various accommodation types. Stay durations helped define how long tourists would stay at each accommodation type. The visitor's bureau, in cooperation with the municipality, also delivered information on businesses located on the island. This included descriptive information (e.g. business classification and ratings) as well as physical information (e.g. square footage and number of occupants). Missing information was supplemented by literature review data. As an example, if square footage of a business was unavailable, Google Map Developer's area calculator was used to get a rough estimation.

3.3 Data organization

Once all necessary data was collected, it was then compiled into an Excel database. Using the delivered water data and industry standards, we were able to convert the utility categories into descriptive categories. In the context of the island, several descriptive categories were defined, however, not all were applicable to the situation of tourism. Therefore, each descriptive category was then classified as either tourism or municipal related. This was done so with the help of the business information as well as the literature review information. We then matched this output with the pre-determined tourism and municipal categories. A depiction of how all information was arranged can be seen in Figure 7. Note that all categories are presented in gallons. It should be noted, however, that this information was also broken down by month in order to account for seasonal variations. Sub-categories within the tourism categories were also defined to better represent tourism activities and behavior (Figure 8). Included in these sub-categories was relevant information pertaining to water usage such as the presence of water intensive features (e.g. pools).

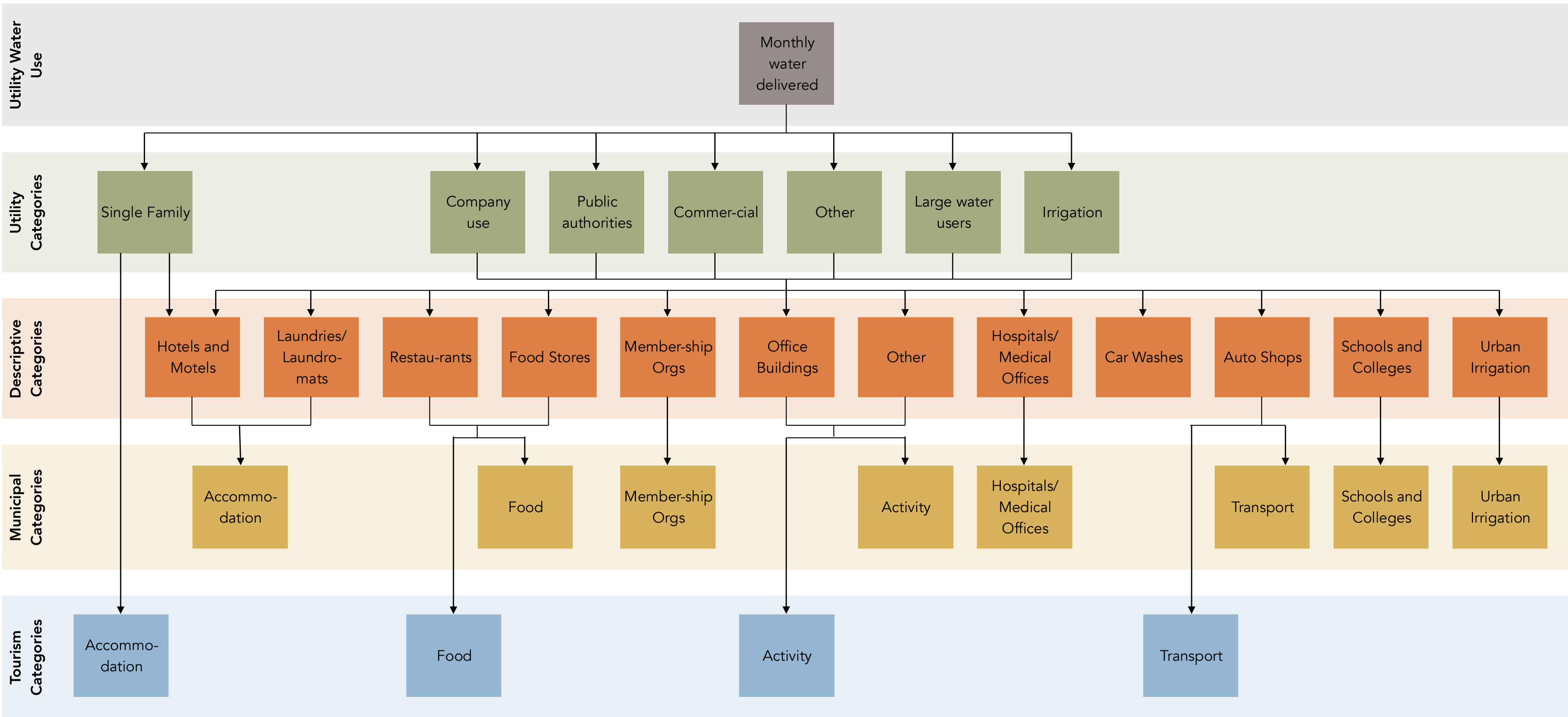


FIGURE 7: INTERACTION OF UTILITY, DESCRIPTIVE, AND TOURISM CATEGORIES

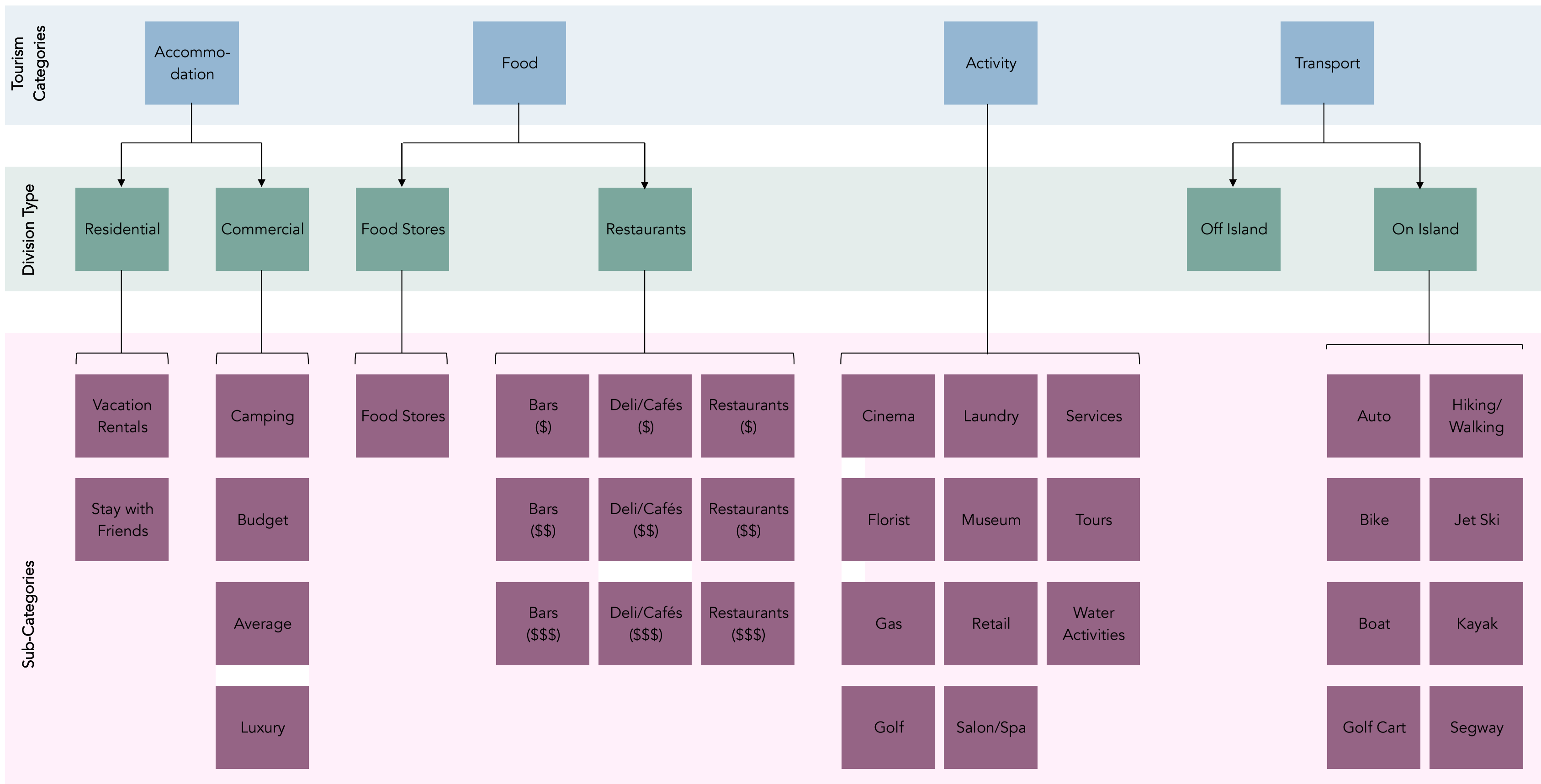


FIGURE 8: TOURISM SUB-CATEGORIES

3.4 General WF

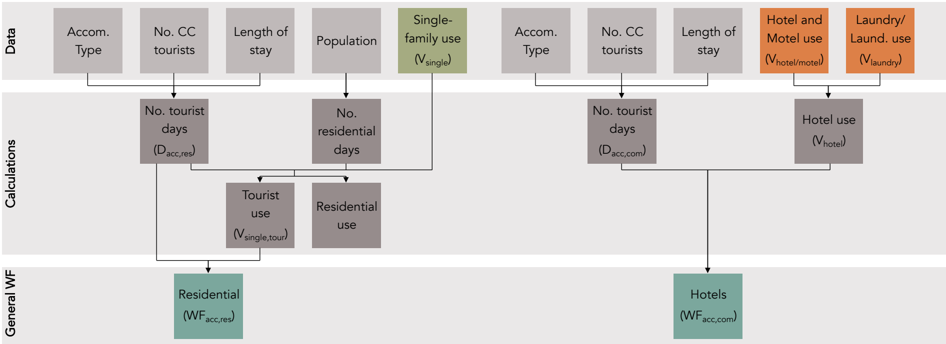
Different approaches were needed for each tourism category. These are depicted in Figure 9, with variable definitions found in Appendix A and specific calculations for accommodation, food, activities, and transportation detailed in Appendix B, C, D, and E, respectively. Generally speaking, the general WF was completed using the total tourist and residential days to determine the amount of water used for each sub-category per tourist per day. This resulted in the general WF of each sub-category, which was then aggregated to form the general WF for each tourism category ($\mathrm{WF_{acc,gen}}$, $\mathrm{WF_{food,gen}}$, $\mathrm{WF_{act,gen}}$, $\mathrm{WF_{trans,gen}}$). The general WF for each tourism category was then used to calculate the general WF ($\mathrm{WF_{gen}}$) of tourism overall, which has the units of water use per tourist per day. The equation for the general WF is detailed in Equation 2.

EQUATION 2:
$$\mathrm{WF_{gen}} = \mathrm{WF_{acc,gen}} + \mathrm{WF_{food,gen}} + \mathrm{WF_{act,gen}} + \mathrm{WF_{trans,gen}}$$

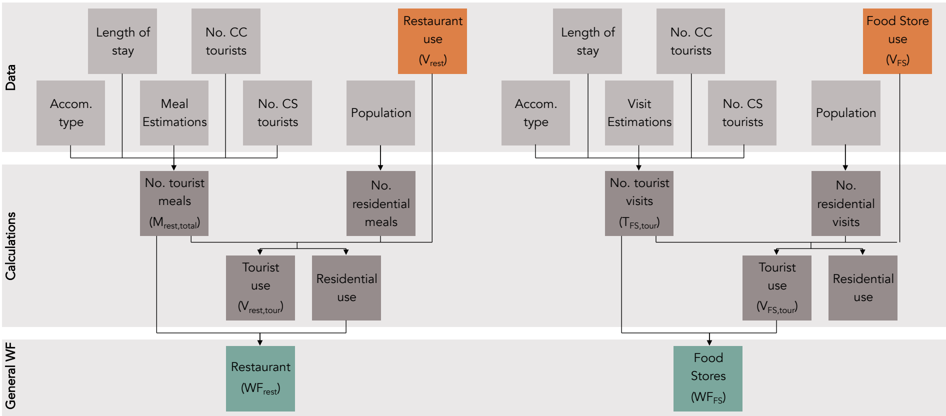
Once the general WF was calculated, we then investigated how much of this was direct vs. indirect water use. As a reminder, direct is freshwater used directly by tourists (e.g. showers), while indirect is freshwater used in the production of the goods and services used by tourists (e.g. agriculture and construction). It was determined that only the accommodation WF was to be considered direct, as all other categories had primarily indirect use. Therefore, the calculation of the direct and indirect general WF resulted in Equation 3 and Equation 4, respectively. Note that the step-by-step calculations for the general WF can be found in Appendix F

EQUATION 3:
$$\mathrm{WF_{gen,direct}} = \mathrm{WF_{acc,gen}}$$

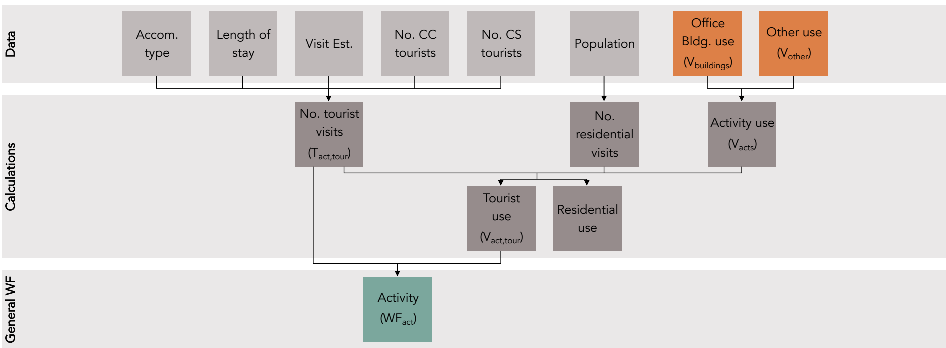
EQUATION 4:
$$\mathrm{WF_{gen,indirect}} = \mathrm{WF_{food,gen}} + \mathrm{WF_{act,gen}} + \mathrm{WF_{trans,gen}}$$



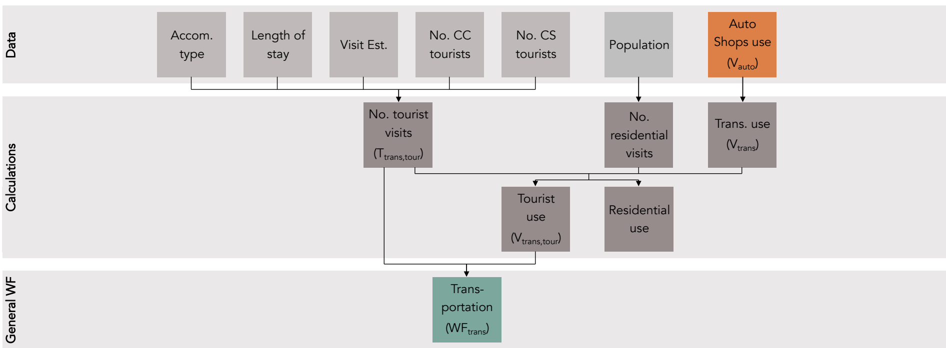
A. ACCOMODATION



B. FOOD



C. ACTIVITY



D. TRANSPORTATION

FIGURE 9: GENERAL WF FOR EACH TOURISM CATEGORY

3.5 Specific WF

The specific WF was developed in order to understand the variance in water usage for different vacation types. To do so, the WF of accommodation, food, activity, and transportation types were calculated per day or per visit, as depicted in Figure 10. These values were then combined in various ways to create the WF for vacation packages. For accommodation, the WF ($\mathrm{WF}_{\mathrm{acc,pack}}$) was equal to the residential WF or the commercial/hotel WF, depending on the accommodation type of the vacation package. For restaurant usage, the WF of each meal would be added up to get the total restaurant WF, while the number of visits to food stores would be used to calculate the food store WF. Adding these two WFs together then gave the food WF ($\mathrm{WF}_{\mathrm{food,pack}}$). For activities and transport, the sum of each activity and transportation visit provided the activity WF ($\mathrm{WF}_{\mathrm{act,pack}}$) and transport WF ($\mathrm{WF}_{\mathrm{trans,pack}}$), respectively. This information was then used to create the specific WF for each vacation package ($\mathrm{WF}_{\mathrm{pack}}$), as shown in Equation 5.

EQUATION 5:
$$\mathrm{WF}_{\mathrm{pack}} = \mathrm{WF}_{\mathrm{acc,pack}} + \mathrm{WF}_{\mathrm{food,pack}} + \mathrm{WF}_{\mathrm{act,pack}} + \mathrm{WF}_{\mathrm{trans,pack}}$$

Six different vacation packages were put together for the month of August: vacation rental/stay with friends, luxury, average, budget, camping, and day trips. The details of these packages are further explained in Section 4.5.

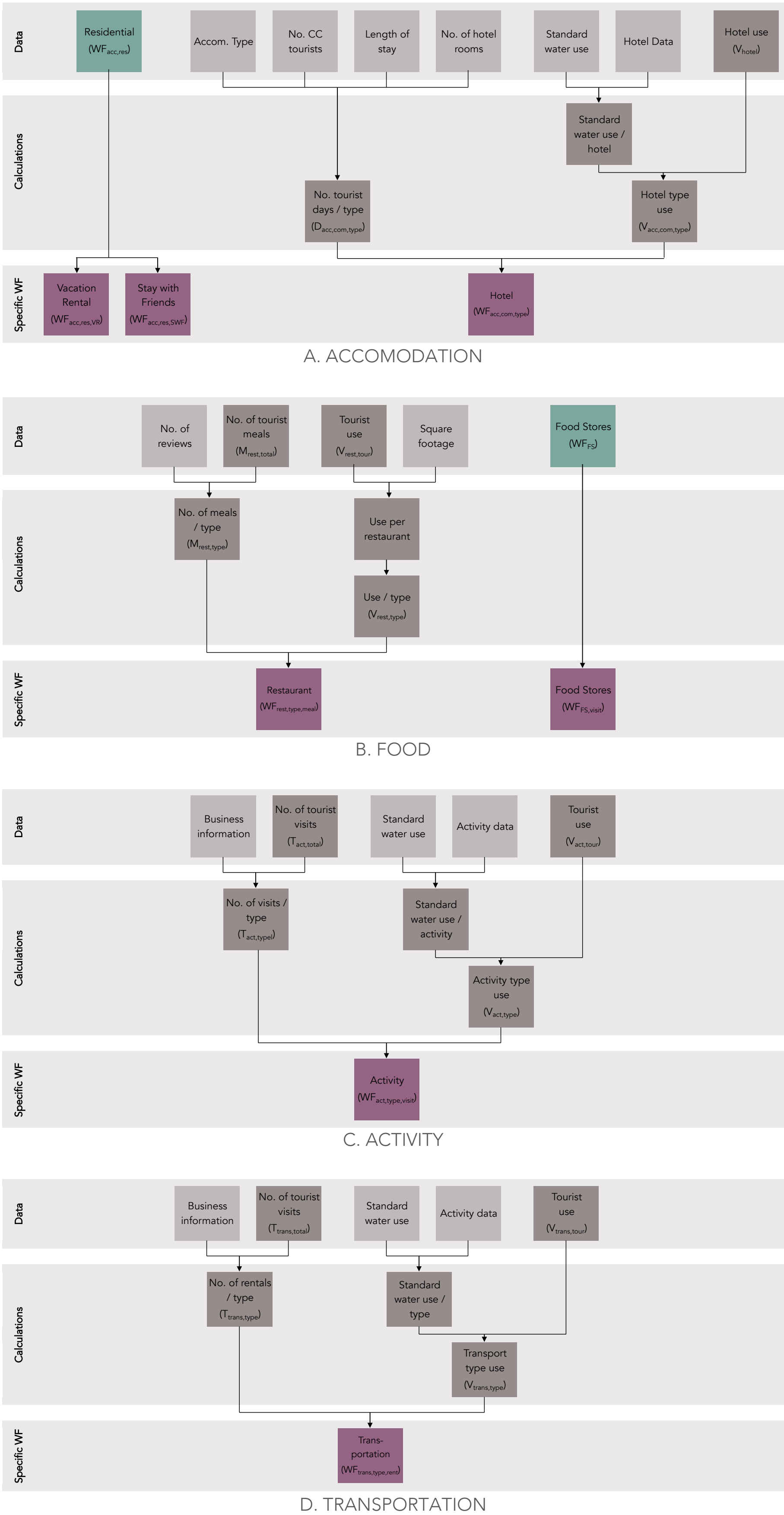


FIGURE 10: SPECIFIC WF FOR EACH TOUISM CATEGORY

3.6 Target WF

The purpose of the target WF is to show how much water should be consumed per person in order to meet specific demand reduction targets. Reduction targets stipulate that total water use must be reduced by a certain amount (typically a percentage) when compared to a baseline year. Note that reductions typically refer to total water use instead of individual water use. As such, the total water use ($\mathrm{V_{tour}}$) is first reduced by the amount of water stipulated in the mandate ($\%_{Red}$). This value is then divided by the total number of expected tourist days ($\mathrm{D_{tour}}$) in order to determine what the WF per tourist should be to achieve the mandate maximum ($\mathrm{WF_{Target}}$) (see Equation 6).

