WATER BENCHMARKING STUDY: RESTAURANTS AND MICROBREWERIES IN THE CITY OF VANCOUVER

Prepared by: **Kamonchanok Sirikan**
Greenest City Scholar, 2018

Prepared for: **Darren Perrett**, Waterworks Design Branch
Richard Tse, Real Estate and Facilities Management Branch

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EXECUTIVE SUMMARY

The **Water Benchmarking Study: Restaurants and Microbreweries in the City of Vancouver** project is the collaborative project between Engineering Department and Real Estate Department to gain a better understanding of the typical water use of restaurants and microbreweries. This project aims to support the Greenest City Action Plan's goal in reducing water consumption by 2020. This report will also be used by the Real Estate Department in determining water operating costs in their tenant lease agreements. This project report summarizes the methodologies used and findings of the water benchmarking study.

The data on water usage was gathered from 152 restaurants and 18 microbreweries within the City of Vancouver. The restaurants benchmarking study was normalized by the floor area and seating capacity. The microbreweries benchmarking study was normalized by annual beer production. Restaurants and microbreweries were further benchmarked against similar establishments according to their respective type since different types of restaurants and microbreweries generally use different amounts of water. Benchmarking methodologies and breakdowns of sub-categories are detailed in Section 3 of the report.

KEY FINDINGS

Restaurant

- The restaurant benchmarking result based on floor area was *29.1 L/Sq. m./Day*.
- The restaurant benchmarking result based on seating capacity was *87.1 L/Seat/Day*.
- The Chinese Restaurant sub-category had the highest water usage compared to other sub-categories.
- The fast food sub-category benchmark had the lowest floor area result compared to the other sub-categories. Conversely, its seating capacity result was highest. A possible explanation is the fast food restaurants have smaller number of seats and higher turnover rate as they focus on take-away service.

Microbrewery

- The microbrewery benchmarking result was *11.7 m^3 of water used per m^3 of beer produced*.
- Some of the benchmarking results were likely elevated as some microbreweries lease space in shared tenant buildings.

KEY RECOMMENDATIONS

- Investigate establishments with extremely high water usage to identify the cause.
- Develop policies and strategies to improve the water efficiency of restaurants and microbreweries by potentially using operational practices found in establishments with lower water usage.
- Carry out future studies of other categories in the industrial, commercial, and institutional sector, such as office buildings and educational facilities, to gain a greater understanding of water usage in the sector.

DEFINITION OF TERMS

Water Use: the amount of finished drinking water produced or sold to customers through metered connections[1]

Benchmark: the numerical value of a metric that denotes a specific level of performance[2] and is used as a reference for comparison in benchmarking

Metric: the unit of measure that can be used to assess the rate of water use during a given period of time and at level of data aggregation[3]

Water Use Metric: the usage ratio, which is calculated by dividing the volume of water used (or sold) per specified period of time (e.g., day, month, year), over the desired metric [4]

Average (μ): the numerical value calculated by summing all data points in the data set and dividing by the number of data points in the data set

Median: the numerical value that falls directly between the top and bottom 50% of data points in the data set

Standard deviation (σ): a measure of how widely values are dispersed from the average value

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1 Dziegielewski and Kiefer, 2010
2 Ibid
3 Ibid
4 Ibid

1.0 INTRODUCTION

This report summarizes the research methodology and findings of a benchmarking study of the water use by restaurants and microbreweries in the City of Vancouver.

1.1 OVERVIEW

Every day the City of Vancouver provides over 300 million litres of drinking water to homes and businesses[5]. Businesses are defined in this study as non-residential consumers and can be categorized as an industrial, commercial, and institutional (ICI) operation. The water use of ICI customers accounts for approximately 30% of the total water use in the City of Vancouver[6]. It is reported that recent economic growth has resulted in increased water use in the ICI sector[7], so water conservation in ICI sector has received more attention. However, it is more complex than the residential sector due to the limited information on the water usage and the variety of customers that have different purposes of water end uses. Figure 1 shows example subcategories that exist within the ICI sector. This benchmarking study will help the City of Vancouver gain better understanding of the water use in **restaurants** and **microbreweries**, which are part of the commercial and industrial sectors of the ICI.

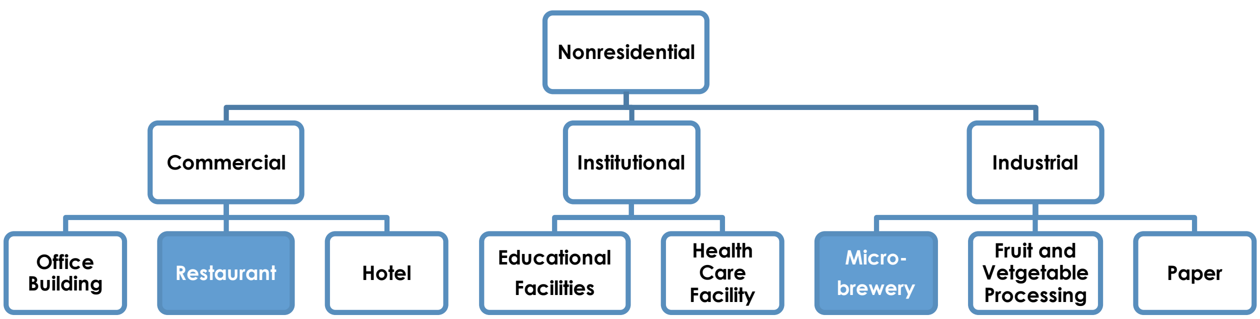

Figure 1: Water End Uses in the Industrial, Commercial and Institutional Sectors[8]

In California, restaurants account for about 9% of the total water used in the commercial and institutional sectors[9] (see Figure 2). Restaurant's water use occurs in the kitchen for food preparation, pre-rising, ice-making, cleaning pots and dishwashing[10]. Restrooms account for the

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[5] City of Vancouver, 2015
[6] Ibid
[7] Ibid
[8] Adapted from Gleick et al., 2004 and Kiefer et al., 2015
[9] Gleick, Srinivasan, Henges-Jeck, & Wolff, 2004
[10] Ibid

remaining water use. Figure 3 breakdown the water end uses in a typical restaurant. In the City of Vancouver, there are approximately 3,000 restaurants and approximately 2,000 limited service food establishments[11].

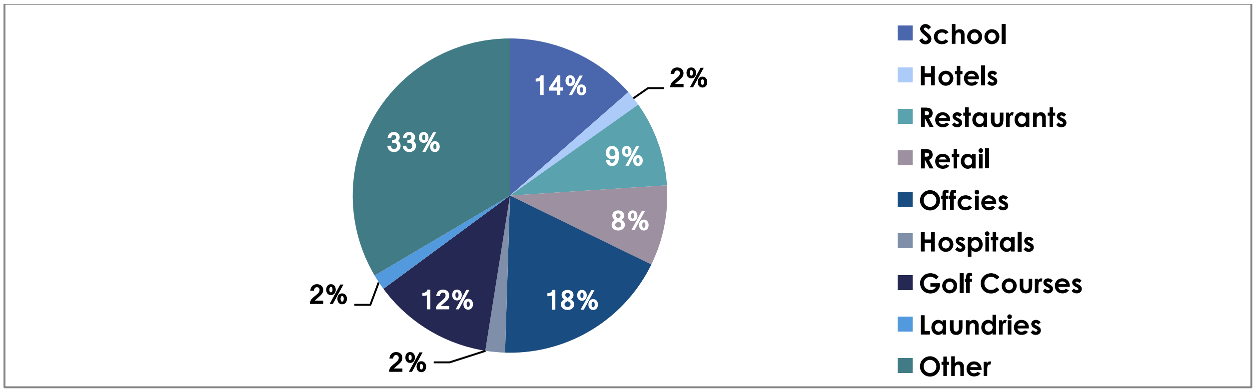

Figure 2: Water End Uses in California's Commercial and Institutional Sectors in 2000[12]

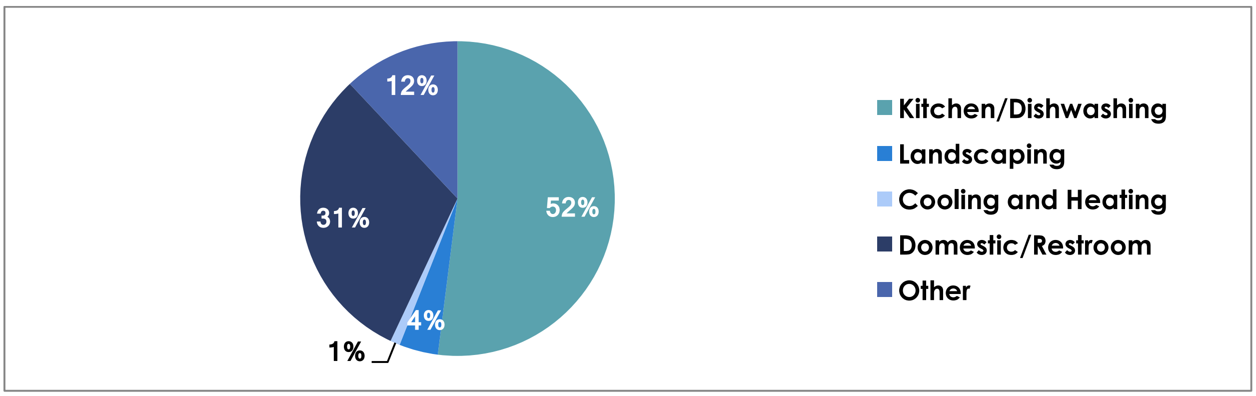

Figure 3: End Uses of Water in Restaurants[13]

Since 2012-2013, craft beer has become more popular in the City of Vancouver. The growth in the craft beer industry has resulted in more than 20 breweries throughout the City of Vancouver[14]. According to the Brewers Association, breweries can be classified into three segments: brewpubs, microbreweries and regional craft breweries. A brewpub is a restaurant-brewery that sells 25 percent or more of its beer on site. A microbrewery is a brewery that produces less than 15,000 barrels (1,760 cubic meter) of beer per year, and a regional craft breweries is a brewery that produces between 15,000 and 6,000,000 barrels annually[15]. In this report, only microbreweries and brewpubs will be used for the benchmarking analysis.

[11] Based on Business License data from City of Vancouver Open Data, 2018
[12] Adapted from Gleick et al., 2004
[13] Adapted from EPA, 2012
[14] Based on the breweries list from Craft Beer Vancouver, 2016
[15] Brewers Association, 2015

Microbreweries use a large amount of water to produce beer and the majority of them discharge 70% of incoming water as effluent[16]. Within a brewery, the main area where water is used is shown in Figure 4. The main water use is in packaging at 38%, where water is used for pasteurising washing and/or rinsing containers and crates, transferring the beer to the filler, as well as washing production equipment[17]. The second water use area is in the brewhouse at 25%, where water is mainly used for beer production process. For the utilities portion at 20%, the water is used for the building's heating, ventilation and air conditioning system, such as cooling towers and evaporative condensers[18]. For the cellars at 17%, the water is used in the beer filtration process to remove any yeast and protein residues from the beer before packaging. Brewpubs, which are breweries that offer food services, have restrooms, but their water use is very small compared to the beer production and the food service[19].

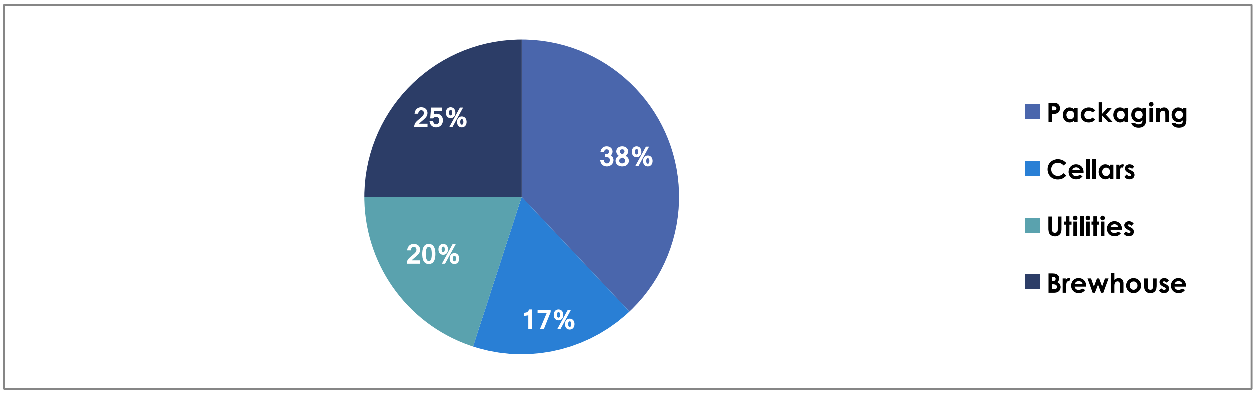

Figure 4: Typical Brewery Water Use Per Area[20]

All restaurants, breweries and other ICI businesses are capable of decreasing water use by improving their water efficiency and water conservation. Water efficiency aims to minimize the amount of water used by using different technologies or using water in smarter and more innovative ways[21,22]. Whereas, water conservation reduces water loss, waste or use[23]. These strategies will prolong the life span of the source waters and can reduce the operational water costs of ICI businesses.

[16] Brewers Association, 2013
[17] Van der Merwe & Friend, 2002
[18] Brewers Association, 2015
[19] Brewers Association, 2015
[20] Adapted from Brewers Association, 2013
[21] GRACE Communications Foundation, 2018
[22] American Rivers, 2018
[23] GRACE Communications Foundation, 2018

1.2 KEY DRIVERS

The main driver in developing this water benchmarking study is the Greenest City 2020 Action Plan, which was approved by Vancouver City Council in 2011 to achieve the City's goal of becoming the greenest city in the world. The Greenest City Action Plan is divided into 10 goal areas[24], two of which are:

- GOAL 6: CLEAN WATER - Target 2: Reduce per capita water consumption by 33% from 2006 levels.
- GOAL 9: GREEN ECONOMY - Target 2: Double the number of companies that are actively engaged in greening their operations over 2011 levels.

In 2015, priority actions for clean water goal were introduced in order to achieve the goal for 2020 and this report will strongly support one of the priority actions which is to

"Reduce institutional, commercial, and industrial (ICI) water consumption through policy and compliance measures" [25].

This water benchmarking study will help achieve the above goals by identifying high and low water usages in restaurants and microbreweries. It will also be used in creating effective ICI water conservation programs as the benchmark will describe their typical water use.

For the City's Real Estate Department, this benchmarking study can be used to estimate the operating water cost in the City's tenant lease and rental agreements. As buildings are increasingly becoming multi-functional and multi-tenanted, allocating water utility costs is becoming more complex. This study may be used to determine the allocation of water costs for restaurants and microbrewery tenants in multi-tenanted buildings.

[24] City of Vancouver, 2015
[25] Ibid

2.0 BACKGROUND

This section provides an overview of the concept of the benchmarking study. It discusses different types and techniques of benchmarking as well as the challenges in performing a water use benchmarking study. It also discusses previously existing benchmarking studies that have been performed by different organizations around the world.

2.1 BENCHMARKING

Benchmarking is the utility management tool to assess performance against other process or activity to improve the one's own performance. Andersen and Petterse[26] defined benchmarking as

"The process of continuously measuring and comparing one's business processes against comparable processes in leading organization to obtain information that will help the organization identify and implement improvements"[27].

The term benchmarking can be defined in several ways based on what is compared and what the comparison is being made against, such as performance benchmarking, strategic benchmarking, and process benchmarking. **Performance benchmarking** is the comparison of the organization to others. **Process benchmarking** is the comparison of the methods and processes to improve the organization's processes. **Strategic benchmarking** is to examine the market and to compare that to the organization and see how the organization can adapt to be more realistic with regards to the current market situation[28]. For the water utility sector, a commonly used benchmarking type is the process benchmarking called *"metric benchmarking"*.