EQUATION 6:

$$\mathrm{WF_{Target}} = \frac{\mathrm{V_{tour}} \times (1 - \%_{Red})}{\mathrm{D_{tour}}}$$

In this case, 2013 will be the baseline year and 2014 will be the target year. The $\mathrm{WF_{Target}}$ will then be compared to the other WF values calculated for the target year to see if they were able to meet the mandate.

3.7 Policy review

Using the above WF's, we then conducted an assessment of the results with the aim of identifying what improvements in water usage could be made and where reduction is the most feasible. The assessment included evaluations of how the different categories compared to each other, feasibility of implementing improvements, and red flags indicating reduction potential. In the end, recommendations tailored to the case study were given using the above information. Specific focus was placed on what aspects are the most water intensive and who is responsible for the water used.

4. Result

In this chapter we will review the results of the previously discussed methodology. In Section 4.1, we discuss our case study of Catalina Island and its applicability to the research. Section 4.2 reviews the outputs of the utility data, while Section 4.3 provides the quantitative breakouts of this information into tourist and municipal water use. We then used this data to produce the results of the general WF (Section 4.4), the specific WF (Section 4.5), and the target WF (Section 4.6). Also included in the target WF is a discussion of the possible options for meeting the mandated reductions for the case study of Catalina.

4.1 Case study: Catalina Island

Known as a beautiful and quiet destination, Catalina is an isolated location where the complexities of water scarcity and economic dependency on tourism collide. It is most commonly visited by Southern Californians who wish to get away from the smog and traffic of Los Angeles without being too far from home. The number of tourists on the island vary throughout the year (Figure 11), with the peak tourist season occuring during the summer months.

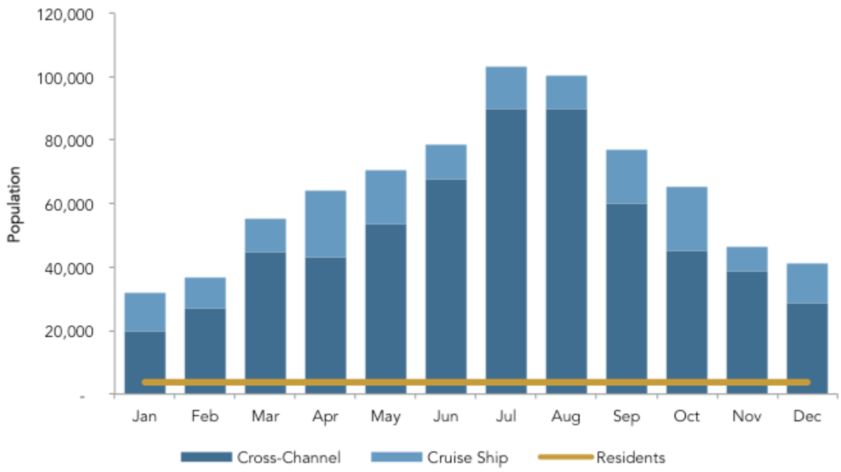


FIGURE 11: VARIATION OF TOURIST AND RESIDENT COUNTS (2013) (CICC & VB, 2012; GRIFFIN, 2014)

As the length of stay for tourists also varies, it is important to understand the amount of tourists on the island per day vs. the number of tourists per month or year. This becomes significantly interesting when compared with the residential poulation located on the island. This comparison, shown in Figure 12, highlights the fact that the tourist population often exceeds the residential population 9 months out of the year.

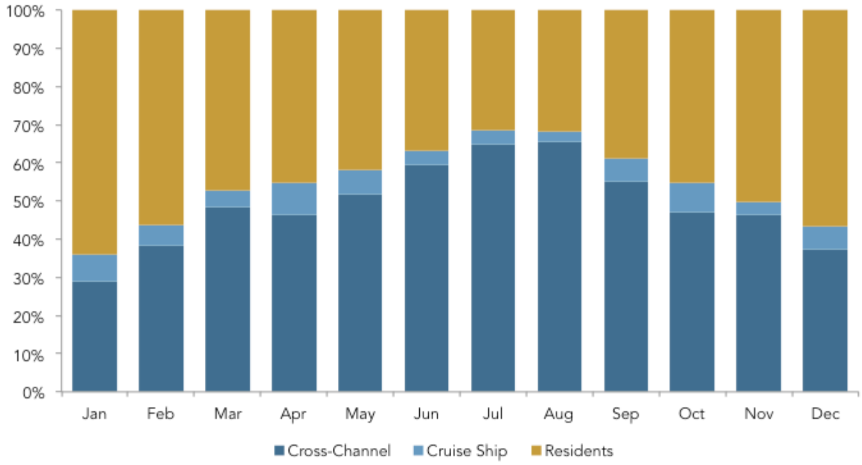


FIGURE 12: AVERAGE DAILY ISLAND OCCUPANTS FOR 2013 (CICC & VB, 2012; GRIFFIN, 2014)

Though the number of tourists who visited the island each year was relatively stable for a longer period of time, tourist vists began to dwindle around 2005. In response, over $40 million was invested in improvements to the island in order to stimilate tourism (Lovett, 2014). This investment was seen as a necessity as Catalina's economy is almost entirely reliant on tourism, which brings in an estimated $100 million per year (CICC & VB, 2009). The result of these improvements was, in fact, considered a success, as tourism rates began to recover and eventually reached a record high in 2014 (Figure 13). Unfortunately, this growth in tourists numbers also coincided with Catalina's growing water availability issues. These events intertwined so much so that tourism began to be regarded as the cause of the island's water scarcity issues (Lovett, 2014; Sahagun, 2014). Though this correlation is discussed further in the text, it should be noted that Catalina has a long history of water scarcity to consider.

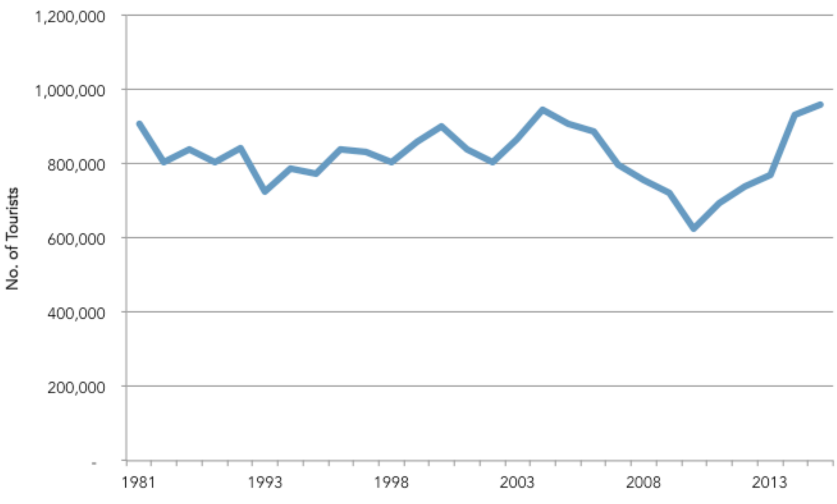


FIGURE 13: ANNUAL NUMBER OF CATALINA TOURISTS (CICC & VB, 2012; GRIFFIN, 2014)

Catalina has dealt with the issue of a dwindling ground water supply for over 25 years (Rose, 1990). Most recently, this issues has increased in importance, as Catalina is currently experienceing its worst drought in over 120 years (Sahagun, 2014; SCE, 2014a). On August 11, 2014, the utility governing Catalina's water supply, SCE, imposed a Stage 2 Water Rationing for the island, mandating a 25% reduction in water use, as compared to 2013, now referred to as the baseline year (SCE, 2014a). Though other areas of Southern California are argued to be experiencing similar or even worse conditions, Catalina is unique because of its location (Lovett, 2014). Catalina is completely self-reliant for its water supply (Figure 14) and, because of its distance from the mainland, it cannot fall back on the larger California water network (Lovett, 2014; SCE, 2014b). With this in mind, the residents of Catalina created Avalon Vision 2020, which highlighted the island's goal of sustainability and, more specifically, its aim to conserve water (CICC, 2014). Despite these and other efforts of the municipality and residents to meet the utility imposed mandate, the water levels of Catalina's most prominent reservoirs have continued to drop. As a result, it is expected that the island will be upgraded to a Stage 3 Water Rationing before the end of the year (SCE, 2015). This would mean that water usage would need to be reduced by 50% as compared to the baseline year.

FIGURE 14: SOURCES OF WATER ON CATALINA (SCE, 2014B)

The response to the imposed mandates have varied in their intensity. Restaurants serve only bottled water, hotels have outsourced their laundry to the mainland, and construction projects must now import needed water in barges (Sahagun, 2015). As island residents and businesses are already struggling to meet the Stage 2 mandate, the threat of increased restrictions will put Catalina in a very precarious position. This is because the largest source of income and the base of the Catalina economy, tourism, is also percieved to be the largest and most difficult to control user group (CICC & VB, 2009; Lovett, 2014; Wood & Haw, 2013). Running out of options to maintain the islands economy and reduce the impacts of tourism on water supplies, discussions are beginning to turn towards accomodation limitations. However, this path of action could have a very detrimental impact on Catalina's economy (Lovett, 2014). Additional discussions tend to focus on increasing the water supply through development of deeper wells. This option, however, requires incredible financial support as well as extensive permits, therefore it cannot assist with shortterm water supply issues. In the end, Catalina is posed with the issue of either compromising it's economic stability through decreased tourism or running out of water completely.

4.2 Utility data

Utility data was provided by SCE in a per-month aggregated format for both 2013 and 2014. Per this information, it was found that water use in 2013 was almost evenly split between residential and commercial use (Figure 15). This data was found using the delivered water information, the specific values of which can be see in Appendix H.

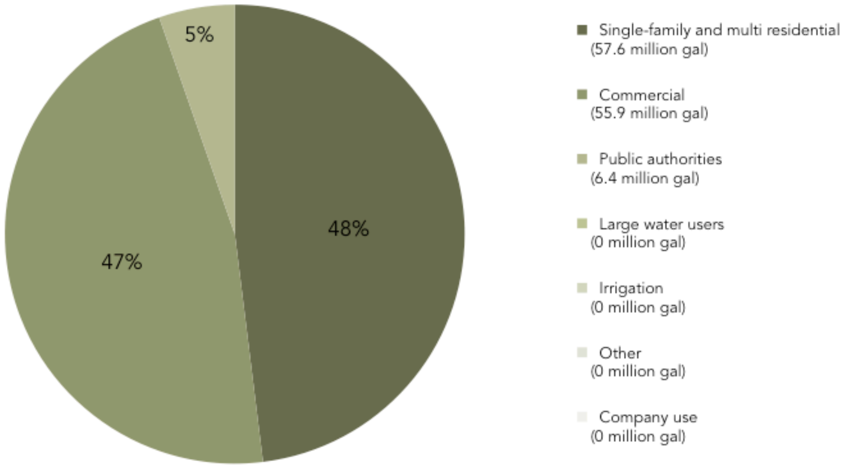


FIGURE 15: WATER DELIVERED PER UTILITY CATEGORY FOR 2013

Following the SCE utility mandate definitions, see Section 4.1, 2013 was defined as the baseline year and 2014 was defined as the target year. Using the water delivered utility data, we were able to see a reduction in overall water usage between 2013 (120 million gal) and 2014 (100 million gal). However, the reduction from 2013 to 2014 was only 16%, therefore falling short of Stage 2's 25% reduction mandate.

To better understand where these reductions were made, we next reviewed the water reduction achievements by utility category (Figure 16). Note that, at this point in the research, the values reviewed were for the island as a whole, therefore tourism use was not yet differentiated. Through this review, it was found that the largest reduction was seen in single-family and multi residential users who were able to reduce their usage by 20%. Public authorities were the second most effective, decreasing their usage by 14%, followed by commercial usage, which achieved a 13% reduction.

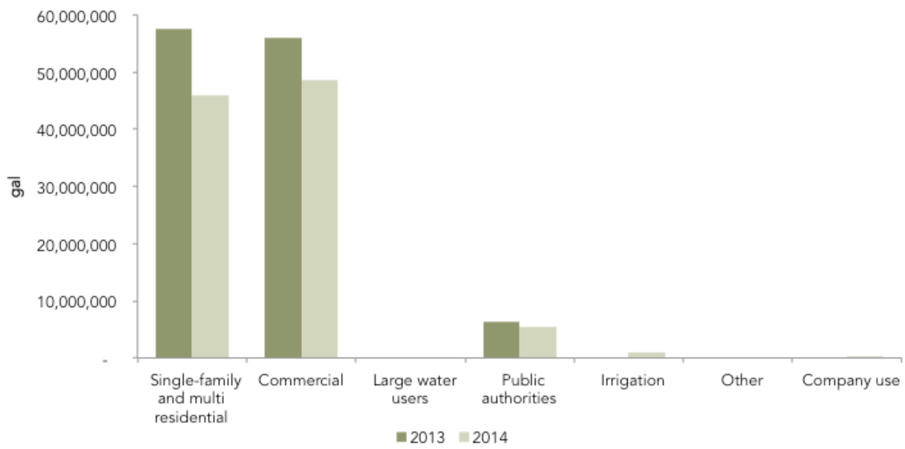


FIGURE 16: COMPARISON OF WATER DELIVERED PER UTILITY CATEGORY FOR 2013 AND 2014

However, it should be noted that the Stage 2 mandate was only imposed in August of 2014. Therefore, we also needed to look at 2014 usage before and after the mandate. It was found that, before August of 2014, water use reduction as compared to the baseline year was 9%. After the mandate was announced, however, the island as a whole reduced its usage by 29% when compared to the baseline year.

4.3 Tourism vs. municipal water use

The next step in this process was to then identify tourism vs. municipal water use. It should be noted that the term municipal is used instead of residential, as residents were not necessarily in control of all non-tourism use. Examples include the island's private winery and the water used to irrigate public spaces. Note that, for this section, all results are in terms of total water use, therefore the units discuss are in gallons.

First, the utility data was defined as either "residential" or "commercial". In this case, single-family and multi-residential were classified as "residential", while all other categories, excluding company use, were classified as "commercial". These were then grouped into descriptive categories that best represented the different practices present on Catalina. Since "residential" use was comprised solely of residential home use, this water use was classified under the accommodation descriptive category. "Commercial" usage, however, applied to multiple descriptive categories. Therefore, using the estimated breakout of commercial use as presented in the US Dept. of Energy's Buildings Energy Data Book (2012), the "commercial" value was divided into 11 descriptive categories. This breakout can be seen in Figure 17, while the specific data is available in Appendix I. Note that the water used indirectly through fuel or electricity production was not identified, as this data was unavailable. Therefore it is assumed that this water usage is embedded in all descriptive categories.

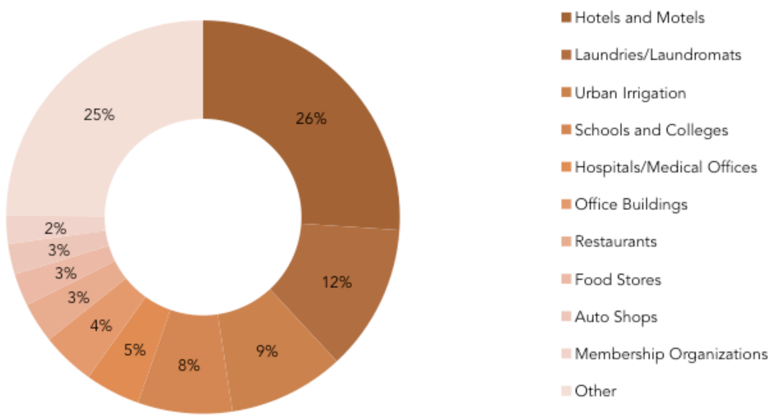


FIGURE 17: STANDARD BREAKOUT OF COMMERCIAL WATER USE (EXCL. CAR WASHES) (USDE, 2012)

These descriptive categories were then classified as tourism related, municipal related, or both. For those that were both, careful assessment of the data was needed in order to separate tourism use from municipal use for each descriptive category. This was not easily achieved, since tourism water use was present in almost all levels and areas of water use. Once separated, a clear separation of tourism and municipal water use was achieved (Figure 18). As can be seen from this figure, the overall municipal water use in 2013 was almost twice that of tourism water use. Looking at this from an entire island perspective, tourism water use was responsible for 33% of the total island usage in 2013. In 2014, this share increased, as tourism was found to be responsible for 36% of total island usage.

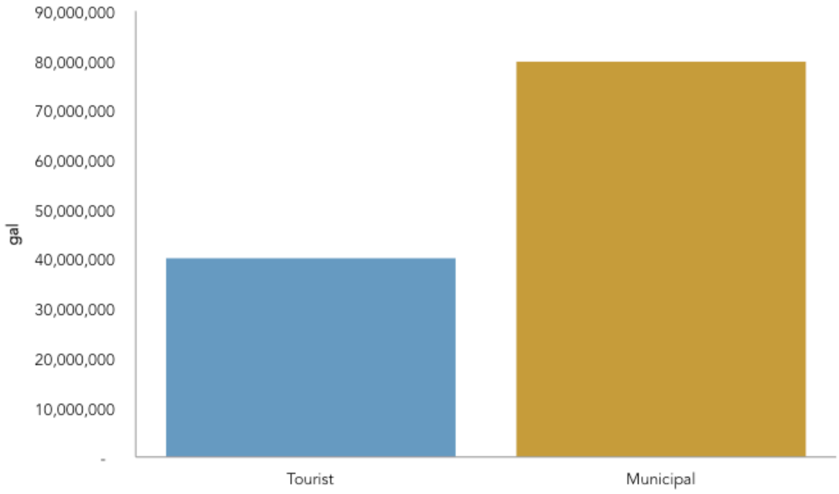


FIGURE 18: TOTAL WATER USE FOR TOURISM AND THE MUNICIPALITY (2013)

This water use was then broken into categories to see where the most water was used. Per Figure 19, accommodations were the largest users of water for the island. Additionally, municipal accommodation use (typically residential use) was found to be almost twice that of tourism accommodation use. This difference is discussed further in Section 5.2.

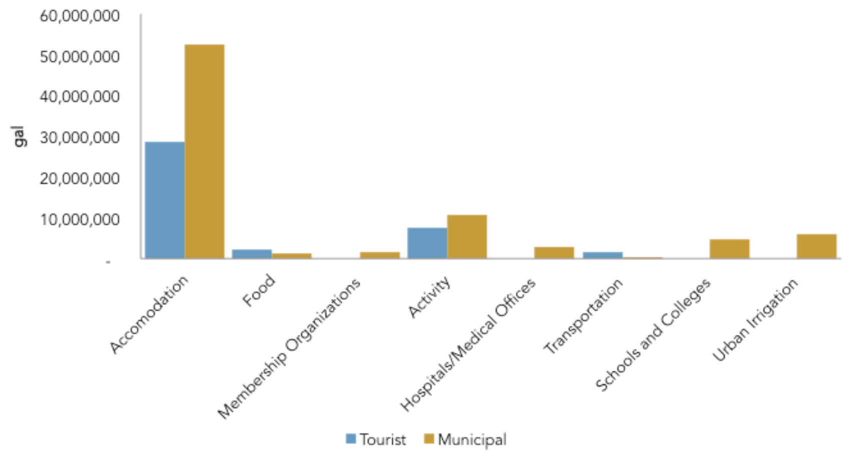


FIGURE 19: TOURISM AND MUNICIPALITY WATER USE BY DESCRIPTIVE CATEGORY (2013)

Since tourism fluctuates by seasons, we also wanted to see the changes in tourism water use over the year. As shown in Figure 20, the share of tourism usage increased in the summer months, however, the ratio between tourism and municipal usage remained somewhat constant over the year.

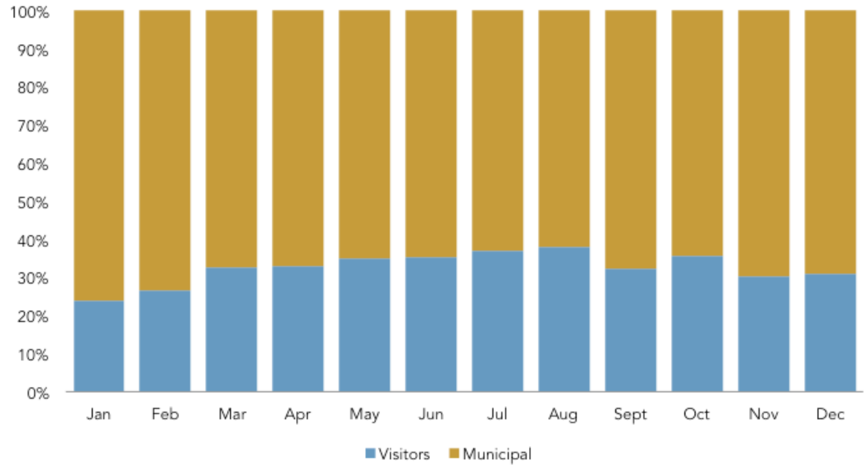


FIGURE 20: TOTAL WATER USE OF TOURISM AND THE MUNICIPALITY PER MONTH (2013)

Next, we then wanted to investigate the effects and correlations between tourism counts/population and water use. While the number of tourists arriving on the island increased steadily over the last 4 years, the population of the island remained consistent (Figure 13). However, though tourism counts increased, water use by tourism decreased by 10%. Additionally, the population remained constant for the municipality and an even larger decrease in usage (18%) was witnessed. These correlations are presented in Figure 21.

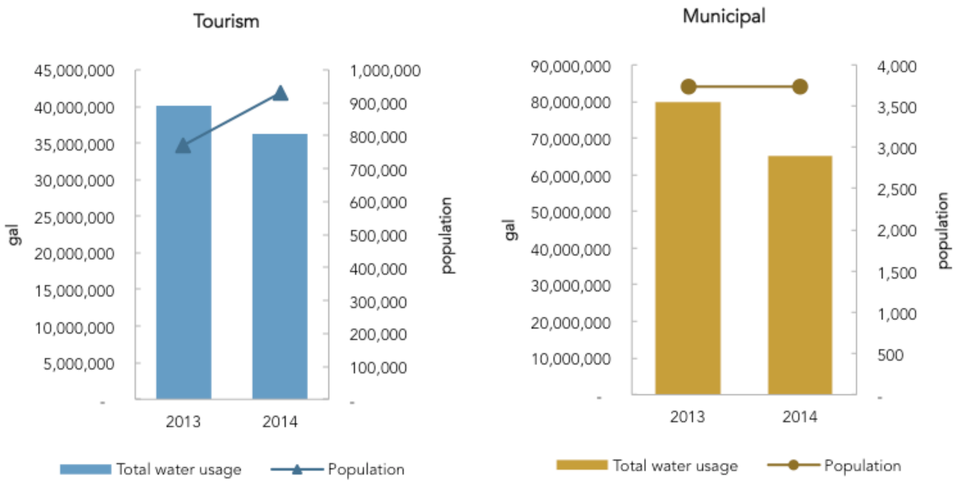


FIGURE 21: WATER USE COMPARISON BETWEEN 2013 AND 2014 INCLUDING POPULATION

A decomposition analyses was completed to further explain the relation of tourist counts/population and efficiencies/reductions. Between 2013 and 2014, the increased number of tourists (volume effect) would have typically result in an increase in tourism usage (approximately 7 million gallons). However, efficiency improvements and reduction measures (efficiency effect) resulted in a reduction in water use (11 million gallons). The output was therefore a net reduction in water use for the tourism sector (Figure 22). This is to say that, if the number of visitors had remained the same between 2013 and 2014, the reduction in tourism related water usage would have been almost 4 times larger than what was achieved.

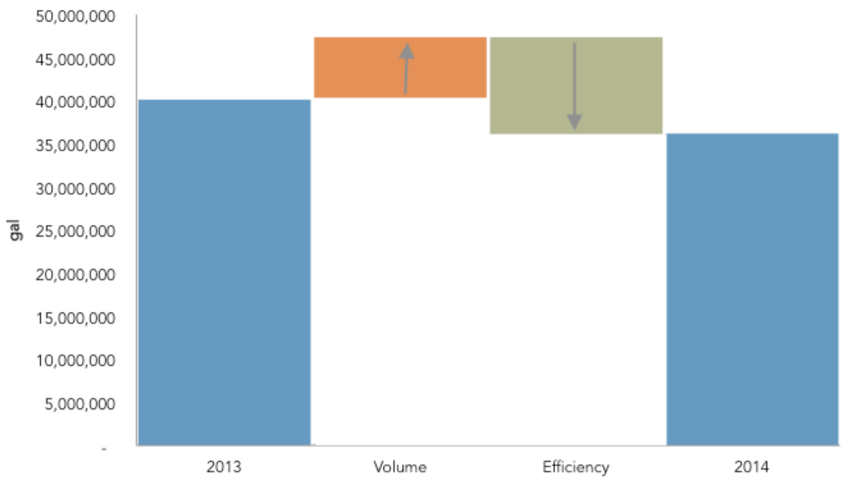


FIGURE 22: DECOMPOSITION OF TOURISM WATER USE SAVINGS

For municipal water use, however, the population remained consistent. Therefore, the reduction in municipal water use was entirely a result of the municipality and residential efforts to conserve Figure 23.

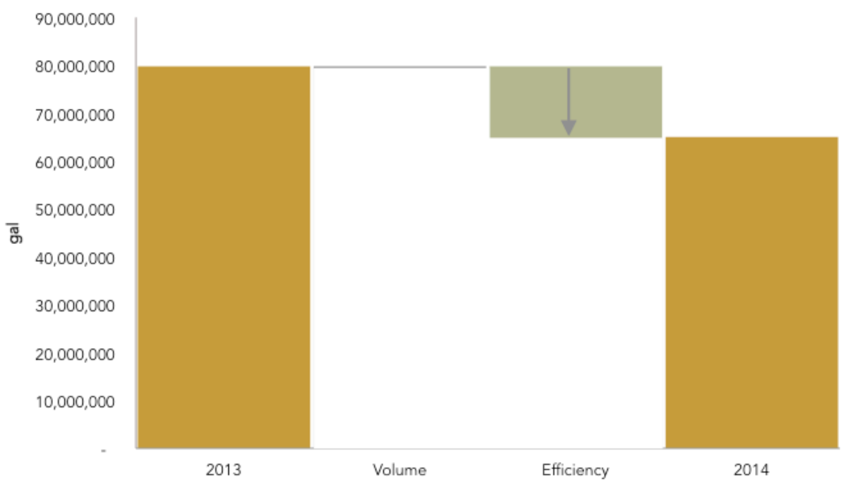


FIGURE 23: DECOMPOSITION OF MUNICIPAL WATER USE SAVINGS

4.4 General WF

Keeping the above information in mind, we then proceeded to calculate the general WF for both tourism and the municipality. Note that the general tourism WF is gallons per tourist per day, while the municipal WF is gallons per resident per day. This is different from water use, which was in terms of gallons and represents the total water consumed. As shown in Figure 24, the WF for the municipality was almost three times that of the WF for tourists.

FIGURE 24: GENERAL WATER FOOTRPINT FOR TOURIST AND MUNICIPAL USERS (2013)

Next we considered the direct vs. indirect water usage for both the municipality and residents. The purpose of doing so was to determine how much of the water used was controlled by the user (direct) vs. hidden in products and activities (indirect). For the case of Catalina, direct water use was generally only found in accommodation, where tourists have direct control over the water used in showers and faucets. As a result, food, activities, and transportation were classified as indirect. This is because tourists typically do not consume or control water directly when visiting restaurants, participating in activities, or travelling around the island. With this approach, it was found that 28% of tourist usage was indirect. This was very similar to municipal use where 31% of water use was found to be indirect. As a result, the primary source of water for both tourist and municipal WF's was found to be direct (Figure 25).

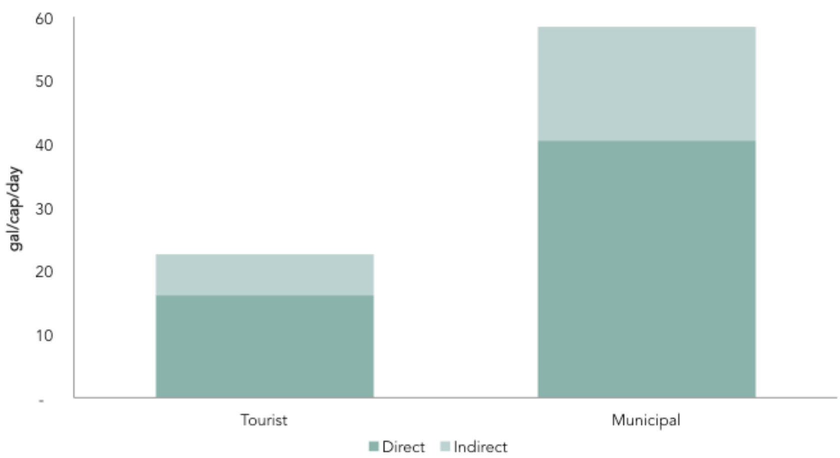


FIGURE 25: DIRECT VS. INDIRECT WATER USE (2013)

4.5 Specific water footprint

To calculate the specific WF, 6 vacation packages were put together to represent the variation in tourism styles. The packages were constructed using different accommodation types, length of stays, meal/food sources, and activities, all of which are outlined in Table 6. These packages were designed around themes that ranged from luxury golf packages to camping trips.

TABLE 6: OUTLINE OF VACATION PACKAGES

	VACATION RENTAL/SWF	LUXURY	AVERAGE	BUDGET	CAMPING	DAY TRIP
ACCOMM.	Vacation Rental	Luxury hotel	Average hotel	Budget hotel	Camping	None
NO. OF NIGHTS	7	4	2	3	2	0
MEALS	Bar ($$) Deli/Café ($$) Restaurant ($) Restaurant ($$)	Restaurant ($$) Restaurant ($$$)	Bar ($) Deli/Café ($$) Restaurant ($) Restaurant ($$)	Bar ($) Deli/Café ($) Deli/Café ($$) Restaurant ($)	Deli/Café ($)	Bar ($) Restaurant ($) Restaurant ($$)
ACTIVITIES	Gas Golf Museum Retail Salon/Spa Tours Water Activities	Cinema Gas Golf Museum Retail Salon/Spa Tours	Gas Museum Retail Tours Water Activities	Museum Retail Tours	Laundromat Retail	Museum Retail Tours
TRANSPORT	Golf cart	Boat Car Golf cart	Boat Golf cart	Bike	Kayak	None

In general, vacation rental and stay with friends (SWF) tourists were expected to have longer stay durations since the majority of vacation rentals were fully equipped homes that anticipated longer visits. Luxury guests were expected to stay for longer weekends due to financial capability, while average and budget packages anticipated shorter trips. As the size Catalina is relatively small, camping trips were also expected to be brief, while day trips were inherently during a single day. Luxury, average, and budget vacation rentals used the corresponding hotels types, while the camping vacation package used campsites and the day trip vacation package had no accommodation.

Meal preparation varied significantly. VR/SWF were expected to eat out a few times at reasonably priced locations ($-$$), however, the majority of their meals were expected to occur at home. Meanwhile, luxury packages anticipated that tourists would primarily dine at more expensive restaurants ($$-$$$). Similarly, average packages primarily visited average priced location ($$) and budget packages frequented cheaper locations ($). Camping packages, on the other hand, anticipated that meals were made at campsites using food purchased at grocery stores, however, an introductory or concluding meal at a an inexpensive deli ($) was included. Day trips anticipated 1-2 meals to occur on the island, as breakfast or dinner would be expected to occur off the island.

Regarding activities, all packages expected some retail shopping and the majority of the packages anticipated visits to museums or tours. This differentiated significantly for camping and luxury packages. Camping packages expected minimal visit to anything other than retail and Laundromats, while luxury packages anticipated golfing and spa trips. Transport was also fairly even between packages, as the use of golf carts is the most common form of transport on the island. Transportation varied somewhat, however, as budget packages were expected to use bikes, while luxury may have used car services.

Using this information, the WF for each individual activity was calculated and summed to produce the vacation package WF, presented in Figure 26.

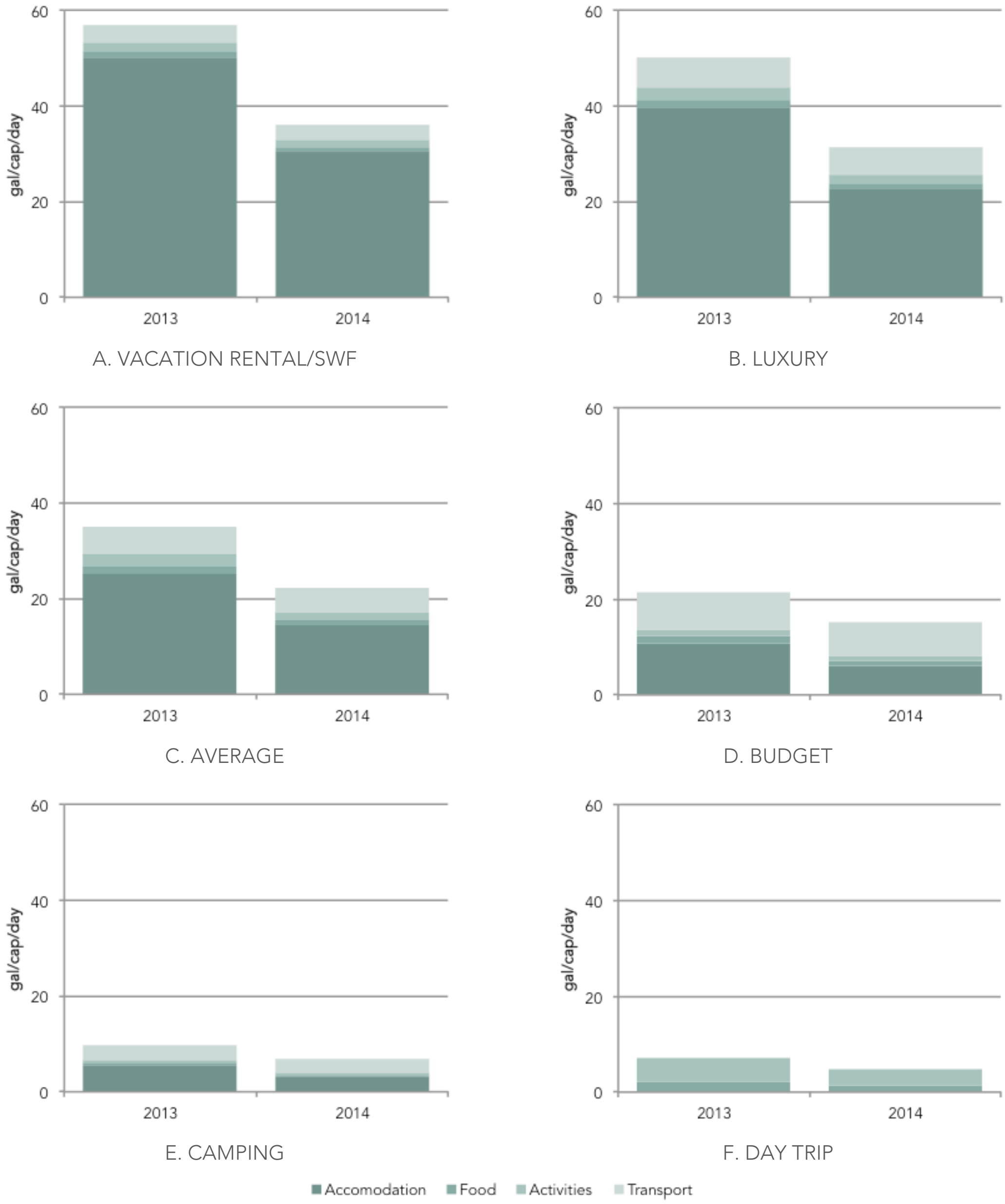


FIGURE 26: SPECIFIC WF FOR VACATION PACKAGES (SUMMER, 2013)

Through comparison of these values (Figure 27), it was found that the camping WF and the day trip WF were by far the lowest. Meanwhile, the largest WF was that of vacation rentals/SWF and luxury tourists. It can also be seen that the amount of water reduced between 2013 and 2014 was larger for the more water intensive vacation packages.

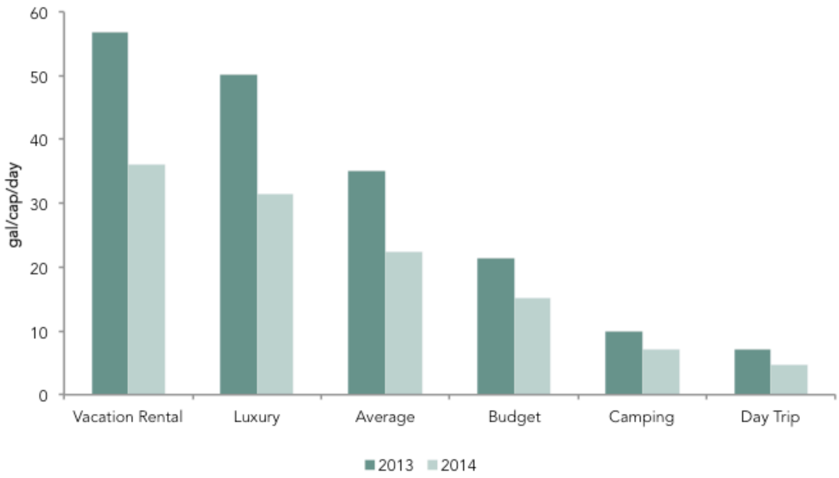


FIGURE 27: COMPARISON OF SPECIFIC WF (SUMMER, 2013)

4.6 Target water footprint

In 2014, SCE mandated a 25% reduction in water usage for Catalina as compared to the baseline year, 2013. Total tourism water use, however, was only reduced by 10% (Figure 28). As mentioned before, however, the mandate was only put into place in August of 2014. By only focusing on the months after the mandate was in place, tourism water use decreased by 18%. Though this is more than the whole of 2014, it still failed to meet the Stage 2 reduction target, and is farther still from the impending Stage 3 mandate.