Metric benchmarking is the quantitative measurement of performance levels against other organizations over time[29,30,31,32]. A **metric**, or performance indicator, is the unit of measure that can be used to assess the rate of water use during a given period of time and at level of data aggregation[33]. Another term for metric is a normalized factor, which is used to normalize the water use by a desired scaling factor (e.g. population, area, or employees)[34]. A **water use metric**

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[26] Andersen and Pettersen, 1996

[27] Ibid

[28] Bhutta and Huq, 1999

[29] Blankenship, Olstein & Liner, 1998

[30] Milnes, 2006

[31] Seppälä, 2015

[32] Berg and Padowski, 2007

[33] Dziegielewski and Kiefer, 2010

[34] Ibid

is the usage ratio, which is calculated by dividing the volume of water used (or sold) per specified period of time (e.g., day, month, year), over the desired metric[35]. A **benchmark** is the numerical value of a metric that denotes a specific level of performance and is used as a reference for comparison in benchmarking. Therefore, the water use benchmarking is usually set as a goal or target for water use through time[36].

2.2 BENCHMARKING TECHNIQUES

According to Sartor, et la.[37], benchmarking techniques in utility sector can be divided into four categories: Statistical Analysis Benchmarking, Points-Based Rating Systems, Simulation Model-Based Benchmarking, and Hierarchical and End-Use Metrics. After reviewing these categories, it was determined only one of them was relevant to this study which is statistical analysis benchmarking. Statistical analysis benchmarking does not require an extremely large dataset compared to model-based benchmarking. It also does not require in-depth data such as end-use demand, facility location, and weather data, which can be difficult to obtain.

In STATISTICAL ANALYSIS BENCHMARKING, statistics for a population of similar facilities are used to generate a benchmark which is then set as a goal or target. This method requires large data sets to produce a reasonably sized sample of similar facilities[38]. In statistical summary, the benchmark is usually represented in terms of the arithmetic-mean (or the average) of the water use metrics. Median, the number where 50th percentile (or the middle) of a data set is, can also be used as the benchmark. The main difference between the median and the average is the sensitivity to extreme high or low values. The average is calculated by summing all data points in the data set and dividing by the number of data points in the data set. Therefore, the average is not the best calculation to use with the data sets containing extreme values. Alternatively, the median is the better calculation in such cases.

2.3 CHALLENGES

Water benchmarking in the ICI sector is typically used to identify the performance in water use of facilities against other similar facilities; however, the main question that needs to be answered is "how do we identify the top performers in term of water use?"[39] There are challenges for metric benchmarking such as:

1. Choosing the appropriate water use metrics used for each ICI sector.
2. Ensuring the data is being compared in the most meaningful way possible.

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35 Ibid

36 Kiefer et al., 2015

37 Sartor et al., 2000

38 Kinney & Piette, 2002

39 Maltz, Bi & Bateman, 2016

3. Avoiding misinterpreted comparisons and inappropriate conclusions made from confounding water use metrics[40,41].

Therefore, the main considerations of selecting the metrics are the availability and validity of data when evaluating facilities against a benchmark value.

When classifying each ICI sector into sub-categories, it can also be challenging to ensure that the sub-categories selected account for distinguishing features that may influence water use. The sub-categories being selected need to ensure appropriate comparisons of water use metrics. They should be based on the mix of end uses present within each sub-category[42]. For restaurants, the sub-categories could be distinguished based on type of meals served and the technology used in the kitchen, for example, the ice machine, wok-station, and dishwashing machines. For microbreweries, the sub-categories could be distinguished based on the size of brewery and the availability of on-site food service.

2.4 EXISTING BENCHMARKING STUDIES

Benchmarking studies have been widely used in water conservation programs for the non-residential sectors. Several organizations around the world performed the benchmarking studies on ICI sectors to understand and manage water use in different facilities. This section provides a summary of existing benchmarking studies for both restaurants and microbreweries.

2.4.1 RESTAURANTS

There are some common elements in the six studies reviewed. It is challenging to directly compare all the benchmarks as they often involved different benchmarking approaches. Table 1 and 2 provide a comparison of the results of the above studies. There is a large range of benchmark values which may be due to the differences in benchmarking approaches, sample sizes, and location of the study.

Table 1: Summary of Existing Restaurant Benchmarking Studies in Litres per Square Meter per Day

Benchmark (Average) in L/Sq. m/Day	Data Source	Restaurant Types	Sample Size
17.9	St. Johns River (2011)	Undefined	101
21.4	Brendle Group (2007)	Full service	302
29.3	Metro Vancouver (2012)	Full service	19
29.7	Kansas State University (2011)	Full service	221
44.8	American Water Works Association (2000)	All service	85

[40] Sartor et al., 2000

[41] Kiefer et al., 2015

[42] Ibid

Table 2: Summary of Existing Restaurant Benchmarking Studies in Litres per Seat per Day

Benchmark (Average) in L/Seat/Day	Data Source	Restaurant Types	Sample Size
48.4	Kansas State University (2011)	Full service	221
67.6	City of Santa Fe (2009)	Full service	4
76.8	Water Research Foundation (2015)	Full service	421
122.8	Metro Vancouver (2012)	Full service	19
129.1	Brendle Group (2007)	Full service	302

In 2000, American Water Works Association Research Foundation and the American Water Works Association produced a study focusing on the water end use for commercial and institutional sectors[43]. Within these sectors, this study established the benchmark for office buildings, restaurants, supermarkets, hotels and high schools. The water data was collected from Los Angeles Department of Water and Power, California, Irvine Ranch Water District, California, City of San Diego Water Utilities Department, California, City of Santa Monica, California, and City of Phoenix Water Services, Arizona. This benchmarking study analyzed both average and median as benchmark values based on several metrics for each establishment. The efficiency benchmark (best practice value) was selected as the 25th percentile, which means that one-fourth of the sample was lower than the selected value. For restaurants, the metrics used were gallons of water per square foot of building area in a year, gallons of water per meal served, gallons of water per seat per day, and gallons of water per employee per day.

In 2007, the Brendle Group prepared a study entitled "Benchmarking Task Force Collaboration for Industrial, Commercial & Institutional Water Conservation" for Colorado Water Wise Council[44]. This study focused on four categories including restaurants, schools, hotels and motels, as well as nursing, assisted living, and independent care facilities. Data was provided by City of Aurora, City of Boulder, City of Fort Collins, City of Greeley, City of Loveland, City of Thornton, City of Westminster, Colorado Springs Utilities, Colorado State University, Denver Water, and Northern Colorado Water Conservancy District. In this study, eating establishments with indoor seating and dishwashing facilities was used. Breweries, bars, and fast food establishments were excluded. The benchmark used was the average of annual water use per metrics, which were thousand gallons of water per square foot of building area in a year, and thousand gallons of water per seat per year.

In 2009, the water division of City of Santa Fe analyzed water use in Santa Fe in "a study of residential and commercial water use in the Santa Fe Urban area"[45]. Commercial use was divided into seven categories including restaurants, hotels, retail stores, office/research, manufacturing, gas station and carwashes, and additional commercial sites. Restaurants were separated into two types of food service providers: full service and limited service (fast food type) restaurants. For full service restaurants, the water use values were from the City of Santa Fe

[43] Dziegielewski. 2000

[44] Brendle Group Inc., 2007

[45] King et al., 2009

and the data was normalized by maximum seating occupancy. The benchmark was the average yearly water use in gallon per seat per year.

In 2011, St. Johns River Water Management District, contracted with Jones Edmunds, evaluated the potential water use reduction by using benchmarking study[46]. Five commercial categories including office buildings, retail, restaurants, hotels, schools, manufacturing, and live-in care were studied. The date range used for this study was January 2008 through December 2009. The average of water used per building area per day was used as a benchmark.

Matthew VanSchenkhof's dissertation at Kansas State University in 2011 investigated the water usage in casual dining restaurants in Kansas[47]. He defined casual dining restaurants as a restaurant where table service is provided and alcohol is available. He developed the benchmarks, which was the average for water usage for restaurants, using the data from local municipal water utilities, the Kansas Department of Revenue, Google's Place Page, and interviews with managers. The metrics used in this study were gallons of water per interior square foot per day, gallons of water per seat per day, and gallons of water per employee per day.

In 2012, WorleyParsons performed a study for Metro Vancouver called "Institutional, Commercial, Agricultural and Recreational (ICAR) Buildings and Operations Water Consumption Benchmarks"[48]. The sectors targeted in this study were educational facilities, hospitality, medical and health facilities, and office buildings. Full service restaurants were included as a sub-category of the hospitality category. Fast food establishments were not included. Data from previous studies from Australia, Canada, the UK and the US were used to create the benchmark in litres per square meter per day, litres per seat per day, and litres per customer per day.

In 2015, Water Research Foundation published a study prepared by Jack C. Kiefer and Lisa R. Krentz entitled "Methodology for Evaluating Water Use in the Commercial, Institutional, and Industrial Sectors"[49]. This study evaluated five categories of commercial and institutional customers, specifically, school, hotel/motels, office buildings, restaurants, and food stores. The sub-categories suggested in this study were full service restaurants, fast food outlets, and bakeries and cafeterias. The water use data were from Tampa Bay Water, the business classifications were from Florida Department of Revenue (FDOR), and business license data from the Florida Department of Business and Professional Regulation (DBPR). Both mean and median of water use per seat were used as a benchmark. This study also suggested three alternatives water use metrics including water use per square feet of building area, water use per employee, water use per customer, and water use per meal.

[46] Jones Edmunds, 2011
[47] VanSchenkhof, 2011
[48] Wynne & Graham, 2012
[49] Kiefer et al., 2015

2.4.2 MICROBREWERIES

The benchmark results from three studies reviewed for this project studies are shown in Table 3 below. The benchmark results vary from 3.53 to 27.7 L/L. Due to the limited information on benchmarking approaches provided by these studies, it is difficult to make a relevant and useful comparison between them because the scale of production in the brewery and the type of brewery greatly affects the water use.

Table 3: Summary of Existing Brewery Benchmarking Studies

Benchmark in L of Water Used/L of Beer Produced	Data Source	Data Year	Brewery Types
27.7	Brewers Association (2015)	2014	Brewpub - 1,000 - 10,000 bbls/yr
6.87	Brewers Association (2015)	2014	Microbrewery - 1,000 - 10,000 bbls/yr
6.02	Brewers Association (2015)	2014	Microbrewery - 10,000 - 100,000 bbls/yr
5.41	BIER (2010)	2007	Undefined
4.98	BIER (2010)	2008	Undefined
4.67	BIER (2010)	2009	Undefined
4.74	BIER (2011)	2008	Undefined
4.52	BIER (2011)	2009	Undefined
4.28	BIER (2011)	2010	Undefined
4.53	BIER (2012)	2009	Undefined
4.27	BIER (2012)	2010	Undefined
4.00	BIER (2012)	2010	Undefined
4.12	BIER (2016)	2011	Undefined
3.79	BIER (2016)	2013	Undefined
3.53	BIER (2016)	2015	Undefined
5.5	China Water Risk (2016)	2013	Undefined

In 2015, the Brewers Association published the Sustainability Benchmarking Report[50]. This report presented a summary of the benchmark of water and energy use and efficiency in the U.S. craft beer industry. This report classified the craft beer industry market into in three distinct segments: brewpubs, microbreweries and regional craft breweries. The average and median volume of water used per volume of beer produced was used as a benchmark. This report also divided breweries by production volume and showed that larger breweries tend to use less water because they might have more automated processes, which can provide for tighter control of the amount of water used for cleaning and sanitization.

Since 2007 the Beverage Industry Environmental Roundtable (BIER)[51,52,53,54] has completed an annual report on benchmark of water use and efficiency in the beverage industry, including bottling, brewery, distillery and winery, around the world. Every annual report compared the

[50] Brewers Association, 2015
[51] BIER, 2010
[52] Brewers Association, 2013
[53] BIER, 2012
[54] BIER, 2016

benchmark value over a three-year period. However, the report did not define whether the benchmark value is the average value or median value.

China Water Risk translated a report on the water footprint in China[55]. It reported that the average water used in brewery is around 5.5 litres per 1 litre of beer produced.

[55] Chan, 2016

3.0 METHODOLOGY

This section describes the methodology used in this study. This methodology covers the full process of the study from metrics selection to data collection and analyses. The framework for the benchmarking study is shown in Figure 5.

Figure 5: A Framework for Benchmarking

3.0.1 METRICS AND SUB-CATEGORIZATION

Metrics were selected based on the following considerations:

- Availability of data from internal City databases.
- Usefulness of the metric in evaluating the business against the benchmark.

The selected metrics were tested for correlation with the water uses through the assessment of the coefficient of correlation "r^2". The r^2 value is a measure of the data relationships or the degree of relation between two variables. An r^2 of close to zero indicates that there is no relationship between the two variables being assessed. An r^2 approaching 1 indicates a strong relationship between the two variables[56]. Sub-categorization, or classification, is based on the common types of goods and services that are produced by facilities which may influence the water uses. The r^2 value can be calculated by:

1. Plotting two variables on the graph and adding trend line and r^2 value, or
2. Using the built-in R-squared formula in MS Excel, RSQ(known_y's, known_x's).

Sub-categorization is mainly based on the presence of any specific water end uses and any water use technologies which may influence the total water use in each ICI sector.

[56] Bannister et al., 2005

3.0.2 DATA COLLECTION AND PROCESSING

General steps for data collection and processing are listed below:

1. Identify potential facilities for the study based on business licenses.
2. Examine the selected facilities to verify that the facilities are suitable for the analysis. The suitable facilities are the ones that will represent the specific end uses of water (i.e. facilities that do not share a meter with other facilities). The possible verification methods are:
    - CHECK BUSINESS LICENSES USING VANMAP: the facility with one business license is suitable
    - CHECK LOCATION AND BUILDING TYPE USING GOOGLE MAPS STREETVIEW: the facility that is one story building and does not share the building with other business is suitable
3. The Tempest accounts for selected facilities, which can be found on VanMap, are used to obtain the water usage data from Tempest Application. In this study, the water usage data for the 2016-2017 billing periods were used. The water usage data for each facility is manually verified as it is possible to have missing water usage data for some facilities.
4. Business licenses for selected facilities are used to obtain data from internal data source, such as address, business name, and other data.
5. External sources, such as Google, are used to verify the location, business type, and any required information for selected facilities.

3.0.3 BENCHMARK ANALYSIS

Statistical analysis benchmarking is the best technique for this study. The average (μ) was used as the benchmark value, and is referred to as the **Typical Water Use**. To determine whether the facility is a high or low performer, a control chart typically used in statistics for quality control was used[57]. Each control chart consists of a centre line, an upper control limit (UCL), and a lower control limit (LCL). In the control chart, the center line indicates the expected or average value of the sample. A value below lower control limit indicates **Best Practice Water Use**, a value between upper control limit and lower control limit indicates **Normal Water Use**, and a value above upper control limit indicates **Excessive Water Use**. The control limits are placed three standard deviations (σ) above and below the center line, respectively[58] and can be calculated using the following equations:

[57] Maltz, Bi & Bateman, 2016

[58] Ibid

Equation 1: Average $\boldsymbol{\mu = \frac{\Sigma x}{n}}$

Equation 2: Standard Deviations $\sigma = \sqrt{\frac{\Sigma(x-\mu)^2}{(n-1)}}$

Equation 3: Upper Control Limit $UCL = \mu + \frac{3}{\sqrt{n}}\sigma$

Equation 4: Lower Control Limit $LCL = \mu - \frac{3}{\sqrt{n}}\sigma$

where n is the number of data points in the data set. The average and standard deviations can also be calculated using the Microsoft Excel built-in functions, AVERAGE function STDEV function, respectively.

While using the largest possible data set is ideal, the removal of outliers that may potentially skew the outcomes is required. Outliers are facilities that have excessively high or low water use comparing to others. To account for outliers, the standard deviation is used to filter out the outliers, and the average of the filtered data will be used as the final benchmark value.