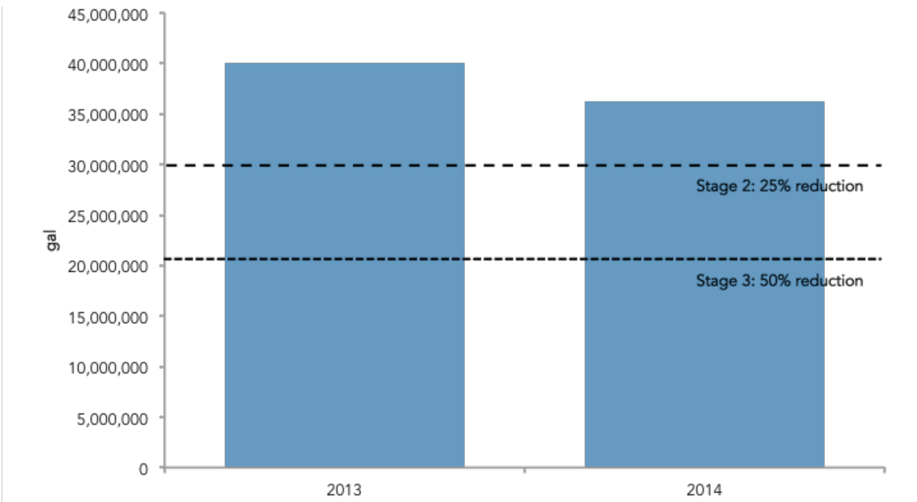


FIGURE 28: COMPARISON OF TOTAL TOURSM WATER USE TO REDUCTION MANDATES

Considering that the Stage 3 mandate is expected before 2016, considerable reductions in tourism water use are needed. As such, we have prepared 4 possible approaches to resolve this problem:

- Option 1: Limit the number of tourists allowed on the island
- Option 2: Promote "mandate compliant" vacation packages
- Option 3: Reduce per tourist usage
- Option 4: Limit the number of tourists allowed for each type of vacation package

In the following, we will discuss the needs for each of these options, while the discussion of their appropriateness will be examined in Section 5.4.

4.6.1 Option 1: Limit the number of tourists allowed on the island

This "across the board" option recommends that water usage rates should be maintained at a 2014 level while the total number of tourists permitted on the island should be reduced. Using this approach, the number of tourists arriving on the island would have to decrease 15%, from 930,000 per year to 775,000, per year, in order to meet the Stage 2 mandate. Not that this reduction assumes that the average length of stay would stay similar to that of the 2014 length of stays. In order to meet Stage 3 water rationing levels, the total number of tourists would have to be limited to 515,000, which is a 45% decrease in yearly tourism rates as compared to 2014. Considering that tourism brings in $100 million per year, reducing tourism rates to meet the Stage 2 and Stage 3 mandates would result in economic losses to the island of $15 million and $45 million, respectively. A depiction of the necessary tourist arrival reductions and the potential impacts to income can be seen in Figure 29.

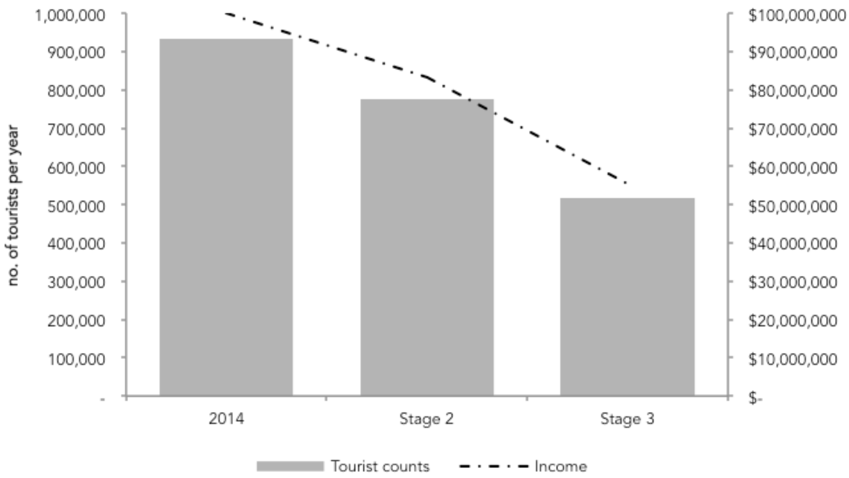


FIGURE 29: MAXIMUM NUMBER OF TOURISTS ALLOWED PER WATER REDUCTION TARGET

4.6.2 Option 2: Promote "mandate compliant" vacation packages

A different option would be to approach the issue from the individual vacation packages. Since some of the existing vacation packages already meet the target WF's, it is, therefore, recommended that these vacation packages should be promoted as "mandate compliant". However, as shown in Figure 30, only two existing vacation packages met the Stage 2 water-rationing targets: camping and day trips. Further, none of the designed vacation packages met the requirements of the 50% reduction, though day trips are the closest in doing so.

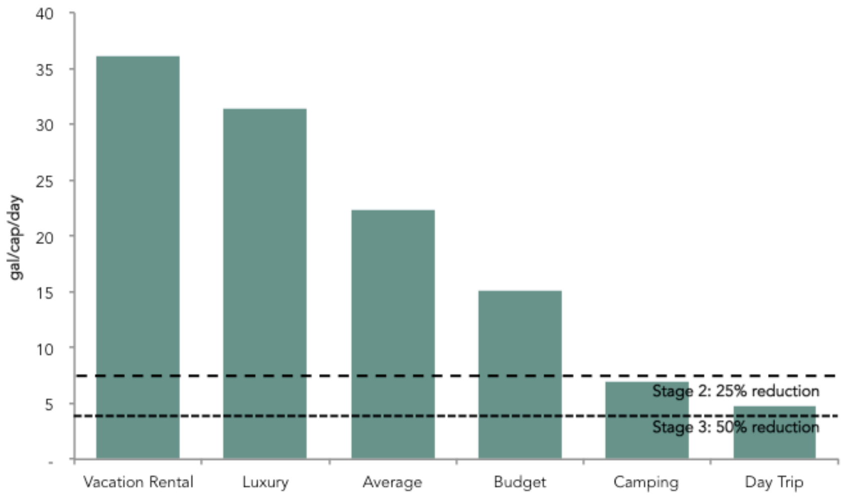


FIGURE 30: COMPARISON OF SPECFICIC WF TO REDUCTION MANDATES

4.6.3 Option 3: Reduce per tourist usage

The third option is to reduce water use on an individual level. To look at how much water use needs to be reduced per tourist, we assumed that the number of tourists would stay frozen at the 2014 level. By doing this, it was determined that to meet the Stage 2 mandate, individual tourist use would need to decrease by 68%. Further, to meet the 50% mandate, per tourist use would need to decrease by 79%. The current WF of tourists as compared to the target WF for each mandate can be seen in Figure 31.

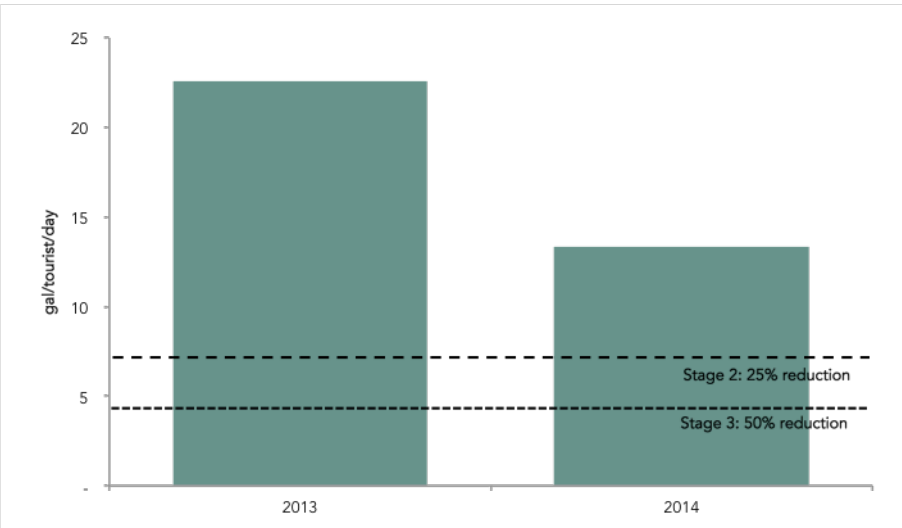


FIGURE 31: COMPARISON OF GENERAL WF TO REDUCTION MANDATES

4.6.4 Option 4: Limit the number of tourists allowed for each type of vacation package

The fourth option is to combine the previous options by reducing the number of tourists by vacation package type. In doing so, the municipality can decide which tourist package is the most beneficial to them, meeting their economic and water impact needs. To view this trade off, we evaluated the maximum number of tourists per vacation package that the island's water supply could handle while also meeting the water mandates (Figure 32). Note this assumes that only one vacation package type would exist for the island, which is not necessarily feasible.

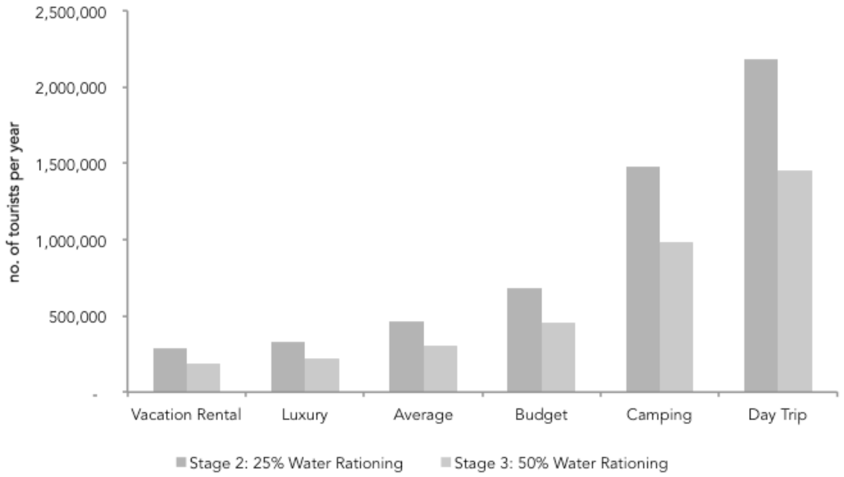


FIGURE 32: MAXIMUM NUMBER OF TOURISTS ALLOWED PER VACATION PACKAGE

5. Discussion

The intent of this research was to use the WF approach to both quantify tourism water use for a water independent island and determine how the outputs could assist in supporting water conservation measures. To structure this approach, we aimed to answer the following research questions:

RQ: How can the water footprint of tourism be applied to support water conservation measures for water-independent islands?

SQ1: What is the general WF of tourism and how does this compare with the target WF of tourism, as dictated by local needs?

SQ2: What are the most water intensive aspects of tourism and who is responsible for each water source?

SQ3: What policies can be recommended that will reduce the amount of water used by tourists while considering the effects on tourism rates and economic impacts?

In this chapter, we will address each of the sub-questions through the discussion presented in Sections 5.1, 5.2, 5.3, and 5.4. Note that the research question will be addressed in Chapter 6. We will then review the WF and its applicability as a methodology for tourism water use (Section 5.5). This will be followed by a summary of the issues that occurred during the study as well as other limitations (Section 5.6). This chapter will then conclude with recommendations for future research (Section 5.7).

5.1 Tourism vs. municipal water use

As shown in Figure 20, the share of tourism usage varied over the year and peaked in the summer. This was somewhat expected as the number of tourists also peak in the summer. However, this peak was not substantial, as the share of tourism use only fluctuated by 10% over the entire year. Even with these fluctuations, in 2013, tourists were found to be responsible for 33% of total water use of Catalina. In other words, municipal use was twice that of tourism use, as shown in Figure 18. This result made our case study appear to be the deviation rather than the norm when comparing it to the results of Becken (2014). According to their research, of the 21 countries reviewed, only 7 found the tourism water use to be less than the municipal. This puts Catalina in the company of Australia, France, Italy, New Zealand, Spain, and the UK. This does make some relative sense, as these countries are all developed and share similar technologies and information as Catalina. However, it is also possible that our findings could be the result of other reasons.

One thought is that it could be because municipal use includes a variety of non-tourist activities (e.g. schools, hospitals, etc.) as well as indirect uses (e.g. agriculture, fuel processing plants, etc.). Additionally, though we were able to separate the most obvious tourism related use, there is still the possibility that some tourism use is embedded in municipal use. This includes construction of hotels, water use through electricity and fuel production, as well as other unknown overlaps. However, the main driver for this difference, according to Figure 19, appears to be accommodation use. Municipal accommodation use is shown to be twice that of tourism accommodation use, even though the number of tourist days exceeds, and in some cases doubles, that of the number of resident days (Figure 12). The higher water use by the municipality is partially explained by the fact that municipality accommodation category includes a variety of activities (e.g. laundry, dishwashing, and meal prep), while tourism separates these activities into different descriptive categories (e.g. activities and food). This would explain the higher water use by municipal accommodations as compared to tourist accommodations.

Though reductions in both municipal and tourism water use occurred in 2014, the share of tourism water use increased to 36%. This was partially because of the decreased municipal use and the increased number of tourists. Looking at 2013 and 2014 as a whole, the largest reduction was seen in single-family and multi residential users. This was also true when looking at the percent reductions, as residents were able to achieve a 20% reduction. The second largest reduction was that of commercial users, however this was only 13%. Since the rationing and its penalties were primarily aimed at and enforced for residential users, the reductions achieved by residents, though impressive, is somewhat expected.

5.2 Comparing the general WF to the target WF

If looking at the general tourism WF, a decrease of over 40% was achieved for tourism between 2013 and 2014 (see Figure 31). Specifically, the general WF of tourism in 2013 was 22.6 gal/tourist/day, which was approximately 1/3 of the municipal WF. In 2014, the general WF of tourism was reduced dramatically to 13.3 gal/tourist/day. Though impressive, the increase in the number of tourist almost completely offset this savings. As a result, the net reduction of tourism water use form 2013 to 2014 was only 10%. In order to meet Stage 2 and 3 water rationings, the target WF for tourism would be 7.2 and 4.8 gal/tourist/day, respectively. This means that the general WF of tourism, in order to meet the Stage 2 mandate, would need to decrease by an additional 50%, as compared to its 2014 value.

5.3 The most water intensive aspects of tourism

Accommodation use was found to be the largest aspect of tourism water use, making up over 70% of the general WF of tourism. Accommodation is also the only direct water used by tourists, as tourists control the water used in showers and faucets. The second largest aspect of tourism water use was activities, representing 19% of the general WF for tourism. Unlike accommodation, however, activity related water use was considered to be indirect, as the tourists do not actually have control of the water used. As such, the water used for this aspect as controlled by business owners. This was also true for the remaining tourist categories of food and transport. However, the total indirect water usage only amounts to 28% of tourism's total usage, therefore indirectly controlled water use was found to be much less than that of the tourist controlled direct water use.

When looking at the specific WF, however, the aspects that are the most water intensive vary. As an example, for luxury tourism, accommodation was still the most water intensive aspect, but for budget tourism, accommodation and transportation were almost equal in their water used per tourist per day. Additionally, the reductions in water use between 2013 and 2014 varied by vacation package (Figure 26). The amount of water reduced was larger for the more water intensive vacation packages and smaller for the less water intensive packages. This could be because the less intensive packages were already efficient in their water use or, more simply, the larger WF's had more water to reduce.

While identifying water intensive aspects is a logical approach to developing conservation policies, identification of water intensive vacation packages can also be a solid approach. Per Figure 26 the largest specific WF was that of vacation rentals and SWF. This was one of the most surprising findings, as it was expected that luxury tourists would have the largest WF based on their extravagant activities and staying in highly water intensive accommodations. In comparing residential tourists to hotel tourists, both had similar access to toilets, showers, and baths. However, residential tourists also had access to dish washers and washing machines. It is estimated that this was the primary reason for the higher usage. This is because appliances would be run regardless of the number of people residing in the home. It was therefore possible that these accommodations end up being less water efficient on a per tourist bases, thus making vacation rental/SWF tourists have larger WF. Hotels, on the other hand, were more likely to run these types of appliances in bulk; therefore less water was used per tourist. Additionally, hotels are now outsourcing their laundry to the mainland and relying on disposable items instead of reusable, therefore they are technically outsourcing a significant portion of the hotel tourist's WF (Sahagun, 2015).

Though this may explain the accommodation aspect of the WF, luxury tourists also included the very water intense activity of golfing. Therefore, it is also possible that the reliance on standard breakouts for commercial usage could have resulted in an inaccurate allocation of water usage. As an example, the difference between budget, average, and luxury hotel usage may be larger on the island, or other descriptive categories may have used more water than determined through our approach. These things could result in the luxury breakout being higher than determined in the results.

5.4 Policy recommendations

Before discussing the types of policies that could be put in place, a review of the effectiveness of existing policies should be addressed. For the case of Catalina, the primary policy implemented was mandated reductions in water use as imposed by the utility. It should be noted that there is a clear difference in water conservation rates before and after the mandate was announced. Note that the details of the mandate are explained in Section 4.1. Before the mandate was in place, water reduction as compared to the baseline year was at 9%. However, after the mandate was announced, water use reductions were at 29%. This sudden change in water use is quite impressive, considering this was achieved in less than 5 months. However, the mandate approach is not likely to be able to achieve Stage 3 rations and imposing rations is also not likely maintainable in the long run. Therefore, additional policies and reduction methods should be considered. Based on our research, we developed 4 possible policies that could help achieve the mandated reductions while also considering the effects on tourism rates and the islands economy. It should be noted that the option to increase the water supply was not included, as our focus was on reducing the impacts of tourism.

Option 1: Limit the number of tourists allowed on the island

Since water usage was shown to increase with the number of tourists arriving on the island (Figure 22), it is therefore expected that limiting the amount of tourists could achieve the needed reduction in water use. Placing a mandate on the maximum number of tourists permitted on the island would help reduce the water used by tourism. However, by placing a general limit, there would be no control over the type of tourist, and therefore the water use is not certain to decrease. Additionally, imposing a cap would also limit the economic health of the island, as shown in Figure 33.The decreased number of tourists would mean a decreased need for employees and activities for the island. This could potentially lead to business closures, lay offs, and potentially migration of residents off of the island. As such, additional measures would be needed to address the financial impacts of this option as well as guarantee water use reductions.

Option 2: Promote "mandate compliant" vacation packages

The promotion of vacation packages that already meet the utility imposed mandates could help reduce water usage while maintaining vacation quality. Based on the specific WF vacation packages (Figure 27), however, only two vacation packages meet the mandate requirements: camping and day trips. Therefore, it could be advised that the Visitor's Bureau should promote these vacation packages for the purpose of alleviating the water demand of tourism. However, just promoting these packages would not be enough to meet the water rationing mandates. This is partially because these vacation packages only meet the Stage 2 mandate. If Stage 3 were to be implemented, additional efforts would be needed. Additionally, these vacation packages only meet the Stage 2 mandate if the rate of tourism does not exceed the arrival numbers of 2014. Therefore, more extreme measures would be needed. The ability of this option to address the three most relevant needs for policy formation for Catalina are presented in Figure 33.

Option 3: Reduce per tourist usage

The third option was to focus on reducing the per tourist water use. In order to do so, we first needed to determine which aspect of tourism used the most water. Per the break out of water use for Catalina (Figure 19) and the general tourism WF (Figure 24), it was shown that tourists use the most water for accommodations (72%) and activities (19%). This makes sense, as accommodations are known to be the highest use of water for commercial use (USDE, 2012). However, this does not match up with other tourism studies. Typically, food is the largest WF of tourism as agriculture is extremely water intensive (Hadjikakou et al., 2013). For the case of Catalina, however, no agriculture was present; therefore, the WF for food was comprised of restaurant related usage, which was much smaller. As such, for the case of Catalina, it is recommended that water reduction measures should focus on accommodation related usage.

The next step in reducing water usage is to determine who regulates and manages this water use. Tourists are primarily responsible for their direct water use while residents and business owners are typically responsible for indirect. Since accommodation use is categorized as direct water use, this means that the tourists themselves are responsible for the largest share of their WF. To date, however, water reduction measures have primarily targeted residents and business owners. This has shown to be quite effective as residential usage had the greatest decrease. Therefore, water reduction policies should be expanded to include water used directly by tourists in accommodations.