3.0.4 DEMOGRAPHIC VARIABLES ANALYSIS

The paired t-test will be used to determine whether significant differences existed between water use and demographic variables. Two-tail analysis of P-Value and T-Value in paired t-test will be used with the following information:

- Null hypothesis: there is no significant difference in the means of each sample
- Alpha: 0.05, which corresponds to a 5% chance of obtaining a result like the one that was observed if the null hypothesis was true

The p-value gives the probability of observing the test results under the null hypothesis:

- A small p-value (≤ 0.05) indicates strong evidence against the null hypothesis, therefore reject the null hypothesis
- A large p-value (> 0.05) indicates weak evidence against the null hypothesis, therefore accept the null hypothesis

The t-value measures the size of the difference relative to the variation in the sample data:

- T-statistic value is calculated from t-table using the degrees of freedom and alpha
- If the absolute value of the t-statistic is greater than this critical value, then reject the null hypothesis
- If the absolute value of the t-statistic is smaller than this critical value, then accept the null hypothesis

3.1 RESTAURANTS

3.1.1 METRICS AND SUB-CATEGORIZATION

Potential variables that can be used as metrics to explained and normalized water use of restaurants are listed below:

- Floor area
- Seating capacity
- Number of meals served
- Number of consumers
- Number of employees
- Type of restaurants
- Type of kitchen operations
- Average meal price
- Operating hours

METRICS

With the metric considerations mentioned in the previous section (section 3.0.1), **floor area** and **seating capacity** were selected as the metrics for this study as this information was accessible from internal sources. For the further development of the benchmarking study, others metrics such as the number of consumers and number of meals served can also be used to normalize the water use n, however, field survey is required to obtain this information.

The relationship between water usage and the following key variables was assessed in terms of r^2 values as listed below (refer to Appendix B):

- Floor area (unfiltered data): $r^2 = 0.167$
- Seating capacity (unfiltered data): $r^2 = 0.282$

SUB-CATEGORIZATION

One possible classification for restaurant is the classification by type of restaurant. The type of restaurants can be divided into 6 sub-categories based on the type of meals served, the technologies used in the kitchen, and the seating facility. Dziegielewski[59] found that Chinese restaurants had the highest daily water use due to the wok-station while the fast food restaurant had the lowest use. VanSchenkhof[60] also investigated the effect of menu types on water use, and the menus were classified into seven categories including combination, American Mexican, Asian, Italian, Pizza, and other. The Water Research Foundation[61] also suggested sub-categories

[59] Dziegielewski, 2000
[60] VanSchenkhof, 2011
[61] Kiefer et al., 2015

for restaurant such as full-service restaurants, fast food outlets, bakeries, and cafeterias. Based on studies mentioned earlier, the **type of restaurants** used in this study and their definitions are listed below:

- FAST FOOD: Chain or franchise restaurants with/without table service; possibly no on-site dish washing; serve food on take away container.
- BAKERY: an establishment that produces and sells bread, cookies, cakes, pastries, etc.; no table service and on-site dish washing.
- CAFÉ: restaurants selling coffee, tea and other drink, and as well as light meals, bakeries and desserts.
- CHINESE: Chinese cuisine restaurant with the usage wok-stations; not including hotpot.
- ASIAN: Asian cuisine including hotpot, Japanese, Thai, Korean, Indian, Malaysian, Vietnamese, and Middle Eastern, which may or may not use wok-stations.
- OTHER: Any restaurant that did not fit into the existing categories.

Another classification for restaurants is the classification by type of service. Most of the studies mentioned in the Existing Benchmarking Studies section (section 2.4.1) performed the benchmarking study on full service restaurants because they have dishwashing facilities, which consume a large portion of the total water usage in a restaurant. Therefore, the **type of service** classification can be divided into 2 sub-categories and are listed below:

- FULL SERVICE: Restaurants with seating and dishwashing facilities.
- LIMITED SERVICE: Restaurants with/without table service, serve food on take away containers, and have no dishwashing facilities.

3.1.2 DATA COLLECTION AND PROCESSING

DATA COLLECTION

The sample data used for the restaurant benchmarking study were facilities with business licenses of Restaurant class 1, Restaurant Class 2, and Ltd Service Food Establishment in the City of Vancouver. In order to determine the total water use for each restaurant, properties with only one registered business license were required. This initial filtering was completed using ArcGIS to select properties with only one business license. This filtered the initial sample to 355 licenses. Using Google Maps and Vanmap, the businesses that shared a meter with other businesses or located in high-rise building were removed and the sample size decreased to 187. With this sample size, water usage data was collected for the 2016-2017 billing periods from Tempest, which is a software platform the City uses for water utility billing. The following internal data was collected, where available, for the selected restaurants:

- Restaurant No. – simple identifying number is used for each restaurants due to the confidentiality policy
- Address

- Business name
- Business license number
- Floor area
- Seating Capacity
- Tempest account number
- Water usage by billing period starting from Period 1 of 2016 to Period 6 of 2017 (total of 12 periods)

Address, business name, business license number and Tempest account number can be found in Vanmap. The floor area and seating capacity information can be obtained from the Amanda database, in which all business license data is stored. To bulk extract the information held in the Amanda database, IT Services was contacted and provided a list of licenses. The water usage information can be obtained by using a Tempest account number. Additional restaurant information, such as the restaurant type, was also collected from various external sources to identify the sub-category.

DATA PROCESSING

From the Tempest database, the meter reading of water usage for 12 billing periods were collected. The water usage per day was calculated by dividing the summation of "Total Consumption Billed Units" by the summation of "Read Days". The unit of daily water usage is converted from “Unit per day” to “Litre per day” by using the following unit conversion: *1 Unit = 2830 Litre*.

The daily water usage data was then divided by the selected metrics: seating capacity and floor area.

After the data was processed and filtered a total of 152 restaurants were suitable for benchmarking analysis. The data source roadmap is shown in Figure 6 and the list of restaurant for this study is shown in Appendix A.

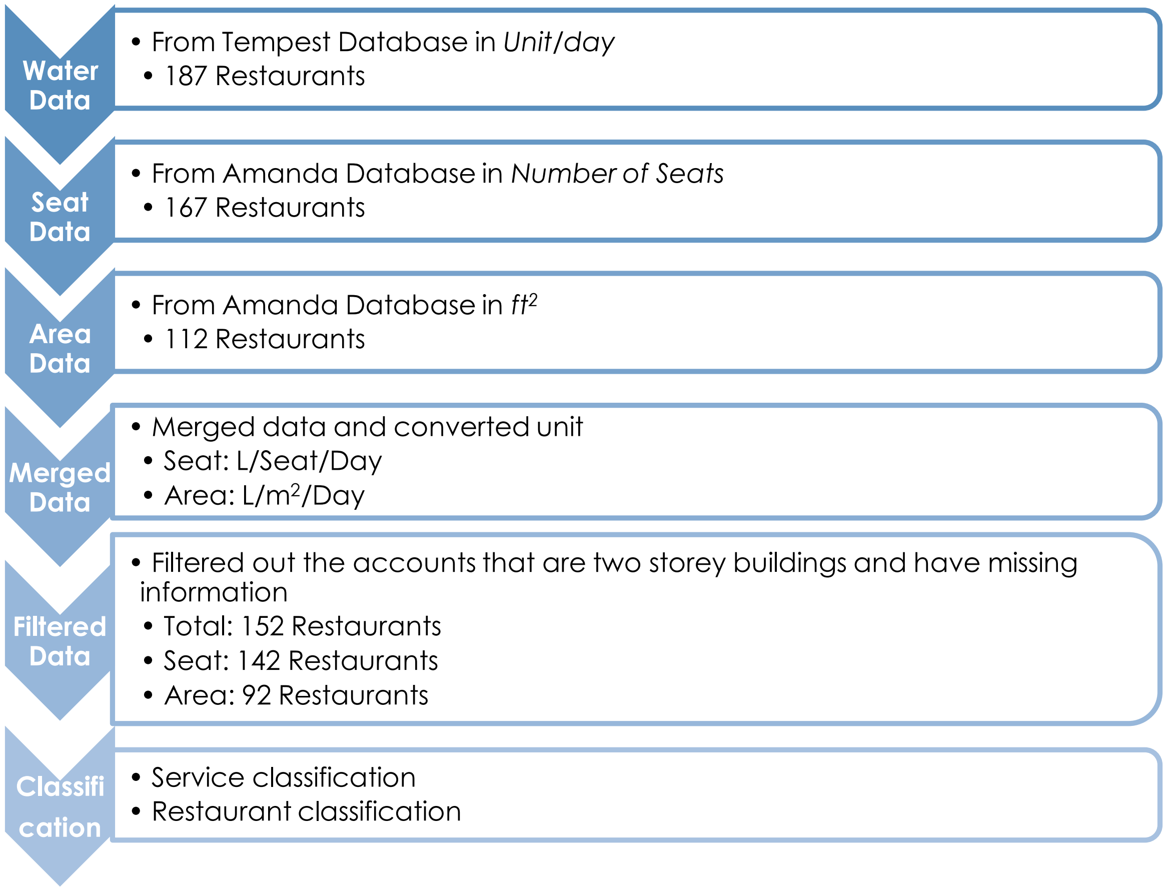

Figure 6: Restaurant Data Source Roadmap

3.1.3 BENCHMARKING ANALYSIS

For this study, outliers were filtered out based on the average (μ) and standard deviation (σ) of the initial benchmark results. This resulted in the restaurant floor area sample size decreasing from 92 to 80, and the restaurant seating capacity sample size decreasing from 142 to 127. Outliers were any points that were above or below plus or minus one standard deviation ($\mu + \sigma$) and ($\mu - \sigma$). This resulted in the removal of several restaurants with extremely high water usage.

Using sample sizes for the floor area and seating capacity datasets, the margin of error was calculated using a 95% confidence level[62] and the summary of the result is shown in Table 4.

Table 4: Summary of Margin of Error for Restaurants Sample Size

Floor Area		Seating Capacity	
Unfiltered data	Filtered data	Unfiltered data	Filtered data
10.12%	10.87%	8.11%	8.59%

[62] CheckMarket, 2018

After the outlier filtration, the relationship between water usage and the following key variables was improved as follow (refer to Appendix B):

- Floor area (unfiltered data): $r^2 = 0.167$
- Floor area (filtered data): $r^2 = 0.499$
- Seating capacity (unfiltered data): $r^2 = 0.282$
- Seating capacity (filtered data): $r^2 = 0.505$

3.1.4 DEMOGRAPHIC VARIABLES ANALYSIS

One of the demographic variables that may affect the water uses in the restaurants is the time of a year.

Seasons: Water use was stratified into seasons based on the meter reading periods (winter; spring; summer) using the following guidelines:

- Winter: Period 1 and 2 (from October to February)
- Spring: Period 3 and 4 (from February to June)
- Summer: Period 5 and 6 (from June to October)

3.2 MICROBREWERIES

3.2.1 METRICS AND CLASSIFICATION

METRICS

For brewery and other beverage industries, the most appropriated metric to use was the standard normalization factor, which would be the total water use per total beverage production. It can also be called the "Water Ratio".

SUB-CATEGORIZATION

Only microbreweries and brewpubs were used in this analysis. In the City of Vancouver, a number of small microbreweries lease space in shared tenant buildings so it is hard to determine their actual water usage. Where possible, follow up calls were made in cases of shared tenancy to confirm the water usage data was only for the microbreweries. In cases where the water usage was shared between the microbrewery and another tenant(s), it was reported that the microbrewery was responsible for 70%-90% of the total water use. As a result, the microbrewery classification in this study is listed as follow:

- BREWPUB: Microbreweries that serve full-menu food
- MICROBREWERY: Microbreweries that serve only snacks
- MICROBREWERY WITH SHARED TENANT: microbreweries that share their building with other businesses

Both may also have growler fills, samples, tasting room, or tours.

3.2.2 DATA COLLECTION

DATA COLLECTION

The primary sample size for microbreweries was based on the City's previous studies and the list of breweries in the City from craftbeervancouver.ca, which resulted in 27 microbreweries. After verifying each microbrewery using Google Maps and Vanmap, it was determined 13 microbreweries shared a meter with other businesses and 7 microbreweries were located in high-rise buildings. Due to small primary sample size for microbreweries, only microbreweries located in high-rise buildings were removed. The resulting sample size decreased to 18 microbreweries. With this sample size, internal data were collected from 2016-2017 periods. The following internal data were collected, where available, for the selected microbreweries:

- Microbreweries No. – simple identifying number is used for each microbreweries due to the confidentiality policy
- Address
- Business name
- Business license number
- Annual beer production
- Tempest account number
- Water Usage starting for the 2016 to 2017 billing periods

Address, business name, business license number and Tempest account number can be found in Vanmap. The annual production data was obtained from the Environmental Services department, to whom microbreweries need to report their annual total production. The water usage information can be obtained from Tempest by using a Tempest account number. Addition microbreweries information, such as microbrewery type, was also collected from external sources to identify the sub-categorization.

DATA PROCESSING

From the Tempest database, the Tempest readings of water usage from the 2016-2017 billing period were collected. The Tempest readings were interpolated into daily data from 1st January 2016 to 31st December 2017, and all daily values were summed to obtain annual water usage.

The annual water usage data was then divided by the annual beer production. The data source roadmap is shown in Figure 7.

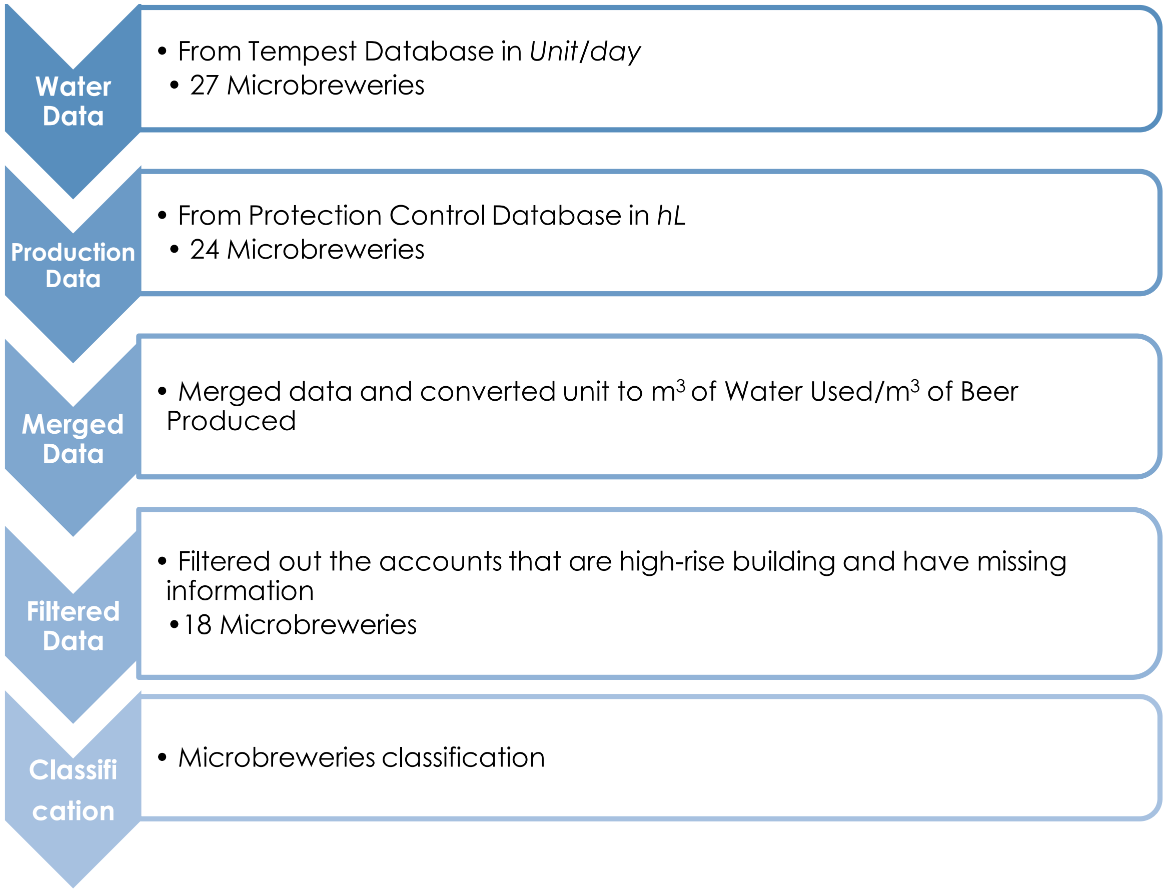

Figure 7: Microbreweries Data Source Roadmap

3.2.4 BENCHMARKING ANALYSIS

For the microbrewery benchmarking study, the same filter criteria used in the restaurant benchmarking study was applied to filter out any outliers. As a result, the sample size decreased from 18 to 13 breweries.

After the outlier filtration, the relationship between water uses and the following key variables was significantly improved as follow (refer Appendix D):

- Unfiltered data: $r^2 = 0.6998$
- Filtered data: $r^2 = 0.9085$

A sensitivity analysis for breweries sharing their building with other tenants was performed and Figure 8 shows the result of the sensitivity analysis. A 10% change in the microbrewery's portion of the total water consumed, resulted in the average water ratio between water used and beer produced changing by around 1.2, a 4% difference. Given the challenges in determining the actual water used in cases where there were multiple tenants, and the relative insensitivity of altering the percentage of the microbrewery's proportion, no change was made to water usage data in cases of shared tenancy.

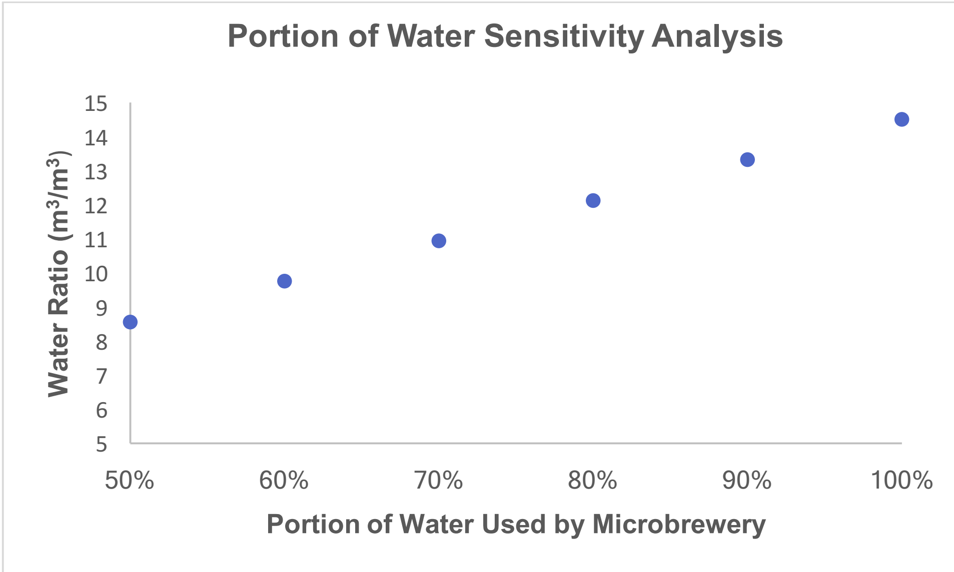

Figure 8: Portion of Water Sensitivity Analysis for Microbreweries-Shared Tenant

3.2.4 DEMOGRAPHIC VARIABLES ANALYSIS

One of the demographic variables that may affect the water uses in microbreweries is the time of a year, however, the monthly total beverage production information is not available. Therefore, the demographic variables analysis was not performed for microbreweries.

4.0 RESULTS

This section presents the benchmarking results of restaurants and microbreweries in the City of Vancouver. The guideline for best practice range and excessive range are:

- BEST PRACTICE RANGE: lower than Best Practice Value
- TYPICAL USE RANGE: between Best Practice Value and Excessive Use Value
- EXCESSIVE USE RANGE: lower than Excessive Use Value

4.1 RESTAURANTS

The summary of the restaurant benchmarking study results for both unfiltered and filtered data are shown in Table 5. Table 5 shows the benchmark (or the average), the median, the standard deviation, as well as the guideline for best practice range and excessive range for water use in restaurants. The results under filtered data columns are the result after outliers were removed due to excessively higher or lower water usage than the remaining data. Figure 9 and 10 represent the water use metric based on floor area and seating capacity, respectively. For Figures 9 through 12 and 14 and 15, outliers that were removed are highlighted in black outline. The detailed benchmarking results of restaurants will be divided into 2 main sections: floor area (section 4.1.1) and seating capacity (section 4.1.2).

Table 5: Summary of Restaurant Benchmark Result

	Floor Area		Seating Capacity	
	Unfiltered Data	Filtered Data	Unfiltered Data	Filtered Data
Sample Size	92	80	142	127
Unit	L/Sq. m/Day		L/Seat/Day	
Benchmark	**40.5**	**29.1**	**115.8**	**87.1**
Median	30.3	25.7	83.8	77.7
Standard Deviation	38.4	16.3	111.9	47.8
Excessive Use Value	52.6	34.6	144.0	99.8
Best Practice Value	28.5	23.7	87.6	74.4

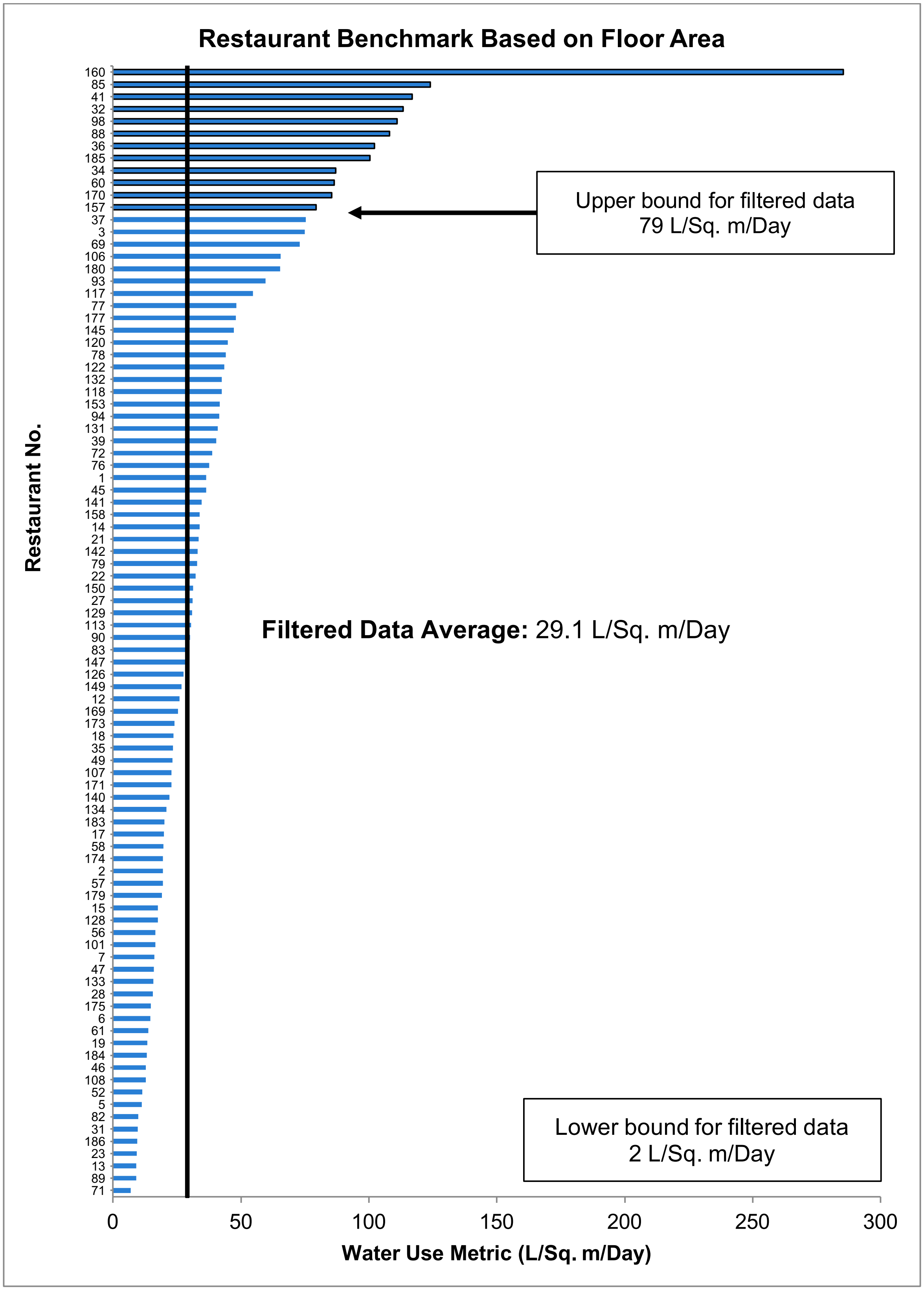

Figure 9: Restaurant Benchmark Based on Floor Area

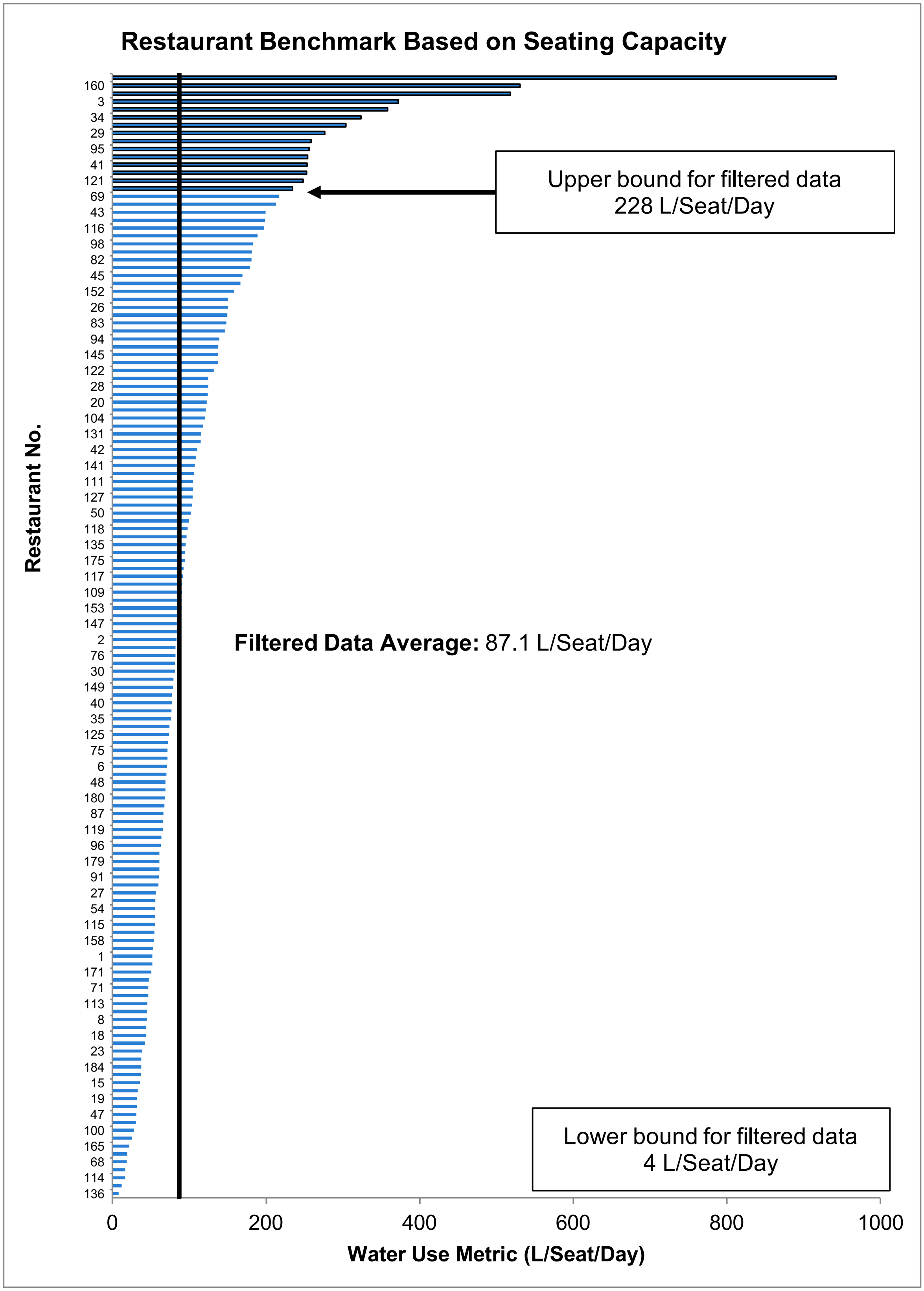

Figure 10: Restaurant Benchmark Based on Seating Capacity

4.1.1 FLOOR AREA

Table 6 below presents a summary of the results for floor area metric for restaurant classification and service classification. For restaurant classification (see Figure 11), the water use in Chinese sub-category is higher than the rest of sub-categories, likely due to wok-stations which are typically found in Chinese cuisine restaurants. Fast food, bakery and café of sub-categories have lower benchmark results. This could be due to the limited services in such establishments, such as lack of seating or dishwashing facilities, or to the different types of food which require different amounts of water. For service classification, the limited service restaurants, including fast food and bakery sub-categories, have a lower water benchmark than the full service restaurants (see Figure 12).

Table 6: Summary of Restaurant Benchmark Result with Sub-Categories Based on Floor Area

	Restaurant Classification							Service Classification	
	All	Fast Food	Bakery	Café	Chinese	Asian	Other	Limited service	Full service
	Unfiltered Data								
Average (L/Sq. m/Day)	41	28	21	17	90	35	35	26	44
Median (L/Sq. m/Day)	30	24	11	18	83	32	30	20	32
Sample Size	92	12	5	6	14	18	37	18	74
	Filtered Data								
Lower Bound for Filtered Data	2	8	-1	13	24	13	12	6	3
Upper Bound for Filtered Data	79	48	42	21	156	57	58	46	85
Average (L/Sq. m/Day)	**29**	**23**	**11**	**17**	**85**	**31**	**31**	**20**	**32**
Sample Size	80	11	4	4	11	14	29	16	64

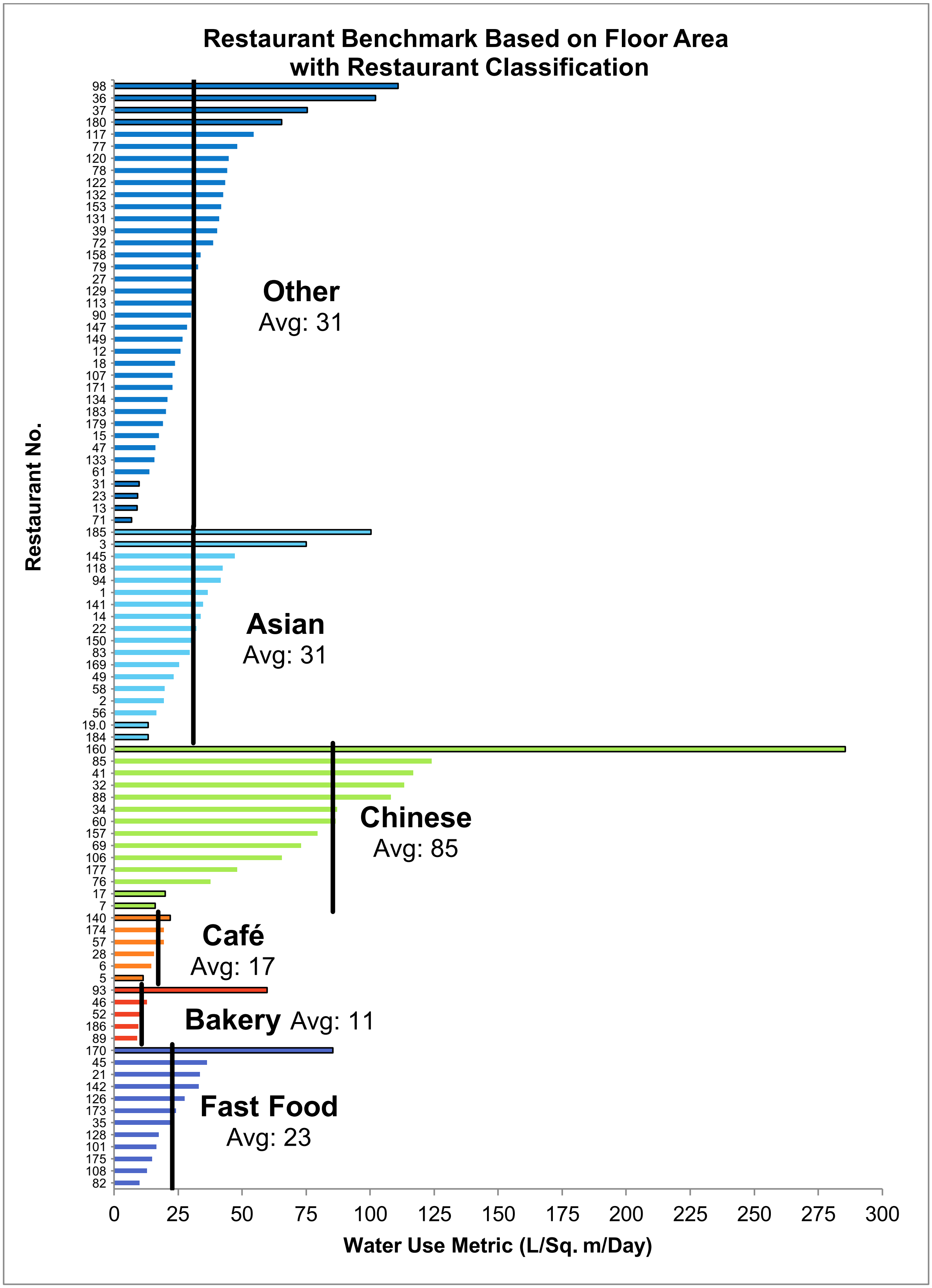

Figure 11: Restaurant Benchmark with Restaurant Classification Based on Floor Area Metric