In addition to targeting tourists in policymaking, additional technologies could be implemented to help assist in reducing water used by tourists in accommodation settings. Catalina is already quite advanced in water conservation measures. Examples are that almost all of the island's toilets use ocean water treated by the desalination plant. Focusing on tourist accommodation, specifically, the installation of low flow showerheads and other water reducing technologies are already in place. However, there are new technologies on the horizon that could further reduce accommodation water use. One development is the closed-loop shower, which captures shower water, treats it, and then reuses it (Orbital Systems, 2015). Similar in approach, the US military has also developed a dishwashing system that recycles the water as well (Church et al., 2015). Both approaches close the loop of water waste and can see water savings of up to 90%. Though both are still in the beginning stages of their development, they are examples of water recycling that could be very beneficial to assisting Catalina in its water reduction targets.

The issue with reducing the water usage of individual tourists, aside from the general complexity of effectively reaching this target group, is that reductions in use could be lost with the increase in tourists on the island. As shown from the decomposition analyses, the general WF of tourists had decreased dramatically from 2013 to 2014. However, the city's efforts to increase tourism rates almost negated the savings methods implemented. Therefore, knowing how much to reduce the general WF of tourists is completely dependent on the number of tourists arriving on the island. A depiction of this option's success in reducing the water used by tourists, maintaining the quality of the tourist's experience, and preserving the economic health of the island is shown in Figure 33.

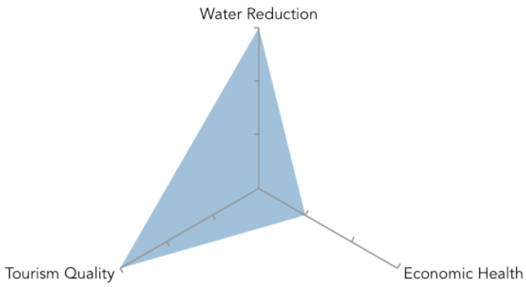
Option 4: Limit the number of tourists allowed for each type of vacation package

Option 4 focuses on bringing all four aspects into play, in order to better address the problem. The idea of this option is to limit the number of tourists by vacation package while attempting to maintain current per tourist water use or lower. This could come in different forms, as could be decided by the island. The first form would be to limiting the island to only day trips and campers. This would help bring down the demand of tourists to the island while also endorsing the two vacation packages that have the lowest WF. This potential option has been previously adopted by neighboring islands, however, these islands were never developed in the first place, therefore this would be much more difficult to implement. Though good for meeting the water mandates, limiting the island to camping/day trips would eliminate the need for accommodations on the island. This would result in a mass closure of business and, therefore, a high amount of unemployment.

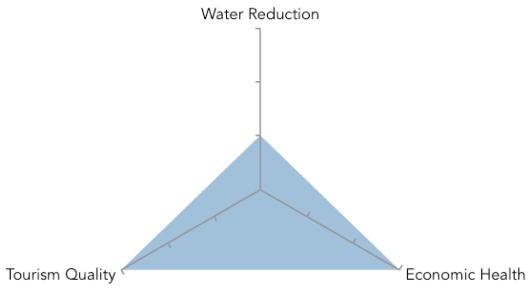
The second form would be for the island to become more exclusive, catering only to luxury tourism. In this case, the number of tourists on the island would need to decrease dramatically, but the high cost of the vacations could help offset the lack of tourist numbers.

Limiting the amount of luxury tourists would also reduce the need for tourism related water. However, making the island exclusive could cause many other issues such as how to decide the cut off of luxury vs. average and the elimination of vacation rentals could have dangerous consequences to the residents. . By limiting the island to luxury tourism, the cost of staying on the island would need to be extremely high to offset the lack of other tourism types. While this could help meet the economic needs of the island, it would also drastically reduce the number of tourists on the island, and therefore the need for the majority of services. The cost to stay on the island could also easily exceed the quality of the accommodations and activities, therefore driving tourism away completely.

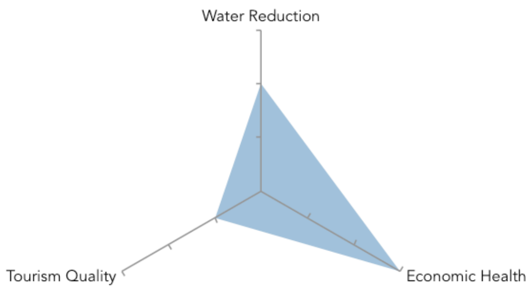
It is therefore recommended that a middle form be proposed such as limiting the number of tourists through a cap by vacation type. This would ensure that all aspects of tourism on the island are still used, therefore minimizing the amount of business closures/unemployment, while also reducing the impact of tourism on the islands water supply. This approach would require coordination of the tourism industry, businesses, and residents to determine how many rooms should actually be available for each vacation type. This cap would limit the number of tourists, but would hopefully result in a financially sustainable situation that would be within the limits of the water use mandates, as seen in Figure 33. Additionally, with the continued promotion of water conservation measures, the cap could increase to include more tourism as seen fit with the water supply.



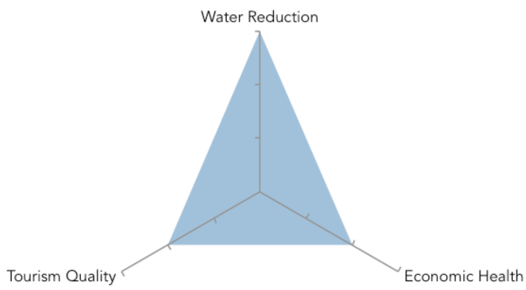
OPTION 1: LIMIT THE NUMBER OF TOURISTS ALLOWED ON THE ISLAND



OPTION 2: PROMOTE "MANDATE COMPLIANT" VACATION PACKAGES



OPTION 3: REDUCE PER TOURIST USAGE



OPTION 4: LIMIT THE NUMBER OF TOURISTS ALLOWED FOR EACH TYPE OF VACATION PACKAGE

FIGURE 33: EACH OPTIONS ABILITY TO MEET WATER, TOURISM, AND ECONOMIC NEEDS

5.5 Application of the WF

Overall, the most notable outcome from our application of the WF was that the results for Catalina varied considerably from other studies. Specifically, our approach varied from

Hadjikakou et al. (2013) in several ways, including the definition of the direct and indirect WF. Hadjikakou had included activities in the direct water usage, however, our investigation into Catalina tourism activities showed very little sign of direct water usage. Additionally, Hadjikakou and Cazcarro et al. (2014) both found that the indirect WF was the most prominent in tourism. This was primarily due to the food and diet WF, which was based on the water used for agriculture to produce the food that was consumed by tourists. For the case of Catalina, no agriculture was found that was consumed by tourists, therefore this typically large WF was drastically reduced.

The application of the WF in different capacities provided insight on the general problem as well as the specific impacts. As such, the general WF and the specific WF provided differing conclusions. Per the break out of water use for Catalina (Figure 19) and the general tourism WF (Figure 24), tourists use the most water for accommodations and activities. However, when looking at the specific WF for various packages, the largest water use is shown to be accommodation and transportation. The difference may be that not that many tourists use transportation on the island, as it is small and easily walk able. Therefore, the use of any transportation results in a larger share of the usage and thus a larger WF representation. It is also possible that, since the break out for transportation is based on standard usage for auto mechanics for mainland locations, that the break out was not accurately applicable to the situation on Catalina. Therefore, the actual WF for transportation could be smaller. Additionally, since the specific WF is based on designed vacation packages and is only meant to provide an estimation, it is very possible that the vacation package design is not perfectly representative.

5.6 Issues and limitations

Through the course of this study there were several issues that arose, which put a limit on the thoroughness of the study. These items were primarily related to data quality, data availability, and calculation assumptions.

5.6.1 Data quality

The data provided by SCE was pivotal to this research, however, it was delivered in a monthly aggregated format. As a result, it was not possible to get an accurate value per business or even per business type. It is important to note that this information is available, however, was not given to us for this research because of access restrictions. It is possible with more time and better partnerships with utilities, this information could be provided. Had it been provided, more accurate values could have been used and possibly more relevant results.

In addition, the data provided had errors that, though relevant for the utility, were in appropriate for this study. These errors were primarily in the form of billing corrections and yearly adjustments. As a result, some data appeared as extreme outliers (e.g. water usage was negative for the month of January). In order to correct this, we were able to use the averages between the month before and the month after. Though probably close, it was not entirely accurate. Additionally, the sporadic values for irrigation were somewhat puzzling, as it seemed odd that water would only be used during one month of 2014. It therefore raises the question whether this was actually a reallocation of the water use from commercial instead.

This is to say that this use may have occurred in 2013 and the other months of 2014, however, it was included in the commercial usage instead of being broken out. This would partially explain the reduction in commercial and increase in other categories. The data collected from the Visitor's Bureau also had inconsistencies and errors. As an example, the rate of accommodation and stay duration numbers were derived from a 2009 survey completed by the visitor's bureau. However, it was confirmed that this survey was quite informal and contained some errors. This resulted in the possible inaccuracy of our calculations of tourist visitor days and visit counts. The Catalina Chamber of Commerce has already recognized this and is planning for a more robust survey to be implemented in the near future. Finally, the standard values used to breakout the commercial usage were not the most reliable for this research. The standards available were sourced primarily from the southwest area of the US, which was relevant to our location but may not be accurate for all locations. Additionally, this information was for mainland locations. Since this information was not available for island, it is expected that there may be some variation.

5.6.2 Missing information/lack of data

Part of the appeal of this research was the lack of information on the WF when paired with tourism. This advantage was also a hindrance, as there was very little research to build a base on the topic and build from. In fact, at the time of this document only 3 papers directly addressed this coupling. One of the topics that are still under construction is the development of accurate and useful metrics (e.g. gal/sq ft). Square footage is the most typical metric used, as almost any location with a water meter will also have a building. However, this metric has some inaccuracies, as a result of the variation in business types. For example, the water used by a drive through restaurant is not necessarily comparable to the water used by restaurant, however both are in the food category. Metrics such as water use per employee, per meal, or per restaurant type could be relevant, however, for this study this information was not available.

On the topic of data availability, information relevant to the calculation of the WF was also missing. This included the water used for electricity and gas production. As a result, our calculations did not identify the water used indirectly through fuel or electricity production. Other missing information included the number of tourists arriving on the island by private ships. As this is a common method of getting to Catalina, it is quite possible that the actual amount of tourists that arrived to the island were much higher than recorded. Regarding missing business information, often the square footage of locations, as well as other business information, was unavailable. In these cases, estimations were based on online information such the Google Map Developer website and Trip Advisor.

5.6.3 Calculation inaccuracies

As a result of the missing data and information, several estimations were used to fill the gaps. A compilation of these assumptions is presented in Appendix J. In addition, other estimations were also included such as the creation of the vacation package estimations. Vacation packages were established to capture a range, since not every vacation type and pattern could be completed. As such, this should be seen as examples, which can be modified for each package independently. Additionally, in establishing the target WF, it was assumed that the number of tourists remained constant with no variation in their numbers or stay durations. It is quite possible that both of these could vary with the conditions on the island and should be considered in future research.

5.7 Further research

It is recommended that further research in this area be done on three themes:

Empirically based development of subcategories and metrics

Though sub categories were developed to be more applicable to the island's situation, it is possible that other sub categories should be defined. Additionally, the metrics were based on available data such as square footage or number of hotel rooms, however, more applicable metrics (e.g. no. Of meals) should be used in the future. This step back was again due to data availability.

Investigation of the water-energy nexus and its impacts on the indirect WF of tourism

Regarding the water-energy nexus, research is need on how the WF of tourism would change should this be included in the WF calculation. Again, this is dictated by data availability, therefore case studies should be selected based on access to this information.

Application of the practices method to connect water measurement indices and reduction policies for tourism

In structuring our descriptive categories and recommendations, it was found that the social practices model developed by Spaargaren (2011).could have been an excellent way to frame our approach. It is therefore recommended that a deeper investigation into the practices method and how social practices should be defined within tourism should be completed. Additionally, a strengthening of the connection between water index outputs and policy decisions could be completed through this investigation.

6. Conclusion

The limited availability of fresh water is becoming an increasing issue worldwide. This is especially true for islands that are self-dependent for their water supply. They rely solely on their own resources, which are often finite and rapidly decreasing. Compounding the problem is that many of these locations are also leading tourist destinations. Tourism has been known to be water intensive and, in some cases, the largest consumer of the limited water supply. As such, more information on how to reduce the impact of tourism for these locations is needed. However, in order to address this, an understanding of how much and in what capacity water is used is needed. Therefore, the aim of this research was to use the WF method to determine both how much water was consumed by tourists and, through these results, determine what options there were to reduce tourism water use.

In order to test this approach, the case study of Catalina was selected based on its almost complete economic reliance on tourism and high profile issues with water availability. This case study, however, had several limitations, primarily connected to data availability and data quality. As a result, it is expected that with more detailed information on water usage per customer, a better understanding and pinpointing of water intensive activities could be completed. Regardless, significant findings were achieved and the process of applying the WF to tourism was completed.

Using the general WF, we were able to determine, with some degree of accuracy, the amount water consumed per tourist per day. This was then compared to the target WF, based on the utility enforced mandates, to review how tourism had contributed to the islands water use goals. By applying the general WF, it was found that tourism related water use was responsible for one third of Catalina's water usage in 2013. Efforts to reduce tourism usage were effective, however, the increase in the number of tourists offset the majority of these savings. The result was that, though individual tourism use decreased, total tourism related use did not meet the utility mandates.

The application of the WF also allowed us to identify which aspects of tourism were the most water intensive. This information was then used to prioritize descriptive categories. For the case of Catalina, accommodation usage was by far the most water intensive aspect of tourism and municipal use. Through the calculation of the specific WF, this was found to still be true; however, for vacation packages such as camping, accommodation use was found to be negligible. Additionally, through application of the direct and indirect WF, we were able to identify those responsible for the most water intensive aspects. Since accommodation use was considered to be direct, it was found that the responsible party for the most water intensive aspect of tourism was, in fact, the tourists themselves. As such, it could be concluded that policies should be aimed at tourists and reducing their use in accommodations.

From here, we were then able to recommend possible policy pathways that could address the issue of tourism water use. Currently, the most common method of addressing tourism water use for Catalina has been to limit tourist's access to water. This includes serving only bottled water shipped from the mainland, serving food on disposable dishware, using desalinated water for toilets, and outsourcing laundry services. However, this puts the responsibility of tourism water use on the residents and businesses. Additionally, the residents and businesses are the ones impacted should tourist water use exceed the mandated amount. What is needed is a way to alleviate the burden of tourists off of municipal users and onto the tourists themselves; however, this needs to be approached so that it does not reduce the quality of the vacation or the revenues the island is reliant on. Additionally, the main problem in recommending policies for tourism water usage is that tourists have very little stokehold in the island's situation.

Through our research we were able to come to four feasible options for Catalina. The first option was to focus on limiting tourism, therefore it was recommended to reduce the number of tourists visiting the island. However, this could potentially have devastating effects on the economy of tourism dependent islands. The second option was to promote "mandate compliant" vacation packages. However, water savings would not be guaranteed; therefore, this option may not effectively reduce water use by the necessary amounts. The third option was to then focus on the reducing tourist consumption on the individual level. However, as previously stated, the decreased usage can easily be offset by the increase in tourism rates. The fourth option was to combine the previous three options in order to address the issues of water use needs, economic stability, and tourism quality. This option took the form of creating tourism visit maximums that are managed by vacation type. This would better guarantee water use reductions, could maintain the existing economy (to some extent), and would not affect the quality of the vacation. Though this option is the best of the four to meet all three needs, there are still other factors to consider and a more thorough investigation of this option is needed.

It should be noted that, although the concluding recommendations are specific to the case study, the approach of the general, specific, and target WF has the capability to be applied to a variety of locations. This approach can help decipher tourism vs. municipal use for multiple locations and, using this information, customized recommendations can be made. However, because each location will have a different situation, recommendations are specific to the location. In order to get a more thorough understanding of the varying issues related to tourism, water use, and the application of the WF to this problem, it is therefore recommended that more empirically based research be completed. It is our hope that the research completed in this study will help better inform people on the actually impacts of tourism and be used as a step form which useful policies and continuing research can be derived.

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Appendix A: List of Variables

$\%_{Red}$	Water reduction mandate (%)
a	Individual business name
A	Square footage (sq ft)
A_{ave}	Average square footage (sq ft)
A_{golf}	Square footage of the golf course (sq ft)
A_{wine}	Square footage of the winery (sq ft)
Acc_{hotel}	Share of tourists that will stay at hotels (%)
Acc_{SWF}	Share of tourists that will SWF (%)
Acc_{VR}	Share of tourists that will stay at vacation rentals (%)
$cap_{max,a}$	Maximum occupancy for a specific location
$D_{acc,res,tour}$	Number of tourist days spent at residential accommodations (days)
$D_{acc,com,type}$	Number of tourist days spent at each commerical accomodation type (days)
$D_{acc,com}$	Number of tourist days spent at commerical accommodations (days)
$D_{acc,res,total}$	Total number of nights spent at residential accomodations (days)
D_{month}	Number of days in the month (days)
D_{res}	Number of residential days (days)
D_{SWF}	Number of tourist days for SWF (days)
D_{tour}	Total number of tourist days (days)
D_{VR}	Number of tourist days for vacation rentals (days)
$L_{\%}$	Stay duration (%)
M_a	Number of meal visits for a specific restaurant (meals)
M_{camp}	Number of meal visits expected for camping tourists (meals)
M_{day}	Number of meal visits expected for day visit tourists (meals)
$M_{est,type}$	Estimated number of meal visits expected for each vacation type (meals)
M_{hotel}	Number of meal visits expected for hotel tourists (meals)
M_{res}	Number of resident meal visits (meals)
$M_{rest,tour}$	Number of tourists meal visits (meals)
$M_{rest,type}$	Number of meals expected by restaurant type (meals)
M_{rest}	Total number of meal visits (meals)
M_{SWF}	Number of meal visits expected for SWF tourists (meals)
M_{type}	Number of meal visits expected for each vacation type (meals)
M_{VR}	Number of meal visits expected for vacation rentals tourists (meals)
N_{ave}	Total number of tourists staying at average hotels
N_{budget}	Total number of tourists staying at budget hotels

N_{camp}	Total number of tourists staying at campsites
N_{CC}	Total number of cross-channel tourists
N_{CS}	Total number of cruise ship tourists
$N_{hotel,type}$	Total number of tourists staying at each hotel type
N_{hotel}	Total number of tourists staying at hotels
N_{lux}	Total number of tourists staying at luxury hotels
$N_{rest,res}$	Total number of residents visiting restaurants
$N_{rest,tour}$	Total number of tourists staying at luxury hotels
N_{SWF}	Total number of SWF rental tourists
$N_{tour,curr}$	Total number of tourists for the current month
$N_{tour,peak}$	Total number of tourists for the peak month
N_{tour}	Total number of expected tourists
N_{type}	Total number of visits expected per vacation type
N_{VR}	Total number of vacation rental tourists
No_{a}	Number of vehicles at a specific location
P_{a}	Presence of fixtures at a specific location
POP	Total population
R_{a}	Total number of rooms at a specific location
R_{type}	Total number of rooms associated with each hotel type
$rate_{a}$	Level of visits expected based on reviews
$rate_{res,a}$	Level of resident visits expected based on reviews
$rate_{tour,a}$	Level of toursit visits expected based on reviews
$rent_{\%}$	Rate of rentals (%)
T_{a}	Number of food store visits for a specific location (visits)
$T_{act,camp}$	Number of activity visits for camping tourists (visits)
$T_{act,day}$	Number of activity visits for day visit tourists (visits)
$T_{act,hotel}$	Number of activity visits for hotel tourists (visits)
$T_{act,res}$	Number of activity visits for residents (visits)
$T_{act,SWF}$	Number of activity visits for SWF tourists (visits)
$T_{act,total}$	Total number of activity visits (visits)
$T_{act,tour,type}$	Total number of tourist visits per activity type (visits)
$T_{act,tour}$	Total number of activity visits by tourists (visits)
$T_{act,type}$	Number of visits per activity type (visits)
$T_{act,VR}$	Number of activity visits for vacation rental tourists (visits)
$T_{est,act,camp}$	Estimated number of activity visits for camping tourists (visits)

$T_{est,act,day}$ Estimated number of activity visits for day visit tourists (visits)