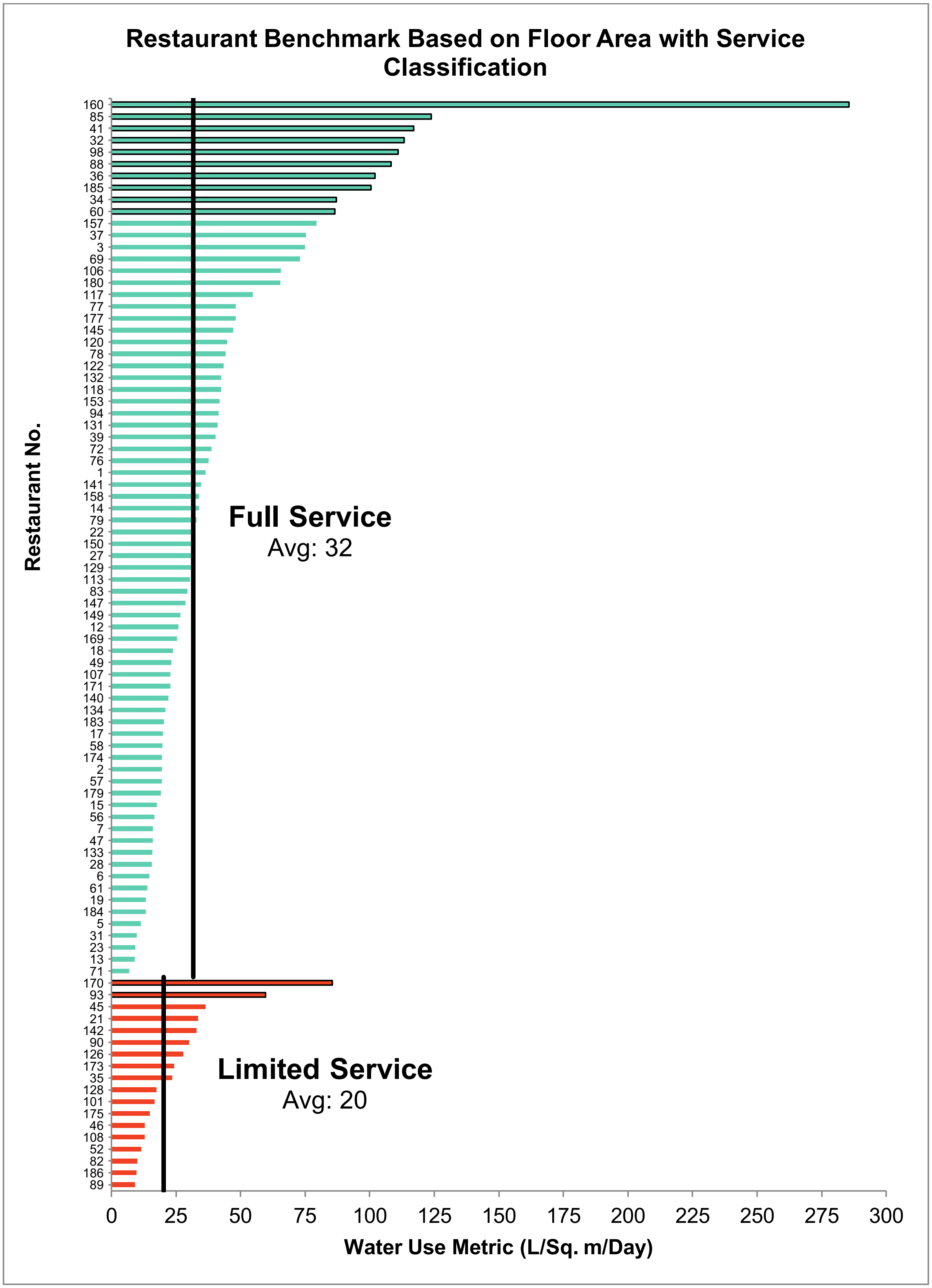

Figure 12: Restaurant Benchmark with Service Classification Based on Floor Area

COMPARISON WITH OTHER STUDIES

The resulting benchmark for the restaurants is similar to the benchmarks from other sources (see Table 1) and the comparison is shown in Figure 13 below. However, there was a difference in the restaurant classifications used in other studies. Most of other studies were focused on the water benchmarking of full service restaurants, except for the AWWA's study in 2000[63], in which both full service and limited service restaurants were used. In the St. Johns River's study in 2010[64], the restaurant classification used in the analysis is not defined.

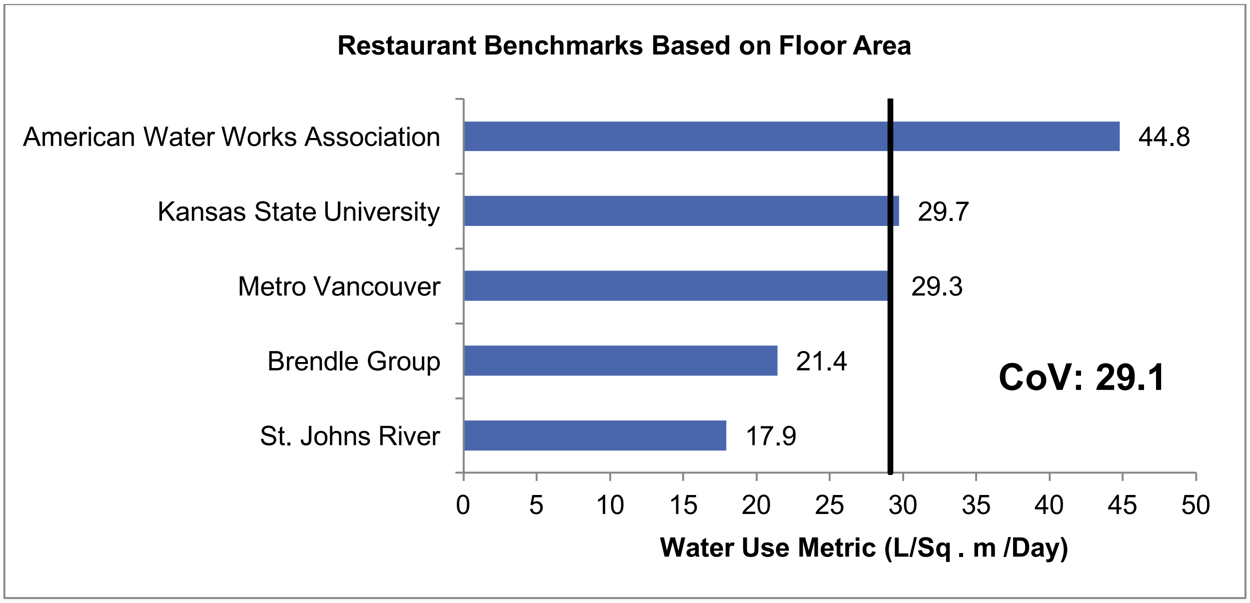

Figure 13: Comparison of Restaurant Benchmark to Other Studies Based on Floor Area

SEASONAL T-TEST

Paired T-Tests were run among all seasons: winter; spring; summer (refer to Appendix C). Significant differences were found between summer and all the other seasons (Winter-Summer, $p \leq 0.00378$; Spring-Summer, $p \leq 0.00012$). There were no significant differences between spring and winter ($p \leq 0.87274$).

4.1.2 SEATING CAPACITY

Table 7 below presents a summary of the results for the seating capacity metric for restaurant classification and service classification. Similar to the floor area metric result, the water use in the Chinese sub-category is higher than the rest of the other sub-categories (see Figure 14). There is no bakery sub-category for the seating capacity metric since none of the bakeries had seating

[63] Dziegielewski. 2000

[64] Jones Edmunds, 2011

capacity information. The fast food and café sub-categories, and limited service classification have higher benchmark results because they have smaller maximum seating capacity, which results in a higher water use metric, as shown in Figure 14 and 15). The average seating capacity for limited service restaurants is 62 seats and the average seating capacity for full service restaurants is 106 seats.

Table 7: Summary of Restaurant Benchmark Result with Sub-Categories Based on Seating Capacity

		Restaurant Types Classification					Service Classification	
	All	Fast Food	Café	Chinese	Asian	Other	Limited service	Full service
	Unfiltered Data							
Average (L/Seat/Day)	116	130	102	207	99	84	130	114
Median (L/Seat/Day)	84	116	91	163	78	69	116	79
Sample Size	142	18	11	24	34	55	18	124
	Filtered Data							
Lower Bound for Filtered Data	4	71	46	8	0	28	71	-4
Upper Bound for Filtered Data	228	189	158	406	198	141	189	231
Average (L/Seat/Day)	**87**	**123**	**92**	**159**	**78**	**69**	**123**	**82**
Sample Size	127	13	9	22	32	44	13	110

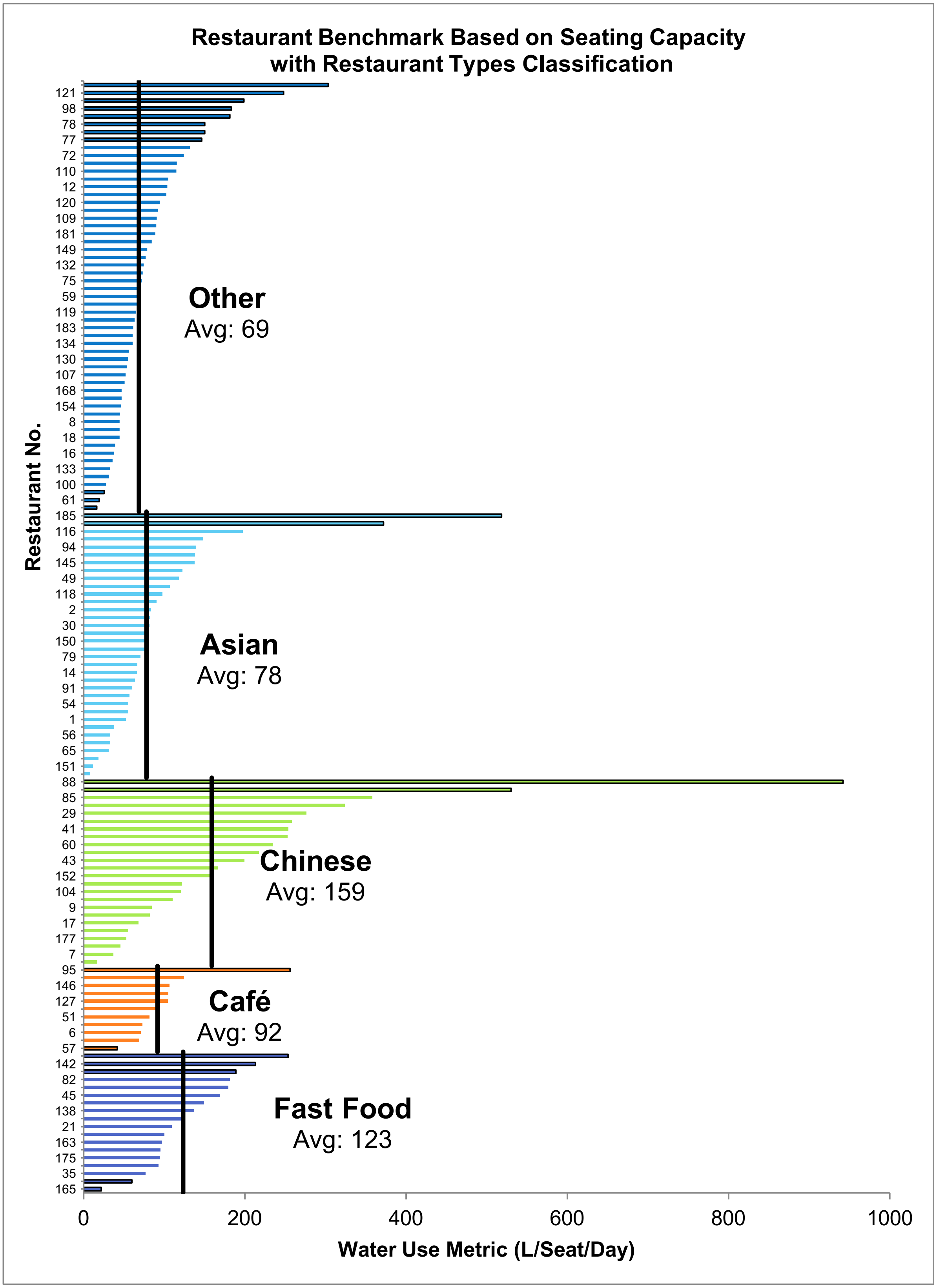

Figure 14: Restaurant Benchmark with Restaurant Classification Based on Seating Capacity

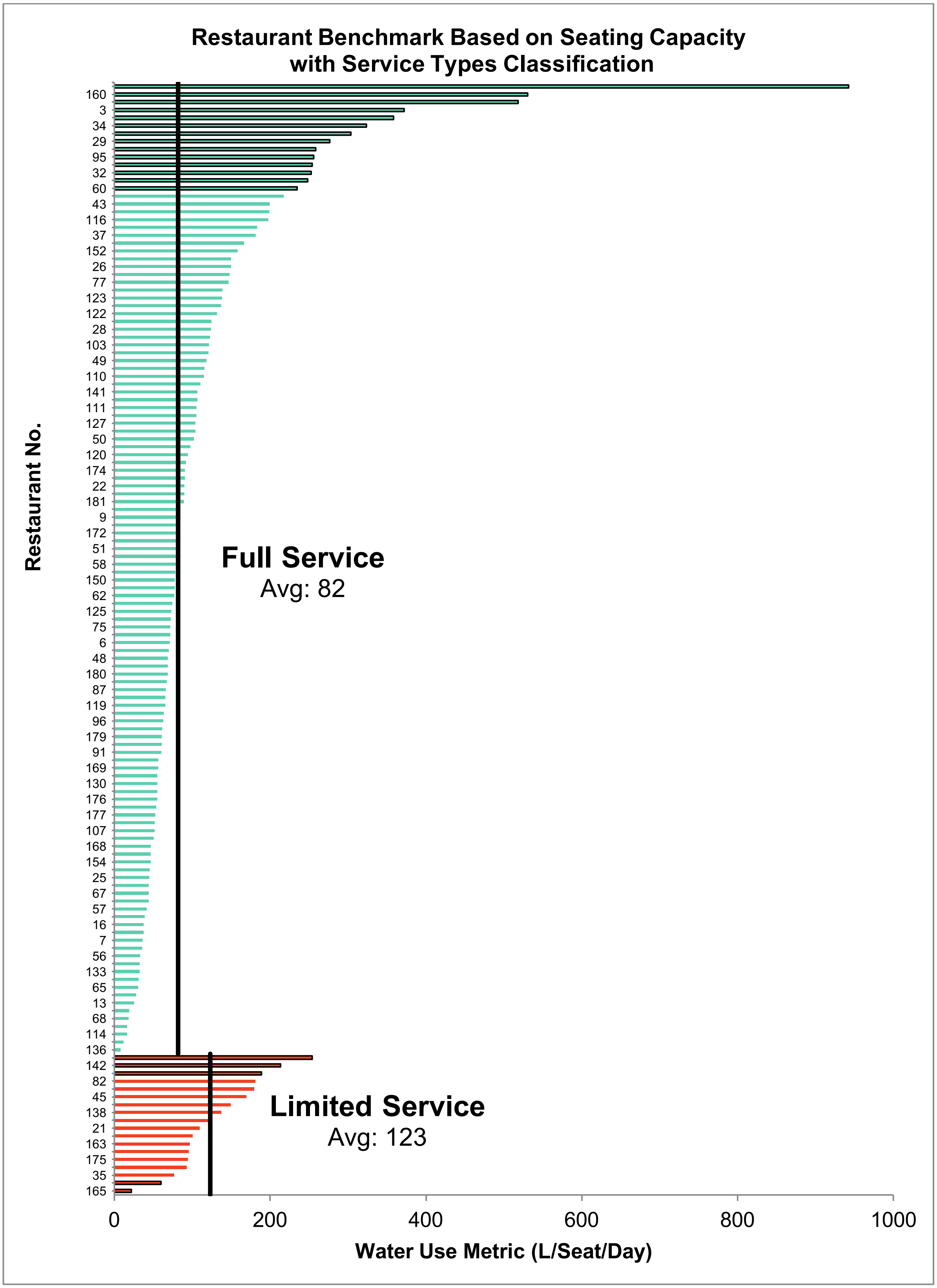

Figure 15: Restaurant Benchmark with Service Classification Based on Seating Capacity

COMPARISON WITH OTHER STUDIES

The resulting benchmark for the restaurants lies within the range of the benchmarks from other sources (see Table 2) and the comparison is shown in Figure 16 below. Within this figure, the City of Vancouver's benchmark includes all restaurants in the study. However, the benchmarks from other sources were calculated using only full service restaurants. If only full service restaurants were used for the calculation, the City of Vancouver's benchmark changes from 87.1 to 81.6 L/Seat/Day.