$T_{est,act,hotel}$ Estimated number of activity visits for hotel tourists (visits)

$T_{est,act,res}$ Estimated number of activity visits for residents (visits)

$T_{est,act,SWF}$ Estimated number of activity visits for SWF tourists (visits)

$T_{est,act,type}$ Estimated number of activity visits per food store type (visits)

$T_{est,act,VR}$ Estimated number of activity visits for vacation rental tourists (visits)

$T_{est,FS,camp}$ Estimated number of food store visits for camping tourists (visits)

$T_{est,FS,day}$ Estimated number of food store visits for day visit tourists (visits)

$T_{est,FS,hotel}$ Estimated number of food store visits for hotel tourists (visits)

$T_{est,FS,res}$ Estimated number of food store visits for residents (visits)

$T_{est,FS,SWF}$ Estimated number of food store visits for SWF tourists (visits)

$T_{est,FS,type}$ Estimated number of food store visits per food store type (visits)

$T_{est,FS,VR}$ Estimated number of food store visits for vacation rental tourists (visits)

$T_{FS,camp}$ Number of food store visits for camping tourists (visits)

$T_{FS,day}$ Number of food store visits for day visit tourists (visits)

$T_{FS,hotel}$ Number of food store visits for hotel tourists (visits)

$T_{FS,res}$ Number of food store visits for residents (visits)

$T_{FS,SWF}$ Number of food store visits for SWF tourists (visits)

$T_{FS,total}$ Total number of food store visits (visits)

$T_{FS,tour}$ Number of food store visits for tourists (visits)

$T_{FS,type}$ Number of visits per food store type (visits)

$T_{FS,VR}$ Number of food store visits for vacation rental tourists (visits)

$T_{trans,a}$ Total number of visits for a specific transportation locaiton (visits)

$T_{trans,tour}$ Total number of transportaion rentals by tourists (visits)

$T_{trans,type}$ Number of visits per transportation type (visits)

$V_{acc,com,a,ST}$ Standard water use for a specific accomodation location (gal)

$V_{acc,com,a}$ Total water used for a specific accomodation location (gal)

$V_{acc,com,type}$ Total water used per commercial accommodation type (gal)

$V_{acc,tour}$ Total water used by tourists for accomodations (gal)

$V_{act,a,ST}$ Standard water use for a specific activity location (gal)

$V_{act,a}$ Total water used for a specific activity location (gal)

$V_{act,golf,ST}$ Standard water use for a golf course based on square footage (gal)

$V_{act,res}$ Total water used by residents for activities (gal)

$V_{act,tour}$ Total water used by tourists for activities (gal)

$V_{act,type}$ Total water used by activities type (gal)

$V_{act,wine,ST}$	Standard water use for a winery based on square footage (gal)
V_{act}	Total water used for activities (gal)
V_{ave}	Average water use (gal)
$V_{bath,ST}$	Standard water use for baths (gal/room/year)
$V_{faucet,ST}$	Standard water use for faucets (gal/room/year)
$V_{FS,a}$	Total water used for a specific food store location (gal)
$V_{FS,res}$	Total water used by residents at food stores (gal)
$V_{FS,tour}$	Total water used by tourists at food stores (gal)
V_{FS}	Total water used for food stores (gal)
$V_{food,tour}$	Total water used by tourists for food (gal)
$V_{hotel,type}$	Commercial accommodation use per hotel type (gal)
V_{hotel}	Total commercial accommodation use (gal)
$V_{ice,ST}$	Standard water use for ice machines (gal/room/year)
$V_{laundry,ST}$	Standard water use for laundry (gal/room/year)
$V_{leaks,ST}$	Standard water use lost to leaks (gal/room/year)
$V_{other,ST}$	Standard water use for miscellanious fixtures (gal/room/year)
$V_{pool,ST}$	Standard water use for pools (gal/room/year)
$V_{rest,a}$	Total waer used for each individual restaurant (gal)
$V_{rest,res}$	Total water used by residents in restaurants (gal)
$V_{rest,tour}$	Total water used by tourists in restaurants (gal)
$V_{rest,type}$	Total water used by restaurants type (gal)
V_{rest}	Total water used by restaurants (gal)
$V_{shower,ST}$	Standard water use for showers (gal/room/year)
$V_{single,res}$	Total water used by residents for accomodation (gal)
$V_{single,SWF}$	Total water used by SWF for residential accomodation (gal)
$V_{single,VR}$	Total water used by vacation rentals for residential accomodation (gal)
$V_{single,tour}$	Total water used by tourists for residential accomodation (gal)
V_{single}	Total water used by single- and multi-residential (gal)
V_{ST}	Standard water use per fixture (gal/room/year)
$V_{toilet,ST}$	Standard water use for toilets (gal/room/year)
V_{tour}	Total water use (gal)
$V_{trans,a}$	Total waer used for each individual transportation location (gal)
$V_{trans,tour}$	Total water used by tourists for transportation (gal)
$V_{trans,type}$	Total water used by transportation type (gal)
V_{trans}	Total water used by transportation (gal)

WF	Water footprint (gal/cap/day)
$WF_{acc,com,type}$	General water footprint by type of commercial accomodation (gal/cap/day)
$WF_{acc,com}$	General water footprint of commercial accomodations (gal/cap/day)
$WF_{acc,gen}$	General water footprint: accommodation (gal/cap/day)
$WF_{acc,pack}$	Specific water footprint for a vacation package: accommodation (gal/cap/day)
$WF_{acc,res}$	General water footprint of tourist residential accomodations (gal/cap/day)
WF_{accom}	Accommodation water footprint (gal/cap/day)
$WF_{act\ \#}$	Individual water footprint of each activity visit (gal/visit)
$WF_{act,gen}$	General water footprint: activity (gal/cap/day)
$WF_{act,pack}$	Specific water footprint for a vacation package: activity (gal/cap/day)
$WF_{act,type}$	General water footprint by type of activity (gal/cap/day)
WF_{act}	Activity water footprint (gal/cap/day)
WF_{diet}	Diet water footprint (gal/cap/day)
WF_{direct}	Direct water footprint (gal/cap/day)
$WF_{food,gen}$	General water footprint: food (gal/cap/day)
$WF_{food,pack}$	Specific water footprint for a vacation package: food (gal/cap/day)
WF_{FS}	Food store water footprint (gal/cap/day)
$WF_{FS,pack}$	Water footprint by food store type (gal/cap/day)
$WF_{FS,visit}$	Food store water footprint by visit (gal/visit/day)
WF_{fuel}	Fuel water footprint (gal/cap/day)
$WF_{gen,direct}$	General water footprint: direct (gal/cap/day)
$WF_{gen,indirect}$	General water footprint: indirect (gal/cap/day)
WF_{gen}	General water footprint (gal/cap/day)
$WF_{indirect}$	Indirect water footprint (gal/cap/day)
$WF_{meal\ \#}$	Individual water footprint of each meal (gal/meal)
WF_{pack}	Specific water footprint for a vacation package (gal/cap/day)
$WF_{rest,meal}$	Water footprint of individual meals (gal/meal)
$WF_{rest,pack}$	Water footprint by restaurant type (gal/meal)
$WF_{rest,type,meal}$	Water footprint of meals by restaurant type (gal/meal)
WF_{target}	Target water foorprint (gal/cap/day)
$WF_{trans\ \#}$	Individual water footprint of each transportation rental (gal/rental)
$WF_{trans,gen}$	General water footprint: transportation (gal/cap/day)
$WF_{trans,pack}$	Specific water footprint for a vacation package: transportation (gal/cap/day)
$WF_{trans,type,rent}$	Water footprint of by type of transportation per rental (gal/rental)
WF_{trans}	Transportation water footprint (gal/cap/day)

X_{bike}	Standard water use per bicycle (gal/rental)
X_{boat}	Standard water use per boat (gal/rental)
X_{car}	Standard water use per car (gal/rental)
X_{golf}	Standard water use per golf cart (gal/rental)
X_{heli}	Standard water use per helicopter (gal/rental)
X_{hike}	Standard water use for hiking (gal/rental)
X_{kay}	Standard water use per kayak (gal/rental)
X_{plane}	Standard water use per airplane (gal/rental)
X_{seg}	Standard water use per Segway (gal/rental)
X_{ski}	Standard water use per water ski (gal/rental)
$X_{trans,a}$	Standard water used for a specific location (gal)

Appendix B: Accommodation methodology

Accommodations were broken into two main types: residential and commercial. This was because vacation rentals (VR) and tourists staying with friends (SWF) usage would be found in the single-family utility category, while hotel usage would be found in the commercial utility category. It is important to note that, for the accommodation category, only tourists arriving CC were considered, as CS tourists would not stay on the island. Additionally, the main equations for each topic are presented in the following sections, while the step-by-step calculations can be found in Appendix B.

Residential: Vacation rentals and SWF

The VR accommodation type represents tourists who rent out residential homes for their vacation. The SWF accommodation type, on the other hand, represents tourists who stay with residents in a residential home. As the number of tourists present in both categories vary over the year, it is important to first calculate the number of tourist days spent on the island (e.g. 1 tourist staying 5 days would result in 5 tourist days). To do so, we used the rate of accommodation use and stay duration, as provided by the visitor's bureau. The rate of accommodation use (Acc) details the percent of tourists that stay in various accommodation types. Therefore, multiplying this by the total CC tourist number ($\mathrm{N_{CC}}$) allowed us to determine the total number of VR tourists ($\mathrm{N_{VR}}$) and SWF tourists ($\mathrm{N_{SWF}}$). This was completed though Equation 7 and Equation 8, respectfully.

EQUATION 7:
$$\mathrm{N_{VR}} = \mathrm{Acc_{VR}} \times \mathrm{N_{CC}}$$

EQUATION 8:
$$\mathrm{N_{SWF}} = \mathrm{Acc_{SWF}} \times \mathrm{N_{CC}}$$

Stay duration ($\mathrm{L_{\%}}$) is also a percentage breakout that details the length of time (L) that tourists will typically stay on the island. Using this and the above calculations, we determined the number of tourist days for VR tourists ($\mathrm{D_{VR}}$) and SWF tourists ($\mathrm{D_{SWF}}$) (Equation 9 and Equation 10).

EQUATION 9:
$$\mathrm{D_{VR}} = \sum_{\mathrm{i}} \mathrm{L_{i\%}} \times \mathrm{L_i} \times \mathrm{N_{VR}}$$

EQUATION 10:
$$\mathrm{D_{SWF}} = \sum_{\mathrm{i}} \mathrm{L_{i\%}} \times \mathrm{L_i} \times \mathrm{N_{SWF}}$$

The total number of tourist days ($\mathrm{D_{acc,res,tour}}$) is then the summation of the VR and SWF tourist days ($\mathrm{D_{VR}}$ and $\mathrm{D_{SWF}}$) (Equation 11).

EQUATION 11:
$$\mathrm{D_{acc,res,tour}} = \mathrm{D_{VR}} + \mathrm{D_{SWF}}$$

In order to break up the total residential water usage, we also needed to know the number of residential days on the island. This calculation was much more straightforward, as the number of residents is expected to stay constant year-round. Therefore, the calculation of residential days ($\mathrm{D_{res}}$) was achieved by multiplying the total population (POP) by 365 nights (Equation 12).

EQUATION 12:
$$\mathrm{D_{res}} = \mathrm{POP} * 365$$

Combining the total number of residential days with the total number of tourist days for VR and SWF tourists, we then had the total number of users days ($D_{acc,res,total}$) for residential water (Equation 13).

EQUATION 13: $$D_{acc,res,total} = D_{acc,res,tour} + D_{res}$$

Next, we sought to determine the amount of water used for VR tourists, SWF tourists, and residents. Using Equation 14, Equation 15, and Equation 16, we were able to divide the total single-family water use (V_{single}), as provided by the utility, into total gallons of water used by each user type.

EQUATION 14: $$V_{single,VR} = \frac{V_{single}}{D_{total}} \times D_{VR}$$

EQUATION 15: $$V_{single,SWF} = \frac{V_{single}}{D_{total}} \times D_{SWF}$$

EQUATION 16: $$V_{single,res} = \frac{V_{single}}{D_{total}} \times D_{res}$$

The total tourist usage is then the summation of the water used for VR tourists and SWF tourists (Equation 17).

EQUATION 17: $$V_{single,tour} = V_{single,VR} + V_{single,SWF}$$

Using the total tourist days ($D_{acc,res,tour}$), we were able to divide the tourist usage ($V_{single,tour}$) into the residential accommodation WF ($WF_{acc,res}$), which has the units of water use per person per day (Equation 18).

EQUATION 18: $$WF_{acc,res} = \frac{V_{single,tour}}{D_{acc,res,tour}}$$

It is important to note that the residential accommodation WF is the same from tourists as it is for residents.

Commercial: Hotels and camping

To begin our calculations, we first needed to determine the number of tourists staying at hotels (N_{hotel}). This was completed using the total number of CC tourists (N_{CC}) and the rate of accommodation use (Acc) as presented by the visitor's bureau (Equation 19).

EQUATION 19: $$N_{hotel} = Acc_{hotel} \times N_{CC}$$

Next, we needed to determine hotel classifications. Using the visitor's bureau, Yelp, and Trip Advisor, we compiled a list of island hotels, motels, bed and breakfast's (BNB), and campsites. Also included were descriptive information such as price range, ratings, and presence of water intensive features. Based on the average price per room per night, these accommodations were grouped into types such as "camping", "budget", "average", and "luxury". We then needed to estimate the number of tourists that would camp (N_{camp}) or stay at budget (N_{budget}), average (N_{ave}), or luxury hotels (N_{lux}) (Equation 20).

EQUATION 20: $$N_{hotel} = N_{camp} + N_{budget} + N_{ave} + N_{lux}$$

The number of tourists staying at each hotel classification was calculated based on ratio of rooms per type (R_{type}) and total rooms (R). This was then multiplied by the total number of tourists staying in hotels (N_{hotel}), to therefore determine the amount of tourists staying in each hotel type ($N_{hotel,type}$) (Equation 21).

EQUATION 21: $$N_{hotel,type} = N_{hotel} \times \frac{R_{type}}{\sum_i R_i}$$

Using this information, we then determined how many tourist days were spent at each hotel classification ($D_{acc,com,type}$). Using the visitor's bureau information on stay duration ($L_{\%}$ and L_i), we then determined the number of tourist days, as shown in Equation 22.

EQUATION 22: $$D_{acc,com,type} = \sum_i L_{i\%} \times L_i \times N_{hotel,type}$$

Since the total numbers of tourist days were now confirmed, we then needed to focus on the water used by each hotel and each hotel type. To do so, we started with standard water usage values (V_{ST}), as presented in Table 7.

TABLE 7: STANDARD ACCOMMODATION WATER USE (GAL/ROOM/YEAR) (DZIEGIELEWSKI ET AL., 2000)

FIXTURE/END USE	CAMPING	BUDGET	AVERAGE	LUXURY
Bathtub ($V_{bath,ST}$)	-	986	1,659	2,331
Faucets ($V_{faucet,ST}$)	-	2,440	4,368	6,297
Showers ($V_{shower,ST}$)	10,203	11,964	22,208	32,453
Toilets ($V_{toilet,ST}$)	9,493	10,740	19,393	28,047
Leaks ($V_{leaks,ST}$)	-	4,223	4,787	5,351
Laundry ($V_{laundry,ST}$)	-	9,037	41,759	74,480
Ice making ($V_{ice,ST}$)	-	1,190	595	-
Swimming pool ($V_{pool,ST}$)	-	2,857	2,857	2,857
Other/misc. indoor ($V_{other,ST}$)	-	5,450	2,725	-

Using the number of rooms (R) in combination with the presence of these fixtures (P) we were then able to determine the expected usage for each hotel ($V_{acc,com,a,ST}$). The calculation of expected water usage per hotel was then completed using Equation 23. Note that V_{ST} corresponds with hotel classification and the notation A refers to the hotel name.

EQUATION 23: $$\begin{aligned} V_{acc,com,a,ST} = R_a \\ &\times\big[(V_{ST}\times P_a)_{bath} + (V_{ST}\times P_a)_{faucet} + (V_{ST}\times P_a)_{shower} \\ &+ (V_{ST}\times P_a)_{toilet} + (V_{ST}\times P_a)_{leaks} + (V_{ST}\times P_a)_{laundry} \\ &+ (V_{ST}\times P_a)_{ice} + (V_{ST}\times P_a)_{pool} + (V_{ST}\times P_a)_{other}\big] \end{aligned}$$

NOTE: IF A FIXTURE WAS PRESENT, P WILL EQUAL 1; IF NOT, P WILL BE EQUAL TO 0

Once the standard water usage per hotel was complete, we then needed to normalize these values to fit within the actual water used on the island. This was completed by normalizing the standard water usage per hotel ($V_{acc,com,a,ST}$) and then multiplying it by the actual hotel usage (V_{hotel}) to get the actual water use per hotel ($V_{acc,com,a}$) (Equation 24).

EQUATION 24: $$V_{acc,com,a} = V_{hotel} \times \frac{V_{acc,com,a,ST}}{\sum_i V_{acc,com,i,ST}}$$

This information was then used to calculate the total water use per hotel classification ($V_{acc,com,type}$), as presented in Equation 25.

EQUATION 25: $$V_{acc,com,type} = \sum_i V_{hotel,type,i}$$

Unlike for the residential water usage, the water use per hotel visitor is not the same, as some hotel classifications use more water than others. Therefore, we needed to determine both the average water use per tourist as well as the average water use per tourist for each hotel classification. To calculate the average water use per tourist ($WF_{acc,com}$), we divided the total water usage of hotels (V_{hotel}) by the total tourist days ($D_{acc,com}$), as shown in Equation 26.

EQUATION 26: $$WF_{acc,com} = \frac{V_{hotel}}{D_{acc,com}}$$

To determine the water use per tourist for each hotel classification ($WF_{acc,com,type}$), we divided the total water use by hotel classification ($V_{acc,com,type}$) by the number of tourist days relevant to the hotel classification ($D_{acc,com,type}$), as shown in Equation 27.

EQUATION 27: $$WF_{acc,com,type} = \frac{V_{acc,com,type}}{D_{acc,com,type}}$$

Appendix C: Food methodology

The food category was also broken into two descriptive categories: restaurants and food stores. Restaurants included take out, delis, and sit down locations. Food stores, meanwhile, included grocery stores, markets, and seasonal markets.

Restaurants

In order to approach the restaurant WF for tourism, the metric of water use per meal was chosen. The first step in getting this value was to determine the number of meals consumed by both tourists and residents, as both tourists and residents attend restaurants. For restaurants, both CC ($\mathrm{N_{CC}}$) and CS ($\mathrm{N_{CS}}$) tourist numbers were used, as both have the potential to visit restaurants on the island. To calculate the number of tourists going to restaurants ($\mathrm{N_{rest,tour}}$), we summed the total number of tourists, as presented in Equation 28.

EQUATION 28:

$$\mathrm{N_{rest,tour}} = (\mathrm{N_{CC}} + \mathrm{N_{CS}})$$

Additionally, residents are also expected to visit restaurants. Therefore, the total number of residents attending restaurants ($\mathrm{N_{rest,res}}$) was also included. Their numbers are based on the general population statistics provided in the literature review (Equation 29).

EQUATION 29:

$$\mathrm{N_{rest,res}} = \mathrm{POP}$$

However, it is not expected that all tourists and residents will eat three meals a day in restaurants. Therefore we assumed that tourists staying in hotels were more likely to eat out, while tourists staying in vacation rentals would make some meals at home. Similarly, it was estimated that residents would only eat out 2 times per week. With these assumptions, the dining rate for each type of tourist and resident is detailed in Table 8.