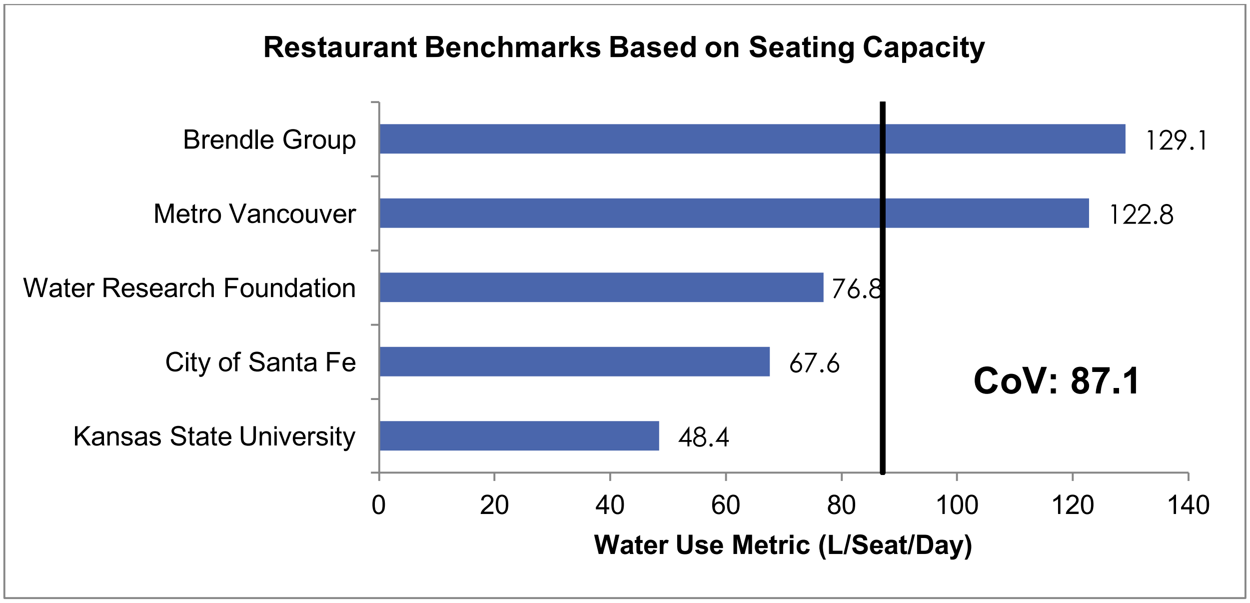

Figure 16: Restaurant Benchmark Based on Seating Capacity with Comparison to Other Studies

SEASONAL T-TEST

Paired T-Tests were run among all seasons: winter; spring; summer (refer to Appendix C). Significant differences were found between summer and all the other seasons (Winter-Summer, $p \leq 0.000013$; Spring-Summer, $p \leq 5.9 \times 10^{-9}$). There were no significant differences between spring and winter ($p \leq 0.70146$).

4.2 MICROBREWERIES

The summary of the microbrewery benchmarking study results for both unfiltered and filtered data are shown in Table 8. Table 8 shows the benchmark (or the average), the median, the standard deviation, as well as the guideline for best practice range and excessive range for water use in the benchmarked microbreweries. The results under the filtered data columns are the ones in which outliers were removed due to an extremely higher or lower water usage than the remaining data. Figure 17 shows the water used per beer produced (Or Water Ratio). For Figure 17 and 18, outliers that were removed from are highlighted in black outline.

Table 8: Summary of Microbrewery Benchmark Result

	Water Ratio	
	Unfiltered Data	Filtered Data
Sample Size	18	13
Unit	**m^3 of Water Used/m^3 of Beer Produced**	
Benchmark	**14.5**	**11.7**
Median	12.2	10.7
Standard Deviation	6.9	3.2
Excessive Use Value	19.4	14.3
Best Practice Value	9.6	9.1

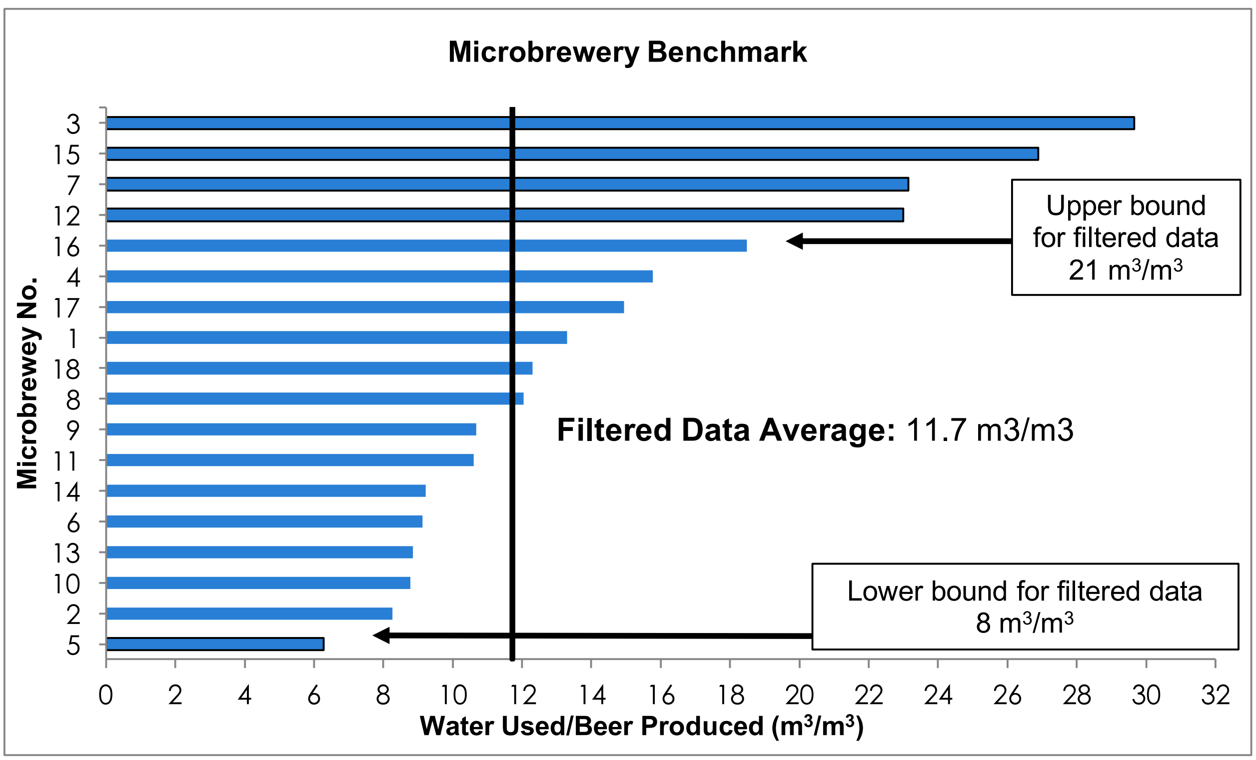

Figure 17: Microbrewery Benchmark

The summary of the microbrewery benchmarking results based on microbrewery sub-categories are shown in Table 9. Most of the brewpubs share a building with other tenants, and only one brewpub has its own water meter, which is microbrewery no. 1 (highlighted in orange). Most microbreweries serve beer flight and snacks which may affect the amount of water usage. The microbreweries that do not serve any snacks are highlighted in light green in Figure 18.

Table 9: Summary of Microbrewery Benchmark Result with Sub-Categories

		Microbrewery Classification		
	All	Brewpub	Microbrewery & Not Shared	Microbrewery & Shared
	Unfiltered Data			
Average (m^3/m^3)	15	16	8	17
Median (m^3/m^3)	12	15	9	12
Sample Size	18	7	4	7
	Filtered Data			
Lower Bound for Filtered Data	8	10	7	8
Upper Bound for Filtered Data	21	22	10	25
Average (m^3/m^3)	**12**	**16**	**9**	**12**
Sample Size	13	7	4	5

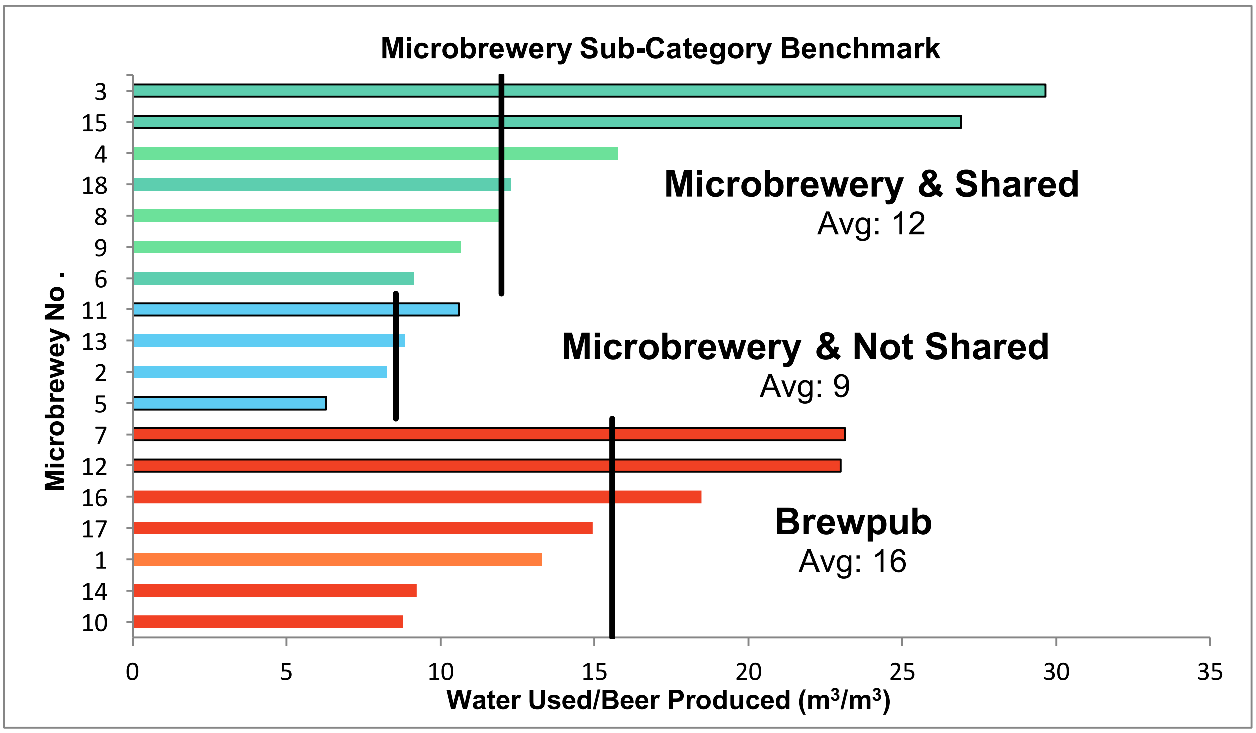

Figure 18: Microbrewery Benchmark with Microbrewery Classification

Table 10: Labels for Microbrewery Benchmark with Microbrewery Classification (Figure 18)

Brewpub		Microbrewery & Not Shared	Microbrewery & Shared	
Shared	Not Shared	Serve beer flight and snacks	Serve beer flight and snacks	Not serve beer flight and snacks

5.0 DISCUSSIONS

The main purpose of this report was to develop benchmarks for water usage for restaurants and microbreweries in the City of Vancouver. Research conducted for this study did not find any other study of water use in the restaurant industry in the City. Two benchmark values for restaurants were developed based on floor area and seating capacity. For microbreweries, a benchmark value based on beer production was developed. These benchmarks support two main key drivers of this report: (1) the Greenest City 2020 Action Plan and (2) definition of water operating cost in tenant lease agreements for the City's Real Estate department.

To support the Greenest City Action Plan, the benchmarking study gives the City a better understanding of water use in restaurants and microbreweries, and can be used as a starting point in the development of water efficiency and water use reduction strategies. The benchmarking results for restaurants were 29.1 L/Sq. m./Day and 87.1 L/Seat/Day. The benchmarking result for microbreweries was 11.7 m^3 of beer produced per m^3 of water used. These benchmark values and excessive water use values were used to identify restaurants and microbreweries that consume larger amounts of water compared to their peers. The City can potentially utilize and strategize water usage policies and compliance measures for these identified establishments to greatly reduce their water usage. Also, the best practice values can be used to identify restaurants and microbreweries that consume smaller amounts of water compared to their peers. Operational practices and technologies from water efficient establishments can be incorporated into the City's polices and strategies to increase water efficiency and conservation in restaurants and microbreweries sectors.

This benchmarking study will support the City's Real Estate Department by defining the water operating costs in tenant lease agreements of restaurants and microbreweries. Results show the amount water used vary within sub-categories of restaurants and microbreweries. For example, Chinese restaurants used more water, on average, than others as they typically have wok-stations which usually have constantly running water to cool and clean the wok. The benchmarking result for Chinese restaurants were 85 L/Sq. m./Day and 159 L/Seat/Day. The results also showed that the fast food sub-category used relatively less water (23 L/Sq. m./Day), compared to other sub-categories when using the floor area metric, as they serve food on take away containers and do not require dishwashing facilities. However, they used more water when using the seating capacity metric (123 L/Seat/Day) as they have smaller number of seats and possibly have higher turnover rate. The difference in the result of the two metrics shows the importance of selecting appropriate metrics for the benchmarking study. As there was limited available data that could be used in this study, only floor area and seating capacity were used as metric. To account for turnover, other metric such as meal served or number of customer could be used as metrics in future water benchmarking studies. For microbreweries, the brewpub sub-category had a higher water benchmark (16 m^3/m^3) than the microbrewery sub-category (12 m^3/m^3) as brewpubs that have food service consume additional amounts of water.

These benchmarks values were also compared with other studies which were outlined in section 2.4. For the restaurant benchmark based on floor area, the City of Vancouver's benchmarking result of 29.1 L/Sq. m./Day were used for the comparison to other studies (refer to Figure 13), which varied from 17.9 to 44.8 L/Sq. m./Day. For the City of Vancouver's benchmarking result for full service restaurants, 81.6 L/Seat/Day was used for the comparison to other studies which were studies of full service restaurants (refer to Figure 16) and varied from 48.4 to 129.1 L/Seat/Day. There is a large range in these studies' benchmark result for both floor area and seating capacity and it cannot be concluded that the City of Vancouver restaurants are more or less water efficient than those benchmarked in other studies due to several factors:

- Different approaches were used in the benchmarking analysis.
- Different restaurant types were used in some of other studies.
- The sample size used for these studies varies from 4 to 302 restaurants.
- The other benchmarking studies were performed at different locations which may have climatic differences.