TABLE 8: RESTAURANT MEAL RATE

TYPE	TOURIST OR RESIDENT	MEALS/DAY
Day visits ($\mathrm{M_{est,day}}$)	Tourist	2.00
Vacation rentals ($\mathrm{M_{est,VR}}$)	Tourist	2.00
SWF ($\mathrm{M_{est,SWF}}$)	Tourist	2.00
Hotels ($\mathrm{M_{est,hotel}}$)	Tourist	3.00
Camping ($\mathrm{M_{est,camp}}$)	Tourist	1.00
Residents ($\mathrm{M_{est,res}}$)	Resident	0.14

Using this information, we then wanted to estimate the total number of meals. Using the length of stay data ($\mathrm{L_{\%}}$ and $\mathrm{L_i}$), we then determined the number of tourist days on the island for each vacation type. We then be multiplied this by the expected number of meals per day ($\mathrm{M_{est,type}}$), to get the total number of meals consumed per visitor type ($\mathrm{M_{type}}$) (Equation 30).

EQUATION 30:

$$\mathrm{M_{type}} = \mathrm{M_{est,type}} \sum_{\mathrm{i}} \mathrm{L_{i\%}} \times \mathrm{L_i} \times \mathrm{N_{type}}$$

The total number of meals was then calculated as the summation of all the meal types (Equation 31).

EQUATION 31: $$M_{rest} = M_{day} + M_{VR} + M_{SWF} + M_{hotel} + M_{camp} + M_{res}$$

We then needed to determine how many meals occurred at each restaurant. This is achieved through Yelp and Trip Advisor reviews. It will be estimated that the restaurants with the highest number of reviews will be the most visited. This information ($rate_a$) was normalized against the total number of meals (M_{rest}) to provide an estimated distribution of meal visits per restaurant (M_a) (Equation 32).

EQUATION 32: $$M_a = M_{total} \times rate_a$$

Once the number of meals was determined, we then needed to quantify the amount of water used for each restaurant. This was approached using the square footage for each location. The total restaurant water usage (V_{rest}), provided by the utility, was divided by the total square footage of all restaurants (A_i), and then multiplied by the area of each individual restaurant (A_a) (Equation 33).

EQUATION 33: $$V_{rest,a} = A_a \times \frac{V_{rest}}{\sum_i A_i}$$

This can then be used to determine the amount of water used for tourism ($V_{rest,tour}$) and the amount of water used for residential use ($V_{rest,res}$) (Equation 34 and Equation 35).

EQUATION 34: $$V_{rest,tour} = \frac{V_{rest}}{M_{rest}} \times M_{rest,tour} = \frac{V_{rest}}{M_{rest}} \times \left(M_{day} + M_{VR} + M_{SWF} + M_{hotel} + M_{camp}\right)$$

EQUATION 35: $$V_{rest,res} = \frac{V_{rest}}{M_{rest}} \times M_{res}$$

Equation 36 was then used to calculate the WF per meal ($WF_{rest,meal}$) using the total tourist usage for restaurants ($V_{rest,tour}$) divided by the total number of tourist meals ($M_{rest,tour}$). Note that the water use per meal is the same for both tourists and residents, though the amount of water used by tourists and residents is different.

EQUATION 36: $$WF_{rest,meal} = \frac{V_{rest,tour}}{M_{rest,tour}}$$

Next, we wanted to determine the WF for each restaurant type. Restaurant types were divided into both classification (bars, deli/cafés, and restaurants) and price class (cheap $, average $$, and expensive $$$).The WF per type/price class ($WF_{rest,type,meal}$) will then be the total water used for that type/class ($V_{rest,type}$) divided by the total number of meals anticipated for that type and class ($M_{rest,type}$) (Equation 37).

EQUATION 37: $$WF_{rest,type,meal} = \frac{V_{rest,type}}{M_{rest,type}}$$

Food stores

The WF for food stores used a similar process to the restaurants, however, instead of water use per meal we aimed for water use per visit. This modification is based on the following assumptions:

- Camping visitors rely mainly on grocery stores
- Vacation rental and SWF visitors use grocery stores occasionally
- Hotel visitors use grocery stores vary rarely
- Residential households visit grocery stores, on average, 2 times per week per household

With this information, the (assumed) number of expected visits per visitor type is shown in Table 9.

TABLE 9: FOOD STORE VISIT RATE

TYPE	TOURIST OR RESIDENT	VISITS/DAY
Day visits ($T_{est,FS,day}$)	Tourist	0.06
Vacation rentals ($T_{est,FS,VR}$)	Tourist	0.25
SWF ($T_{est,FS,SWF}$)	Tourist	0.25
Hotels ($T_{est,FS,hotel}$)	Tourist	0.06
Camping ($T_{est,FS,camp}$)	Tourist	0.25
Residents ($T_{est,FS,res}$)	Resident	0.11

Using this table, we then determined the total number of visits to food stores by vacation type ($T_{FS,type}$) (Equation 38). This was done using the length of stay data ($L_{\%}$ and L_i) and vacation type.

EQUATION 38:

$$T_{FS,type} = T_{est,type} \sum_i L_{i\%} \times L_i \times N_{type}$$

The total number of visits was then calculated as the summation of all visit types (Equation 39).

EQUATION 39:

$$T_{FS,total} = T_{FS,day} + T_{FS,VR} + T_{FS,SWF} + T_{FS,hotel} + T_{FS,camp} + T_{FS,res}$$

We then needed to determine how many visits occurred at each store. This is because specialty grocery stores located in or near hotels are less likely to be accessed by residents and large box markets outside of tourist areas are less likely to be visited by visitors. Therefore, the majority of resident visits are expected to be at larger grocery markets, while visitor visits will be in centrally located areas. This information ($rate_a$) was normalized against the total number of visits ($T_{FS,total}$) to provide an estimated distribution of visits per food store (T_a) (Equation 40).

EQUATION 40:

$$T_a = T_{FS,total} \times rate_a$$

Once the number of visits was determined, we then needed to quantify the amount of water used for each food store. This was done using the square footage for each location. The total food store water usage (V_{FS}), provided by the utility, was divided by the total square footage of all stores (A_i), and then multiplied by the area of each individual store (A_a) (Equation 41).

EQUATION 41:

$$V_{FS,a} = A_a \times \frac{V_{FS}}{\sum_i A_i}$$

This information can then be divided into water used for tourism ($V_{FS,tour}$) and water used for residents ($V_{rest,res}$) (Equation 42 and Equation 43).

EQUATION 42:

$$V_{FS,tour} = \frac{V_{FS}}{T_{FS,total}} \times T_{FS,tour} = \frac{V_{FS}}{T_{FS,total}} \times \left(T_{FS,day} + T_{FS,VR} + T_{FS,SWF} + T_{FS,hotel} + T_{FS,camp}\right)$$

EQUATION 43:

$$V_{FS,res} = \frac{V_{FS}}{T_{FS,total}} \times T_{FS,res}$$

Similar to the restaurant situation, the water use per visit is the same for both groups, however, the amount of water used by tourists and residents is different. This is shown in Equation 44, as the WF per tourist (WF_{FS}) is the total water used for tourists ($V_{FS,tour}$) divided by the total number of tourist visits ($T_{FS,tour}$).

EQUATION 44:

$$WF_{FS} = \frac{V_{FS,tour}}{T_{FS,tour}}$$

Appendix D: Activities methodology and equations

There are multiple levels for calculating the activity WF, as this category includes activities such as shopping, day spas, sports, and other miscellaneous businesses. Similar to the previous calculations, the number of tourist and residential days were needed in order to determine the number of visits. Both CC (N_{CC}) and CS (N_{CS}) tourists are included, since activities include all tourists. Therefore, to calculate the number of tourists and residents participating in activities ($N_{act,tour}$) we followed Equation 28 and Equation 29. On average, it is expected that all tourists, except for campers, would visit at least 2 locations in a given day. This is because campers are expected to be outside of the business areas and, therefore, they are expected to visit 3-4 locations per week. Similarly, residential households are expected to visit 2 locations per week. With this information, the (assumed) number of expected visits per visitor type is shown in Table 10.

TABLE 10: ACTIVITY VISIT RATE

TYPE	TOURIST OR RESIDENT	VISITS/DAY
Day visits ($T_{est,act,day}$)	Tourist	2
Vacation rentals ($T_{est,act,VR}$)	Tourist	2
SWF ($T_{est,act,SWF}$)	Tourist	2
Hotels ($T_{est,act,hotel}$)	Tourist	2
Camping ($T_{est,act,camp}$)	Tourist	0.5
Residents ($T_{est,act,res}$)	Resident	0.11

Using this table, we then determined the total number of activity visits by vacation type (T_{type}) (Equation 45). This was done using the length of stay data ($L_{\%}$ and L_i) and vacation type.

EQUATION 45:

$$T_{act,type} = T_{est,act,type} \sum_{i} L_{i\%} \times L_i \times N_{type}$$

The total number of visits was then calculated as the summation of all visit types (Equation 46).

EQUATION 46:

$$T_{act,total} = T_{act,day} + T_{act,VR} + T_{act,SWF} + T_{act,hotel} + T_{act,camp} + T_{act,res}$$

We then needed to determine how many visits occurred for each activity. This is because activities such as going to the bank or post office are primarily completed by residents, while SCUBA diving and golfing are more likely to be completed by tourists. Therefore, the number of visits for tourists and residents were distributed amongst the different activities based on activity type and number of reviews. This information ($rate_a$) was normalized against the total number of visits (T_{total}) to provide an estimated distribution of visits per activity (T_a) (Equation 47).

EQUATION 47:

$$T_a = \left(T_{day} + T_{VR} + T_{SWF} + T_{hotel} + T_{camp}\right) \times rate_{tour,a} + T_{res} \times rate_{res,a}$$

This information will be used for the various activities below, however, the next step is to calculate the amount of water used for each activity. This will be done by first calculating the standard water usage for each activity and then normalizing the data against the actual water used.

Golf courses
As golf courses tend to have very high water usage, some studies have already identified the water use per square foot. Therefore, we used the empirically based estimations presented in Gleick et al. (2003) (Table 11).

TABLE 11: MODELED IRRIGATION WATER USE AT GOLF COURSES (GLEICK ET AL., 2003)

Hydrologic Region	Percentage Golf Acreage[1]	Acreage 2000[2]	EV Ratio w.r.t Central Coast[3]	Annual Water Use (AF/Acre)	Modeled Total Irrig. Use (TAF)	GED-derived Estimate of Total Use (TAF)
North Coast	3%	2,945	1.01	2.02	**5.9**	
San Francisco	15%	13,394	1.26	2.52	**33.8**	
Central Coast	7%	6,126	1.00	2.00	**12.3**	
South Coast	46%	41,012	1.37	2.74	**112.4**	
Tulare Lake	5%	4,082	1.80	3.60	**14.7**	
San Joaquin	6%	5,687	1.80	3.60	**20.5**	
Sacramento River	13%	11,211	1.80	3.60	**40.4**	
North Lahontan	1%	544	1.56	3.12	**1.7**	
South Lahontan	4%	3,412	2.08	4.16	**14.2**	
Colorado River	0%	360	2.53	5.06	**1.8**	
Total Irrigation		**88,773**			**258**	**324.6**
Total All End Uses						**341.8**

[1] The number of golf courses was reported by county and we translated this into hydrologic region (California Golf Owners Association 2002). We then converted the number of golf courses in each region into a percentage of the state's total golf course acreage.
[2] The total acreage of golf courses was reported by the California Golf Owners Association (2002) and then distributed among regions based on the percentage of golf courses in each region.
[3] see Appendix D.

In order customize this value to the location, we used the average of the four closest golf courses ($(\mathrm{V/A})_{\mathrm{ave}}$). We then applied this to the actual square footage of the golf course ($\mathrm{A}_{\mathrm{golf}}$) to determine the standard water use for courses on the island ($\mathrm{V}_{\mathrm{act,golf,ST}}$) (Equation 48).

EQUATION 48:
$$\mathrm{V}_{\mathrm{act,golf,ST}} = \mathrm{A}_{\mathrm{golf}} \times (\mathrm{V/A})_{\mathrm{ave}}$$

Wineries
Similar to golf courses, there are also many approximations of typical water use for wineries. For the purposes of this study, we will be using empirical water usage of similar wineries as presented in the Wine Industry Insight (2009). Per this source, water use is roughly shown to be between 300,000 and 500,00 gallons per acre per year. As such, we will be using the value of 400,000 gallons per acre per year as our standard value. This will be multiplied by the actual acreage of any wineries present ($\mathrm{A}_{\mathrm{wine}}$) on the island to get an expected water usage ($\mathrm{V}_{\mathrm{act,wine,ST}}$) (Equation 49).

EQUATION 49:
$$\mathrm{V}_{\mathrm{act,wine,ST}} = \mathrm{A}_{\mathrm{wine}} \times 400{,}000\ \mathrm{gal/acre}$$

General
All other general businesses will be calculated using a standard approach that is similar to the method used for hotels. We began by finding standard water usage values that apply to retail and commercial businesses, such as those presented in Gleick et al. (2003) (Table 12).

TABLE 12: ESTIMATES OF ANNUAL WATER USE IN THE RETAIL INDUSTRY

FIXTURE/END USE	STANDARD USAGE (TAF)
Kitchen ($V_{ktichen,ST}$)	7.8
Restrooms ($V_{restroom,ST}$)	36.6
Cooling ($V_{cool,ST}$)	41.7
Landscaping ($V_{landscape,ST}$)	45.9
Other ($V_{other,ST}$)	20.6

If the square footage of a business is larger than 1,000 sq ft, it will be assumed that there is 1 kitchen. All businesses are expected to have 1 restroom, however, if the square footage of the building is larger than 1,000 sq ft, it will then be assumed that there are 2 restrooms. Cooling is only expected to be in select locations, such as movie theaters and florists. The presence of landscaping will be determined via Google Earth. However, if it is clear that the municipality manages the exterior of the building, such as boardwalks or main city owned areas, landscaping will not be included. This is because the landscaping will be part of the municipality water use, not the commercial. Other water use will be present if the business itself appears to have any other water use outside of the previous categories. This includes spas, florists, gas stations, and salons. Using the square footage of each building (A_a) in combination with the presence of these fixtures (P) we were then able to determine the standard usage for each location ($V_{act,a,ST}$), as shown in (Equation 50)

EQUATION 50:

$$V_{act,a,ST} = A_a \times\left[(V_{ST}\times P_a)_{kitchen} + (V_{ST}\times P_a)_{restroom} + (V_{ST}\times P_a)_{cool} + (V_{ST}\times P_a)_{landscape} + (V_{ST}\times P_a)_{other}\right]$$

NOTE: IF A FIXTURE WAS PRESENT, P WILL EQUAL 1; IF NOT, P WILL BE EQUAL TO 0

Once the standard water usage per location is complete, we then needed to normalize these values to fit within the actual water used on the island. This was completed by normalizing the standard water usage per location ($V_{act,a,ST}$), which includes golf courses and wineries. These totals were then multiplied by the actual activity usage (V_{act}) to get the actual water use per location ($V_{act,a}$) (Equation 51).

EQUATION 51:

$$V_{act,a} = V_{act}\times \frac{V_{act,a,ST}}{\sum_i V_{act,i,ST}}$$

This information can then be divided into water used for tourism ($V_{act,tour}$) and water used for residents ($V_{act,res}$) (Equation 52 and Equation 53).

EQUATION 52:

$$V_{act,tour} = \frac{V_{act}}{T_{act,total}}\times T_{act,tour} = \frac{V_{act}}{T_{act,total}}\times\left(T_{act,day} + T_{act,VR} + T_{act,SWF} + T_{act,hotel} + T_{act,camp}\right)$$

EQUATION 53:

$$V_{act,res} = \frac{V_{act}}{T_{act,total}}\times T_{act,res}$$

As each location varies in its water use and visitor rate, the WF of visiting each location is different. Therefore, we calculated the average water use per visit as well as the average water use per visit specific to each location. To calculate the average water use per tourist ($\mathrm{WF_{act}}$), we divided the total water usage of activities for tourists ($\mathrm{V_{act,tour}}$) by the total tourist visits ($\mathrm{T_{act,tour}}$), as shown in Equation 54.

EQUATION 54:

$$\mathrm{WF_{act}} = \frac{\mathrm{V_{act,tour}}}{\mathrm{T_{act,tour}}}$$

This WF is also calculated for the different types of activities. These were broken in to several types such as diving, clothing stores, cinemas, etc. To determine the water use per visit for each activity type ($\mathrm{WF_{act,type}}$), we divided the water use by each activity ($\mathrm{V_{act,type}}$) by the number of visits to the activity ($\mathrm{T_{act,tour,type}}$), as shown in Equation 55.

EQUATION 55:

$$\mathrm{WF_{act,type}} = \frac{\mathrm{V_{act,type}}}{\mathrm{T_{act,tour,type}}}$$

Appendix E: Transport methodology and equations

Using the information obtained from the literature review, the number of transport types, quantity, and max capacity were noted. Transportation types included bikes, cars, boats, and other mobility types. These were then broken into "on island" and "to island" transportation means, with "to island" transportation excluded from the calculations as it was assumed they receive their water from the mainland. Additionally, walking and hiking, though considered a transportation type, were not included as their impact was negligible.

Next we addressed the use of each transportation type. It was assumed that use would vary seasonally at the same rate of tourism rates. We therefore used the rate of tourism and the occupancy maximums to determine the number of uses per day for each transportation type. It is assumed that in the summer months, almost all of the vehicles will be rented. In this case, the rental rate would be 100%. In the winter, however, rental rates are expected to drop with the tourism rate, therefore the rental rate ($\mathrm{rent}_{\%}$) would be the ratio of the current month ($\mathrm{N}_{\mathrm{tour,curr}}$) to the summer month ($\mathrm{N}_{\mathrm{tour,peak}}$) multiplied by 100 (Equation 56).

EQUATION 56:
$$\mathrm{rent}_{\%} = \frac{\mathrm{N}_{\mathrm{tour,curr}}}{\mathrm{N}_{\mathrm{tour,peak}}} \times 100$$

Overall, visits per location ($\mathrm{T}_{\mathrm{trans,a}}$) were calculated using the monthly rental rate ($\mathrm{rent}_{\%,\mathrm{a}}$), the maximum occupancy ($\mathrm{cap}_{\mathrm{max}}$), and the number of days in the month ($\mathrm{D}_{\mathrm{month}}$) (Equation 57).

EQUATION 57:
$$\mathrm{T}_{\mathrm{trans,a}} = \mathrm{rent}_{\%} \times \mathrm{cap}_{\mathrm{max,a}} \times \mathrm{D}_{\mathrm{month}}$$

The total number of visits was then calculated as the sum of all visits for each location (Equation 58).

EQUATION 58:
$$\mathrm{T}_{\mathrm{trans,tour}} = \sum_{\mathrm{i}} \mathrm{T}_{\mathrm{i}}$$

We then needed to determine the water use for each location. This was completed in a similar fashion to hotels, except that there were no standard usage values to use for transportation. As such, stand in values were used to determine the distribution of water usage, as shown in Table 13.

TABLE 13: ESTIMATES OF ANNUAL WATER USE IN THE RETAIL INDUSTRY

FIXTURE/END USE	STANDARD USAGE (NO UNITS)
Hiking / Walking ($\mathrm{X}_{\mathrm{hike}}$)	0
Helicopter ($\mathrm{X}_{\mathrm{heli}}$)	50
Plane ($\mathrm{X}_{\mathrm{plane}}$)	50
Boat ($\mathrm{X}_{\mathrm{boat}}$)	40
Bike ($\mathrm{X}_{\mathrm{bike}}$)	10
Golf Cart ($\mathrm{X}_{\mathrm{golf}}$)	20
Car ($\mathrm{X}_{\mathrm{car}}$)	40
Kayak ($\mathrm{X}_{\mathrm{kay}}$)	10
Jet Ski ($\mathrm{X}_{\mathrm{ski}}$)	20
Segway ($\mathrm{X}_{\mathrm{seg}}$)	10

Using this information, the distribution of water usage is calculated based on the vehicles present at each location. The stand in water used at each location ($\mathrm{X_{trans,a}}$) was then calculated through combination of the stand in water usage (X) and the number of vehicles at each location (No) Equation 59.