For microbrewery benchmark, it was not possible to directly compare all the benchmarks produced by the studies because of the limited information on brewery types used and benchmarking approaches in the analysis.

There are a number of areas where further work is required to refine this benchmarking study, such as:

- Restaurant outliers that had excessive water use, account for around 13% and 11% of the total sample size for floor area and seating capacity, respectively. Additional investigation is required, such as field review, of these restaurants to determine the cause of their high water use.
- There were several restaurants that have lower water use compared to other restaurants within the same sub-category. These restaurants account for around 5-10% of the sample size of each sub-category. Field review is required to understand how these restaurants operate efficiently and what kitchen technologies they use. This knowledge will aid the City's Water Design Department in developing future policies and strategies to improve the water efficiency of restaurants.
- For the microbreweries benchmarking analysis, ones that had excessive water use accounted for around 22% of the total sample size and others that had low water use accounted for around 5% of the total sample size. To increase the reliability of the statistical results of microbreweries, increasing the sample size to include all of the City's microbreweries would be beneficial. This would require site visits to verify the consumption and operational practices of each establishment.
- Another recommendation for future study is to analyze other categories of the ICI sector, such as office buildings and educational facilities, to gain a greater understanding of how the ICI sector uses water.

6.0 LIMITATIONS

This section describes difficulties and limitations in performing this benchmarking study for restaurants and microbreweries.

6.1 RESTAURANTS

There are several difficulties and limitations to the restaurant water use benchmarking study:

1. The selection of suitable restaurants for the analysis was one of the obstacles in the study. Numerous verifications were required to ensure that the water was only used by the restaurant so that the benchmark could produce meaningful results. This proved to be a time consuming task.

2. Sub-categorization identification was based on technologies used in the kitchen, such as wok-station and dishwashing facility, and the table-service, but it was not possible to verify most of the restaurants used in the study.

3. Due to the skewed water use metric, the average may not be the best calculation for the benchmark value. In this case, exclusion of outliers is required. Comparison to the median is also recommended.

4. Seating capacity does not describe the effect of the table turnover rate. For example, some restaurants may have high maximum seating capacity but they do not have as many customers. Some restaurants may have low maximum seating capacity but they have a large turnover rate as well as takeaway service. In theory, the turnover rate could greatly affect the amount of water used.

5. This study did not analyze the effect of restaurant's operating hour on the daily water use. The operating hours may greatly affect the water use in restaurants as the operating hours of the restaurants used in this study varied from 4 to 24 hours.

6. This study did not analyze the effect of a restaurant's location to the daily water use. Restaurants located in busier locations of the City may have higher turnover rates than those located in less busy locations.

6.2 MICROBREWERIES

There are several difficulties and limitations to the microbrewery water use benchmarking study:

1. There are not many microbreweries for the study, so some microbreweries that lease space in shared tenant building were used in the analysis. It was difficult to determine the microbrewery's actual water usage as sub-meter data is not available. This likely lowered the benchmarked water efficiency for some microbreweries used in the analysis.

2. This study did not analyze the effect of the scale of beer production. Breweries with a higher production volume may use less water for cleaning and sanitization as they tend to produce fewer types of beer. The smaller breweries tend to continuously switch between recipes, which requires more cleaning, and changes in packaging[65].

[65] Brewers Association, 2015

7.0 CONCLUSIONS

This report introduced a general benchmarking study for measuring water-use performance of a ICI user in the City of Vancouver. The benchmarking study was performed on two ICI water users, restaurants and microbreweries. The benchmarking study for restaurants was divided into two main analyses based on floor area and seating capacity. The benchmarking study for microbreweries was based on beer production. Water usage was obtained from internal water data for each sampled restaurant and microbrewery. Data from floor area, seating capacity, and beer production also was obtained from internal City sources. The dataset used for this study was 152 restaurants and 18 microbreweries. The benchmark values were represented by average value and the criteria for filtering outliers was based on the standard deviation of each respective dataset. The table below summarizes this benchmarking findings.

The City of Vancouver's benchmarking result for restaurants were 29.1 L/Sq. m./Day and 87.1 L/Seat/Day. The result for the restaurant classification shows that Chinese restaurants have the largest benchmark value. Whereas, bakeries have the smallest benchmark value for the floor area metric and other restaurants sub-category has the smallest benchmark value for seating capacity metrics. The difference between limited and full service restaurants in these results may be due to the fact that limited service restaurants have a smaller number of seats as they mainly focus on the takeaway service. Paired t-tests were performed to analyze the effect of seasons on the water usage. The results show that water use in the summer is different than the water use in other seasons. Higher seasonal water use was found in the summer months which may be due to more customers, tourists, or in rare cases, irrigation.

Table 11: Summary of Restaurant Benchmark Result

		Restaurant Classification						Service Classification	
	All	Fast Food	Bakery	Café	Chinese	Asian	Other	Limited service	Full service
	Based on Floor Area (Filtered Data)								
Average (L/Sq. m/Day)	29	23	11	17	85	31	31	20	32
	Based on Seating Capacity (Filtered Data)								
Average (L/Seat/Day)	87	123	n/a	92	159	78	69	123	82

The City of Vancouver's benchmarking result for microbreweries were 11.7 m^3 of beer produced per m^3 of water used. The result for the brewery classification shown that brewpub has the higher benchmark values of 16 m^3/m^3 than the benchmark of microbrewery (12 m^3/m^3). Most microbreweries used in this analysis shared the building with other businesses, likely resulting in higher benchmarked water usage.

The results of this study can be used by the City of Vancouver's Water Design Branch and Real Estate and Facilities Management Branch to strategically plan water use polices for restaurants and microbreweries to reduce their water usage. Some specific water use measures that these policies may incorporate are water conservation activities, and improvement of technologies and equipment.

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APPENDICES

Appendix A: Restaurant List

Appendix B: Metrics-Water Use Correlation for Restaurant

Appendix C: Restaurant Seasonal for T-Test

Appendix D: Beer Production-Water Use Correlation for Microbrewery

Appendix A Restaurant List

No.	Seat	Floor area (ft2)	Type of Restaurant	Suitable for benchmarking?
1	157	2400	Malaysian	Suitable for benchmarking
2	111	5100	Middle Eastern	Suitable for benchmarking
3	30	1600	Japanese	Suitable for benchmarking
5	16	1600	Tea and dessert	Suitable for benchmarking
6	48	2500	Coffee shop and all-day breakfast	Suitable for benchmarking
7	82	2000	Chinese	Suitable for benchmarking
8	114		Chain restaurant	Suitable for benchmarking
9	64		Chinese - Noodles	Suitable for benchmarking
12	163	7000	Mexican	Suitable for benchmarking
13	67	2000	Brunch	Suitable for benchmarking
14	72	1500	Thai	Suitable for benchmarking
15	82	1800	Italian	Suitable for benchmarking
16	200		Pub	Suitable for benchmarking
17	110	4000	Chinese	Suitable for benchmarking
18	334	6696	Chain restaurant	Suitable for benchmarking
19	230	6000	Japanese	Suitable for benchmarking
20	80		Malaysian	Suitable for benchmarking
21	80	2800	Fast food	Suitable for benchmarking
22	50	1500	Vietnamese	Suitable for benchmarking
23	25	1125	Italian - Pizza	Suitable for benchmarking
25	100		Chinese	Suitable for benchmarking
26	96		Canadian	Suitable for benchmarking
27	136	2650	Burger/salad	Suitable for benchmarking
28	16	1370	Dessert	Suitable for benchmarking
29	118		Chinese	Suitable for benchmarking
30	70		Thai	Suitable for benchmarking
31	90	1620	Spanish	Suitable for benchmarking
32	75	1800	Chinese	Suitable for benchmarking
34	75	3000	Chinese	Suitable for benchmarking
35	80	2800	Fast food	Suitable for benchmarking
36	25	800	French	Suitable for benchmarking
37	27	700	Italian	Suitable for benchmarking
39		700	Pub	Suitable for benchmarking
40	40		Vietnamese	Suitable for benchmarking
41	120	2800	Chinese	Suitable for benchmarking
42	206		Chinese	Suitable for benchmarking
43	217		Chinese	Suitable for benchmarking
45	60	3000	Fast food	Suitable for benchmarking
46		2000	Bakery	Suitable for benchmarking
47	120	2500	Italian	Suitable for benchmarking
48	50		Coffees, gelato & sandwiches	Suitable for benchmarking
49	30	1642	Japanese	Suitable for benchmarking
50	30		Ethiopian food	Suitable for benchmarking
51	50		Coffee	Suitable for benchmarking
52		7000	Bakery	Suitable for benchmarking
54	98		Vietnamese	Suitable for benchmarking
56	94	2000	Japanese	Suitable for benchmarking
57	104	2400	Coffee and donut	Suitable for benchmarking
58	60	2600	Japanese	Suitable for benchmarking
59	97		Comfort food	Suitable for benchmarking
60	120	3500	Chinese	Suitable for benchmarking
61	169	2500	Pizza & steaks	Suitable for benchmarking
62	100		Comfort food	Suitable for benchmarking
64	80		Vietnamese	Suitable for benchmarking
65	87		Thai	Suitable for benchmarking
67	56		Greek	Suitable for benchmarking
68	64		Vietnamese	Suitable for benchmarking
69	50	1600	Chinese	Suitable for benchmarking
70	50		Italian - Pizza	Suitable for benchmarking
71	33	2400	Comfort food	Suitable for benchmarking

No.	Seat	Floor area (ft2)	Type of Restaurant	Suitable for benchmarking?
72	55	1900	Comfort food	Suitable for benchmarking
75	40		Italian - Pizza	Suitable for benchmarking
76	120	2800	Chinese	Suitable for benchmarking
77	107	3500	Chain restaurant	Suitable for benchmarking
78	58	2120	American	Suitable for benchmarking
79	48	1100	Vietnamese	Suitable for benchmarking
80	15		Fast food	Suitable for benchmarking
82	14	2740	Fast-food -Vietnamese	Suitable for benchmarking
83	25	1348	Pakistani	Suitable for benchmarking
85	90	2800	Chinese	Suitable for benchmarking
87	70		All you can eat hotpot	Suitable for benchmarking
88	16	1500	Chinese	Suitable for benchmarking
89		2200	Bakery	Suitable for benchmarking
90		2475	BBQ meat	Suitable for benchmarking
91	16		Indian	Suitable for benchmarking
93	10	2000	Bakery	Suitable for benchmarking
94	50	1800	Vietnamese	Suitable for benchmarking
95	16		Coffee	Suitable for benchmarking
96	138		Italian	Suitable for benchmarking
97	206		Fast food	Suitable for benchmarking
98	169	3000	All day dining	Suitable for benchmarking
100	100		Pizza	Suitable for benchmarking
101		3450	Fast food	Suitable for benchmarking
103	64		Chinese	Suitable for benchmarking
104	130	3.8E+07	Chinese	Suitable for benchmarking
106	73	2000	Chinese	Suitable for benchmarking
107	148	3600	Bar	Suitable for benchmarking
108	30	2500	Fast food	Suitable for benchmarking
109	60		Seafood	Suitable for benchmarking
110	142		Steak House	Suitable for benchmarking
111	121		Pub/burger	Suitable for benchmarking
113	189	3024	Fried chicken and bbq	Suitable for benchmarking
114	160		Chinese	Suitable for benchmarking
115	45		Chinese	Suitable for benchmarking
116	64		Japanese	Suitable for benchmarking
117	83	1500	Italian	Suitable for benchmarking
118	109	2691	Korean	Suitable for benchmarking
119	244		Seafood	Suitable for benchmarking
120	139	3150	Pub	Suitable for benchmarking
121	99		Greek	Suitable for benchmarking
122	54	1760	French	Suitable for benchmarking
123	46		Japanese	Suitable for benchmarking
124	132		Chain restaurant	Suitable for benchmarking
125	289		Chain restaurant	Suitable for benchmarking
126		2000	Fast food	Suitable for benchmarking
127	50		café	Suitable for benchmarking
128	59	4500	Fast food	Suitable for benchmarking
129	4	1200	Fish chips & chowder	Suitable for benchmarking
130	340		Steak House	Suitable for benchmarking
131	56	1700	Canadian	Suitable for benchmarking
132	48	900	Italian	Suitable for benchmarking
133	50	1100	Poutine, sandwiches & hot dogs	Suitable for benchmarking
134	24	750	Bar	Suitable for benchmarking
135	152		Fast food	Suitable for benchmarking
136	75		Indian	Suitable for benchmarking
138	90		Fast food	Suitable for benchmarking
140	48	1700	Dessert/Brunch	Suitable for benchmarking
141	100	3300	All you can eat hotpot	Suitable for benchmarking
142	36	2500	Fast food	Suitable for benchmarking
145	96	3000	Vietnamese	Suitable for benchmarking
146	50		café	Suitable for benchmarking
147	44	1400	Brunch	Suitable for benchmarking
149	73	2300	Caribbean	Suitable for benchmarking
150	75	2000	Thai	Suitable for benchmarking
151	50		Vietnamese	Suitable for benchmarking
152	90		Chinese	Suitable for benchmarking
153	80	1850	Bar	Suitable for benchmarking
154	95		Italian	Suitable for benchmarking

No.	Seat	Floor area (ft2)	Type of Restaurant	Suitable for benchmarking?
157	80	2800	Chinese	Suitable for benchmarking
158	70	1200	Bar	Suitable for benchmarking
160	80	1600	Chinese	Suitable for benchmarking
163	98		Fast food	Suitable for benchmarking
165	87		Fast food	Suitable for benchmarking
166	10		Fast food	Suitable for benchmarking
168	136		Burger/salad	Suitable for benchmarking
169	100	2375	Malaysian	Suitable for benchmarking
170	36	812	Fast food	Suitable for benchmarking
171	545	13000	Pub	Suitable for benchmarking
172	76		All you can eat hotpot	Suitable for benchmarking
173	45	3000	Fast food	Suitable for benchmarking
174	50	2500	Bakery & coffee	Suitable for benchmarking
175	48	3285	Fast food	Suitable for benchmarking
176	65		Indian	Suitable for benchmarking
177	680	8000	Chinese	Suitable for benchmarking
179	73	2500	Italian	Suitable for benchmarking
180	257	2889	Steak House	Suitable for benchmarking
181	121		Taco	Suitable for benchmarking
183	92	3000	Italian	Suitable for benchmarking
184	204	6157	Indian	Suitable for benchmarking
185	36	2000	Japanese	Suitable for benchmarking
186	16	3135	Bakery	Suitable for benchmarking
187	17		Fast food	Suitable for benchmarking
4			Pizza	Missing Benchmarking Data
10			dessert	Missing Benchmarking Data
11	63	3000	Comfort food	Not suitable for benchmarking
24	44	1500	Indian	Not suitable for benchmarking
33			coffee	Missing Benchmarking Data
38	100	3000	Brunch	Not suitable for benchmarking
44			Fast food	Missing Benchmarking Data
53	64	1800	Italian	Not suitable for benchmarking
55			Fast food	Missing Benchmarking Data
63	41	900	Brazilian	Not suitable for benchmarking
66	54	1700	French	Not suitable for benchmarking
73	74		Chinese	Not suitable for benchmarking
74	80	2000	Greek	Not suitable for benchmarking
81	25	1150	Vietnamese	Not suitable for benchmarking
84			Fast food	Missing Benchmarking Data
86	90	3000	Chinese	Not suitable for benchmarking
92		3000	Market	Not suitable for benchmarking
99			Fast food	Missing Benchmarking Data
102			Fast food	Missing Benchmarking Data
105	16	1400	Chinese	Not suitable for benchmarking
112	90		Thai	Not suitable for benchmarking
137	70	2200		Not suitable for benchmarking
139	71	2000	Korean	Not suitable for benchmarking
143	51		Japanese	Not suitable for benchmarking
144	80		Chinese	Not suitable for benchmarking
148	16	996	Thai	Not suitable for benchmarking
155	92	3000		Not suitable for benchmarking
156			Fast food	Missing Benchmarking Data
159		1500	Market/tea house	Not suitable for benchmarking
161			Fast food	Missing Benchmarking Data
162			Fast food	Missing Benchmarking Data
164	82		Japanese	Not suitable for benchmarking
167	92	2100	Korean	Not suitable for benchmarking
178	60	6000	Chinese	Not suitable for benchmarking
182	53	1750	coffee	Not suitable for benchmarking