EQUATION 59:

$$\begin{aligned}\mathrm{X_{trans,a}} = {} & (\mathrm{X{\times}No_a})_{\mathrm{hike}} + (\mathrm{X{\times}No_a})_{\mathrm{heli}} + (\mathrm{X{\times}No_a})_{\mathrm{plane}} + (\mathrm{X{\times}No_a})_{\mathrm{boat}} \\ & + (\mathrm{X{\times}No_a})_{\mathrm{bike}} + (\mathrm{X{\times}No_a})_{\mathrm{golf}} + (\mathrm{X{\times}No_a})_{\mathrm{car}} + (\mathrm{X{\times}No_a})_{\mathrm{kay}} \\ & + (\mathrm{X{\times}No_a})_{\mathrm{ski}} + (\mathrm{X{\times}No_a})_{\mathrm{seg}}\end{aligned}$$

Once the stand in water usage per location was complete, we then needed to normalize these values to fit within the actual water used on the island. This was completed by normalizing the standard water usage per location ($\mathrm{X_{trans,a}}$), multiplying it by the actual transportation usage ($\mathrm{V_{trans}}$), and determining the actual water use per location ($\mathrm{V_{trans,a}}$) (Equation 60).

EQUATION 60:

$$\mathrm{V_{trans,a}} = \mathrm{V_{trans}} \times \frac{\mathrm{X_{trans,a}}}{\sum_{\mathrm{i}} \mathrm{X_{trans,i}}}$$

Additionally, we need to separate tourism water use from residential. This is done through evaluation of the each locations purpose. It is assumed that residents will not rent vehicles, as they will have their own. In addition, tourists will not purchase vehicles, therefore dealerships are not considered to be tourist related. As such, there is almost not overlap, therefore the number of stores that are tourist related can be totaled to determine the total amount of tourist water use ($\mathrm{V_{trans,tour}}$) (Equation 61).

EQUATION 61:

$$\mathrm{V_{trans,tour}} = \sum_{\mathrm{i}} \mathrm{V_{trans,i}} \times P_i$$

NOTE: IF A LOCATION IS TOURISM RELATED, P WILL EQUAL 1; IF NOT, P WILL BE EQUAL TO 0

As each location varies in its water use and visitor rate, the WF of visiting each location is different. Therefore, we calculated the average water use per rental as well as the average water use per rental specific to each location. To calculate the average water use per tourist ($\mathrm{WF_{trans}}$), we divided the total water usage of transportation ($\mathrm{V_{trans,tour}}$) by the total visits ($\mathrm{T_{trans,tour}}$), as shown in Equation 62.

EQUATION 62:

$$\mathrm{WF_{trans}} = \frac{\mathrm{V_{trans,tour}}}{\mathrm{T_{trans,tour}}}$$

This WF is also calculated for the different types of transport. These types were broken into bikes, boats, cars, golf carts, kayaks, and Segways. To determine the water use per day for each transport type ($\mathrm{WF_{trans,type,rent}}$), we divided the water use by each transport type ($\mathrm{V_{trans,type}}$) by the number of rental days for that transportation type ($\mathrm{T_{trans,type}}$), as shown in Equation 63.

EQUATION 63:

$$\mathrm{WF_{trans,type,rent}} = \frac{\mathrm{V_{trans,type}}}{\mathrm{T_{trans,type}}}$$

Appendix F: General WF methodology and equations

Using the values calculated above for each tourist category, we separated the values that are tourism related from those that are municipality related. The reason this is titled municipal and not residential is that some aspects of water usage that were calculated are unrelated to residential use. To begin calculating the general WF, we first needed to determine the total number of tourist days (D_{tour}). This includes both CC (N_{CC}) and CS (N_{CS}) tourist numbers. As CC tourists stay for a variety of days, it is necessary to include the stay duration ($L_{\%}$ and L_i) information obtained from the visitor's bureau. As CS visitors are only on the island for 1 day, their day counts are equal to the total number of tourists. The calculation for total tourist days can be seen in Equation 64.

EQUATION 64:
$$D_{tour} = N_{CS} + \sum_i L_{i\%} \times L_i \times N_{CC}$$

Next, we need to determine the WF for each tourism category. Starting with accommodations, we first calculated the total water consumed by tourists for this category ($V_{acc,tour}$). This was done through Equation 65, which sums the water consumed by vacation rentals ($V_{single,VR}$, Equation 14), SWF ($V_{single,SWF}$, Equation 15), and hotels (V_{hotel}, utility data).

EQUATION 65:
$$V_{acc,tour} = V_{single,VR} + V_{single,SWF} + V_{hotel}$$

From this information and the total number of tourist days we are then able to calculate the general WF for accommodations ($WF_{acc,gen}$) (Equation 66).

EQUATION 66:
$$WF_{acc,gen} = \frac{V_{acc,tour}}{D_{tour}}$$

Next we addressed the general WF for food by first calculating the total amount of water used by the tourism industry. This was done in Equation 67 by adding the restaurant tourism water use ($V_{rest,tour}$, Equation 34) and the food store tourism water use ($V_{FS,tour}$, Equation 42).

EQUATION 67:
$$V_{food,tour} = V_{rest,tour} + V_{FS,tour}$$

The general WF for food ($WF_{food,gen}$) is then calculated by dividing by the total number of tourist days (D_{tour}) (Equation 68).

EQUATION 68:
$$WF_{food,gen} = \frac{V_{food,tour}}{D_{tour}}$$

For activities, the total tourism water use ($V_{act,tour}$) has already been calculated using Equation 69, Therefore, to calculate the general WF of activities ($WF_{act,gen}$) will be the total tourism water use of activities divided by the total number of tourist days (D_{tour}).

EQUATION 69:
$$WF_{act,gen} = \frac{V_{act,tour}}{D_{tour}}$$

Similar for transport, the total tourism water use for transport ($V_{trans,tour}$) was previously calculated in Equation 70. Therefore, this is divided by the total number of tourist days (D_{tour}) to get the general WF for transportation ($WF_{trans,gen}$).

EQUATION 70: $$\mathrm{WF}_{\mathrm{trans,gen}} = \frac{\mathrm{V}_{\mathrm{trans,tour}}}{\mathrm{D}_{\mathrm{tour}}}$$

To get the overall general WF, we then add the WF from each tourism category. This is done using a modified Equation 1, as shown in Equation 71. This then provided a profile of the water used so that target areas are identified.

EQUATION 71: $$\mathrm{WF}_{\mathrm{gen}} = \mathrm{WF}_{\mathrm{acc,gen}} + \mathrm{WF}_{\mathrm{food,gen}} + \mathrm{WF}_{\mathrm{act,gen}} + \mathrm{WF}_{\mathrm{trans,gen}}$$

Additionally, the general WF was broken into direct and indirect water usage, so that this can also be factored in to water consumption patterns. Direct water usage will include residential, hotel, and hospital use, while indirect will include urban irrigation, schools, membership organizations, food stores, restaurants, transportation, and activities. One item to note in the designation of direct vs. indirect is our choice to label activities as indirect. This is because, for the purpose of this study, all activities on the island do not appear to use water directly for tourists, instead water is used in the functioning of the business or landscape. Therefore, activities were determined to be indirect. Though many categories are included in the breakout of direct vs. indirect, our calculation for the purpose of tourism can be seen in Equation 72 and Equation 73.

EQUATION 72: $$\mathrm{WF}_{\mathrm{gen,direct}} = \mathrm{WF}_{\mathrm{acc,gen}}$$

EQUATION 73: $$\mathrm{WF}_{\mathrm{gen,indirect}} = \mathrm{WF}_{\mathrm{food,gen}} + \mathrm{WF}_{\mathrm{act,gen}} + \mathrm{WF}_{\mathrm{trans,gen}}$$

Appendix G: Specific WF methodology and equations

For each of the categories, the total water usage for each location type and the expected number of tourist and resident visits were calculated. Using this information, the water use per visit was calculated. This data was then used to put together sample vacation packages in order to see what the WF is for different tourist types. The break down of the water usage can be seen in Table 14.

TABLE 14: SUBCATEGORIES OF EACH DESCRIPTIVE CATEGORY

ACCOMMODATIONS (gal/cap/day)	**FOOD (gal/meal)**	**ACTIVITIES (gal/visit)**		**TRANSPORT (gal/rental)**
Vacation rental	Bar ($)	Art Galleries	Internet service	Bike
SWF	Bar ($$)	Art Supplies	Laundromat	Boat
Camping	Bar ($$$)	Bank	Library	Car
Budget Hotel	Deli/café ($)	Bookstore	Massage	Golf
Average Hotel	Deli/café ($$)	Child care	Museum	Kayak
Luxury Hotel	Restaurant ($)	Cinema	Print Media	Segway
	Restaurant ($$)	Clothing	Radio station	
	Restaurant ($$$)	Day Spa	Real Estate	
	Food store	Diving	Salon	
		Electronics	Services	
		Florist	Tours	
		Gas	Toy store	
		Gift Shop	Video Store	
		Golf	Winery	
		Hardware Stores		

*(gal/visit)

Six different vacation packages were put together to represent the six types of accommodations as well as the main types of tourists: vacation rental/SWF, luxury, average, budget, camping, and day trips. As an example a luxury package consisted of a 4 night stay at a luxury resort, including eating out at 3 restaurants per day, using a taxi for transportation, and partaking in activities such day spas, boating, and golfing. Though the WF for each varies throughout the year, these vacation packages were completed for a summer month to examine the extremities of these calculations.

For accommodation, the WF ($\mathrm{WF_{acc,pack}}$) was equal to the residential WF ($\mathrm{WF_{acc,res}}$) or the commercial/hotel WF ($\mathrm{WF_{acc,com,type}}$), calculated in Equation 18 and Equation 27, respectively. How this was determined was based on the accommodation type of the vacation package, as explained in Equation 74.

EQUATION 74:

$$\mathrm{WF_{acc,pack}} = \mathrm{WF_{acc,res}} \qquad \text{(VACATION RENTAL/SWP)}$$

$$\mathrm{WF_{acc,pack}} = \mathrm{WF_{acc,com,type}} \qquad \text{(HOTEL/CAMPING)}$$

For food, the calculation was broken into restaurant usage and food store usage. For restaurant usage, the WF of each meal ($\mathrm{WF_{meal\ \#}}$) would be equal to the calculated WF for the meal type ($\mathrm{WF_{rest,type,meal}}$), as calculated in Equation 37. This relation is shown in Equation 75.

EQUATION 75:

$$\mathrm{WF_{meal\ \#}} = \mathrm{WF_{rest,type,meal}}$$

The sum of all the individual WF for each meal ($\mathrm{WF}_{\mathrm{meal}\ \#}$) then became the total WF for the restaurant portion of the vacation package ($\mathrm{WF}_{\mathrm{rest,pack}}$), as can be seen in Equation 76.

EQUATION 76: $$\mathrm{WF}_{\mathrm{rest,pack}} = \mathrm{WF}_{\mathrm{meal}\ 1} + \mathrm{WF}_{\mathrm{meal}\ 2} + \mathrm{WF}_{\mathrm{meal}\ 3} + \ \ldots$$

Food stores, however, are calculated differently, as this depends on the number of visits instead of the number of meals. The package WF for food stores ($\mathrm{WF}_{\mathrm{FS,pack}}$) was then found to be the number of visits multiplied by the WF of food stores ($\mathrm{WF}_{\mathrm{FS,visit}}$) previously calculated in Equation 44. This relation is presented in Equation 77.

EQUATION 77: $$\mathrm{WF}_{\mathrm{FS,pack}} = (\#\ \mathrm{of\ visits}) \times \mathrm{WF}_{\mathrm{FS,visit}}$$

The total WF for food for a vacation package ($\mathrm{WF}_{\mathrm{food,pack}}$) was then the summation of the restaurant WF ($\mathrm{WF}_{\mathrm{rest,pack}}$) and the food store WF ($\mathrm{WF}_{\mathrm{FS,pack}}$), as shown in Equation 78.

EQUATION 78: $$\mathrm{WF}_{\mathrm{food,pack}} = \mathrm{WF}_{\mathrm{rest,pack}} + \mathrm{WF}_{\mathrm{FS,pack}}$$

The WF of activities for each vacation package ($\mathrm{WF}_{\mathrm{act}\ \#}$) used the individual activity type's estimated usage per visit ($\mathrm{WF}_{\mathrm{act,type}}$), as calculated in Equation 55. This relation is shown in Equation 79.

EQUATION 79: $$\mathrm{WF}_{\mathrm{act}\ \#} = \mathrm{WF}_{\mathrm{act,type}}$$

Again, the summation of the activity WF ($\mathrm{WF}_{\mathrm{act}\ \#}$) then equaled the WF of activities for the vacation package ($\mathrm{WF}_{\mathrm{act,pack}}$) (Equation 80).

EQUATION 80: $$\mathrm{WF}_{\mathrm{act,pack}} = \mathrm{WF}_{\mathrm{act}\ 1} + \mathrm{WF}_{\mathrm{act}\ 2} + \mathrm{WF}_{\mathrm{act}\ 3} + \ \ldots$$

For transportation, a similar approach was used as the WF for each type of transportation ($\mathrm{WF}_{\mathrm{trans,type}}$), as previously calculated in Equation 63, was then summed to create the total transportation WF for the vacation package ($\mathrm{WF}_{\mathrm{trans,pack}}$) (Equation 81 and Equation 82).

EQUATION 81: $$\mathrm{WF}_{\mathrm{trans}\ \#} = \mathrm{WF}_{\mathrm{trans,type}}$$

EQUATION 82: $$\mathrm{WF}_{\mathrm{trans,pack}} = \mathrm{WF}_{\mathrm{trans}\ 1} + \mathrm{WF}_{\mathrm{trans}\ 2} + \mathrm{WF}_{\mathrm{trans}\ 3} + \ \ldots$$

Finally, the individual aspects of the vacation package (accommodation, food, activities, and transportation) were then added together to get the total WF for the vacation package type (Equation 83).

EQUATION 83: $$\mathrm{WF}_{\mathrm{pack}} = \mathrm{WF}_{\mathrm{acc,pack}} + \mathrm{WF}_{\mathrm{food,pack}} + \mathrm{WF}_{\mathrm{act,pack}} + \ \mathrm{WF}_{\mathrm{trans,pack}}$$

Appendix H: SCE provided data

TABLE 15: WATER DELIVERED TO CUSTOMERS (1,000 GAL) (2013)

UTILITY CATEGORY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
Single-family and multi residential	4,000	3,500	4,000	4,400	5,100	5,200	6,700	6,700	5,800	4,700	4,000	3,500	**57,600**
Commercial	2,600	2,600	4,000	4,500	5,500	5,200	6,600	7,000	5,000	6,000	3,450	3,450	**55,900**
Large water users	-	-	-	-	-	-	-	-	-	-	-	-	**-**
Public authorities	200	200	400	400	800	600	900	1,100	300	600	400	500	**6,400**
Irrigation	-	-	-	-	-	-	-	-	-	-	-	-	**-**
Other (specify)	-	-	-	-	-	-	-	-	-	-	-	-	**-**
Company use	-	-	-	-	-	-	-	-	-	-	-	-	**-**

TABLE 16: WATER DELIVERED TO CUSTOMERS (1,000 GAL) (2014)

UTILITY CATEGORY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
Single-family and multi residential	3,000	3,300	3,800	4,300	4,200	4,700	5,900	4,100	4,300	3,100	2,600	2,700	**46,000**
Commercial	3,600	2,900	3,300	4,400	3,900	4,800	5,900	5,900	4,850	3,800	3,000	2,200	**48,550**
Large water users	-	-	-	-	-	-	-	-	-	-	-	-	**-**
Public authorities	500	300	200	500	400	500	600	600	400	400	600	500	**5,500**
Irrigation	-	-	-	-	-	-	-	1,000	-	-	-	-	**1,000**
Other (specify)	-	-	-	-	-	-	-	-	-	-	-	-	**-**
Company use	9	18	21	20	13	7	20	10	9	8	18	12	**165**

Appendix I: Breakout of commercial data

TABLE 17: COMMERCIAL WATER USE (1,000 GAL) (2013)

UTILITY CATEGORY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
Hotels and Motels	729	729	1,146	1,276	1,641	1,511	1,954	2,110	1,380	1,719	1,003	1,029	**16,231**
Laundries/Laundromats	337	337	530	590	759	698	903	976	638	795	463	476	**7,507**
Car Washes	-	-	-	-	-	-	-	-	-	-	-	-	**-**
Urban Irrigation	266	266	418	465	599	551	713	770	503	627	366	375	**5,923**
Schools and Colleges	217	217	341	379	488	449	581	628	410	511	298	306	**4,830**
Hospitals/Medical Offices	126	126	199	221	285	262	339	366	239	298	174	178	**2,820**
Office Buildings	123	123	194	216	277	255	330	357	233	291	169	174	**2,747**
Restaurants	92	92	146	162	209	192	248	268	175	219	127	131	**2,067**
Food Stores	74	74	117	130	168	154	200	216	141	176	102	105	**1,663**
Auto Shops	70	70	110	123	158	145	188	203	133	166	96	99	**1,567**
Membership Organizations	64	64	101	112	145	133	172	186	122	152	88	91	**1,435**
Other	696	696	1,095	1,219	1,567	1,443	1,866	2,015	1,319	1,642	958	983	**15,504**

TABLE 18: COMMERCIAL WATER USE (1,000 GAL) (2013)

UTILITY CATEGORY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	TOTAL
Hotels and Motels	1,070	838	917	1,281	1,123	1,382	1,698	1,956	1,370	1,096	942	706	**14,385**
Laundries/Laundromats	495	387	424	592	519	639	785	905	633	507	435	326	**6,653**
Car Washes	-	-	-	-	-	-	-	-	-	-	-	-	**-**
Urban Irrigation	390	305	334	467	410	504	619	714	500	400	344	257	**5,250**
Schools and Colleges	318	249	273	381	334	411	505	582	407	326	280	210	**4,281**
Hospitals/Medical Offices	186	145	159	222	195	240	295	339	238	190	163	122	**2,499**
Office Buildings	181	141	155	216	190	234	287	331	231	185	159	119	**2,434**
Restaurants	136	106	116	163	143	176	216	249	174	139	120	89	**1,832**
Food Stores	109	85	94	131	115	141	174	200	140	112	96	72	**1,474**
Auto Shops	103	80	88	123	108	133	164	188	132	105	91	68	**1,389**
Membership Organizations	94	74	81	113	99	122	150	173	121	96	83	62	**1,272**
Other	1,022	800	876	1,224	1,073	1,320	1,622	1,869	1,308	1,047	900	674	**13,741**

Appendix J: Assumptions

Utility data

- Under number of active service connection, large water user, irrigation, and company users were listed as 0. However, the utility data showed water had been consumed under these categories. As such, we altered the customer data to reflect 1 user for each utility category.
- There were several data points that were seen as extreme outliers. When this occurred, the average of the month before and the month after were used. The specific data points are the following:
    - 2013 – Water delivered – Residential – Jul – Extremely high
    - 2013 – Water delivered – Residential – Aug – Negative value
    - 2013 – Water delivered – Residential – Dec – Extremely high
    - 2013 – Water delivered – Commercial – Nov – Extremely high
    - 2013 – Water delivered – Commercial – Dec – Negative value
    - 2014 – Water delivered – Residential – Jan – Negative value
    - 2014 – Water delivered – Residential – Sep – Extremely low
    - 2014 – Water delivered – Residential – Nov – Extremely low

Standard data

- Seasonal variation was available for all descriptive categories except for other. As such, the average of the other seasonal variations was used.
- As there are not proper auto mechanics on the island, rental and repair shops were assumed to take the place of auto mechanics.
- Note that, as there are no car washes on Catalina, car wash values were eliminated.

Visitor's Bureau information

- Private charter arrivals were not provided, therefore they were excluded from the calculations.

Calculations

- CS visitors do not stay on the island and only visit the island for 1 day.
- Transport too and from the island uses sources from the mainland
- The origin of tourists is irrelevant, as the transportation to the island does not impact the island
- Note that water used indirectly through fuel or electricity production was not identified, as this data was unavailable. Therefore it is assumed that this water usage is embedded in all descriptive categories.