Appendix B Metrics-Water Use Correlation For Restaurant

SEATING CAPACITY

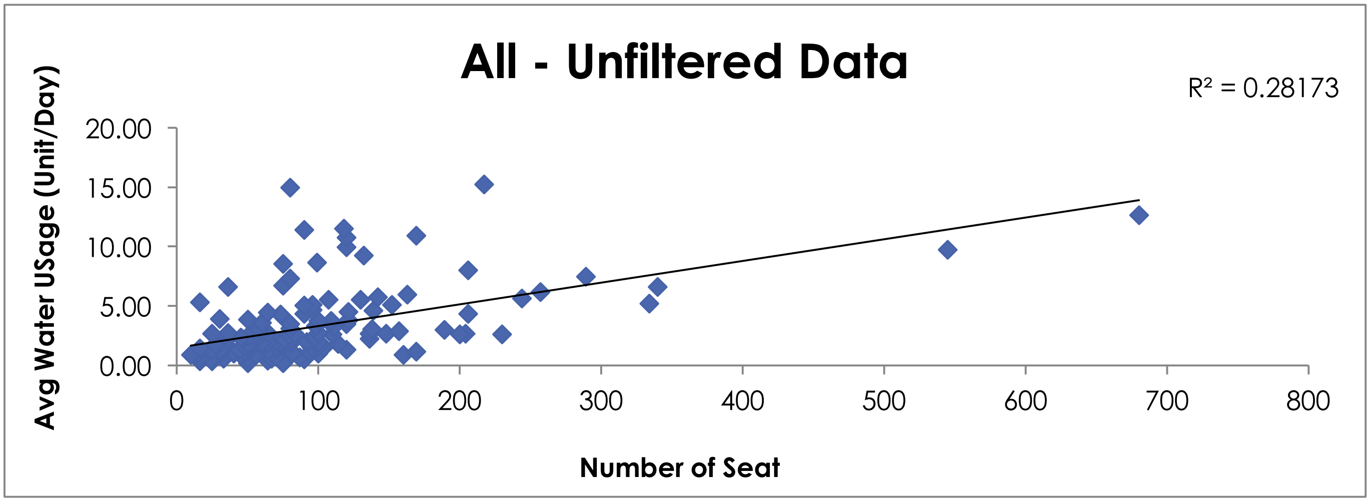

Figure B-1: Correlation between Number of Seat and Water Usage for Unfiltered All Restaurants Data

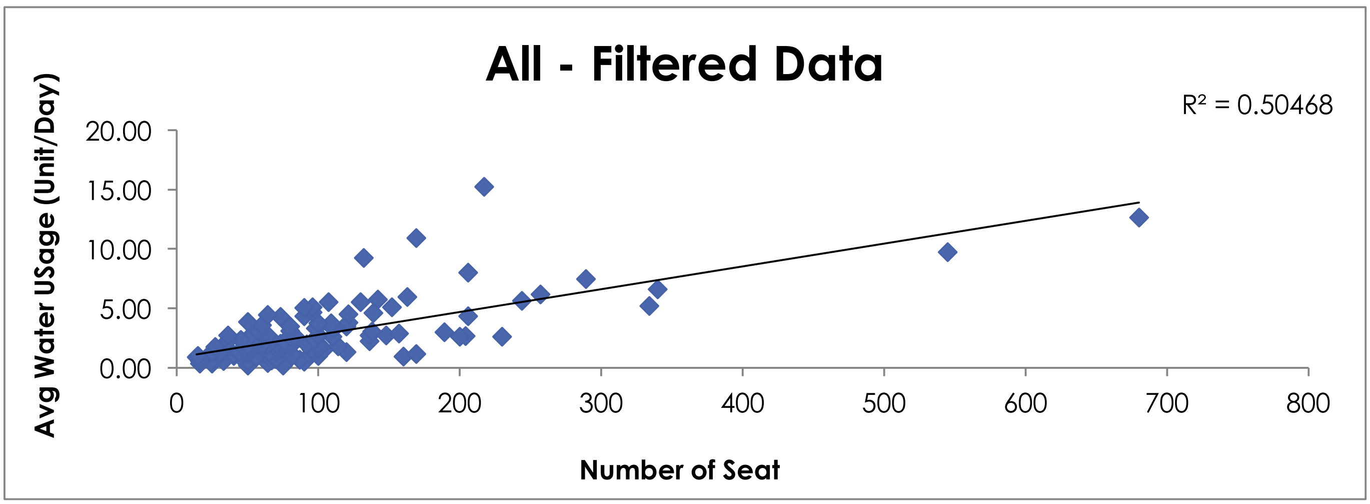

Figure B-2: Correlation between Number of Seat and Water Usage for Filtered All Restaurants Data

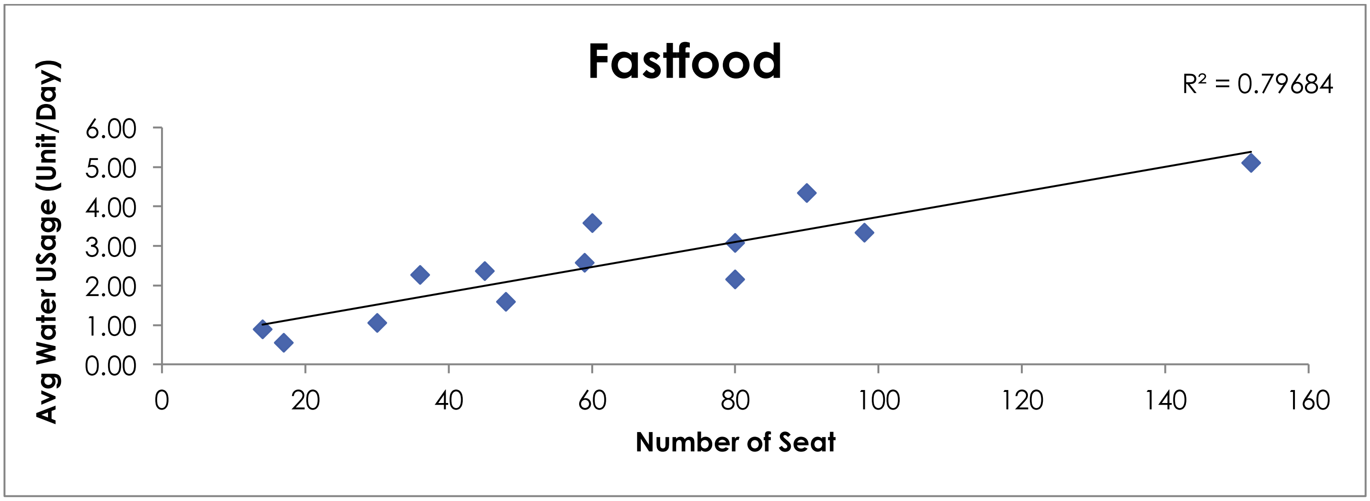

Figure B-3: Correlation between Number of Seat and Water Usage for Filtered Fast Food Data

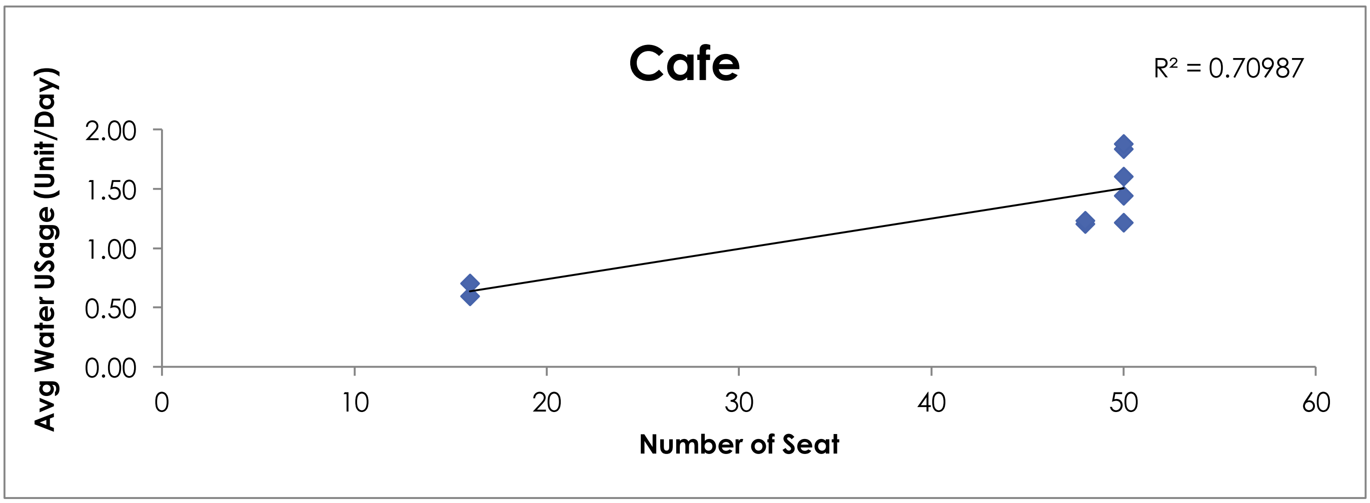

Figure B-4: Correlation between Number of Seat and Water Usage for Filtered Cafe Data

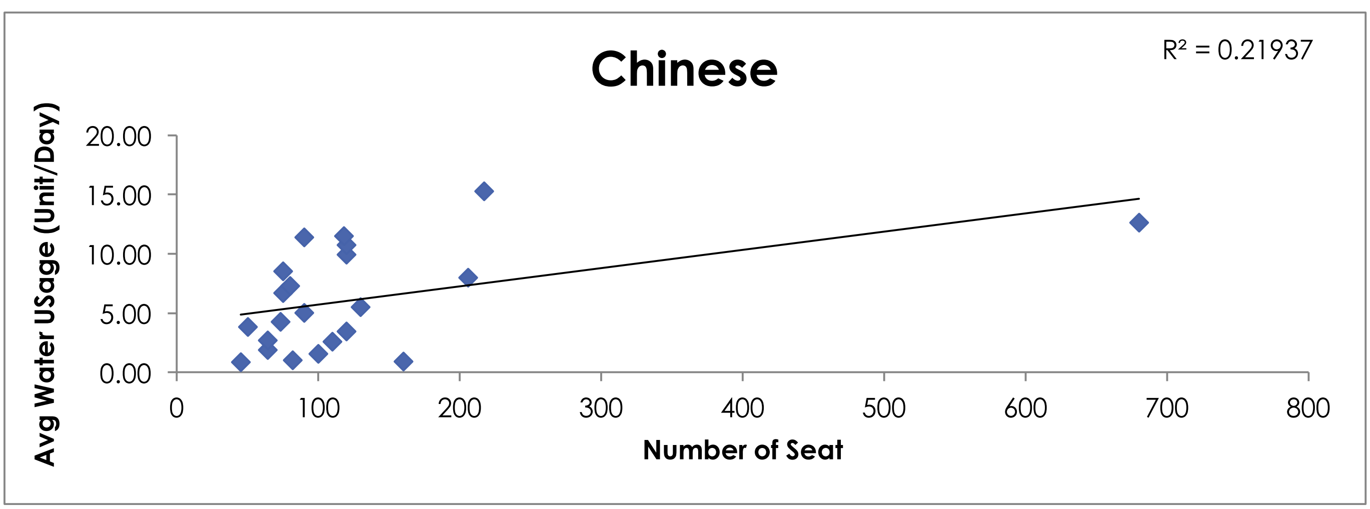

Figure B-5: Correlation between Number of Seat and Water Usage for Filtered Chinese Restaurants Data

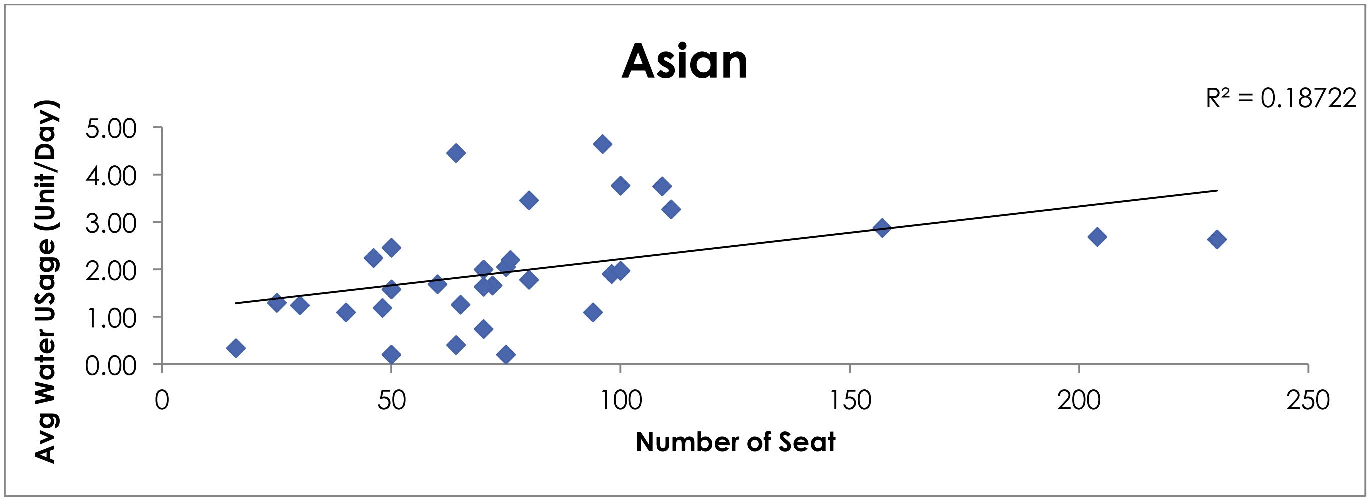

Figure B-6: Correlation between Number of Seat and Water Usage for Filtered Asian Restaurants Data

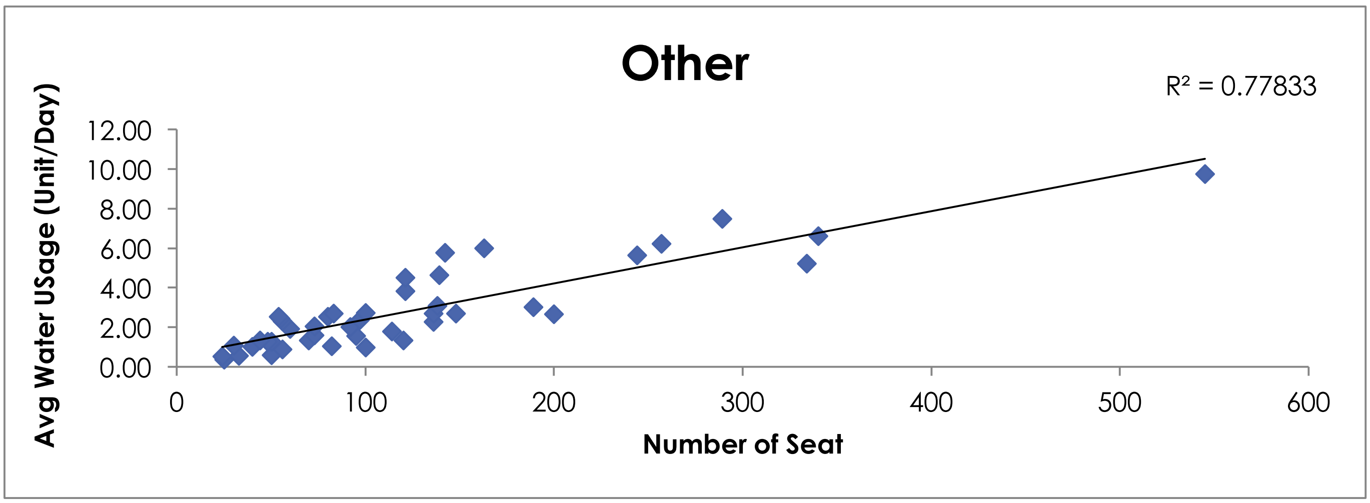

Figure B-7: Correlation between Number of Seat and Water Usage for Filtered Other Restaurants Data

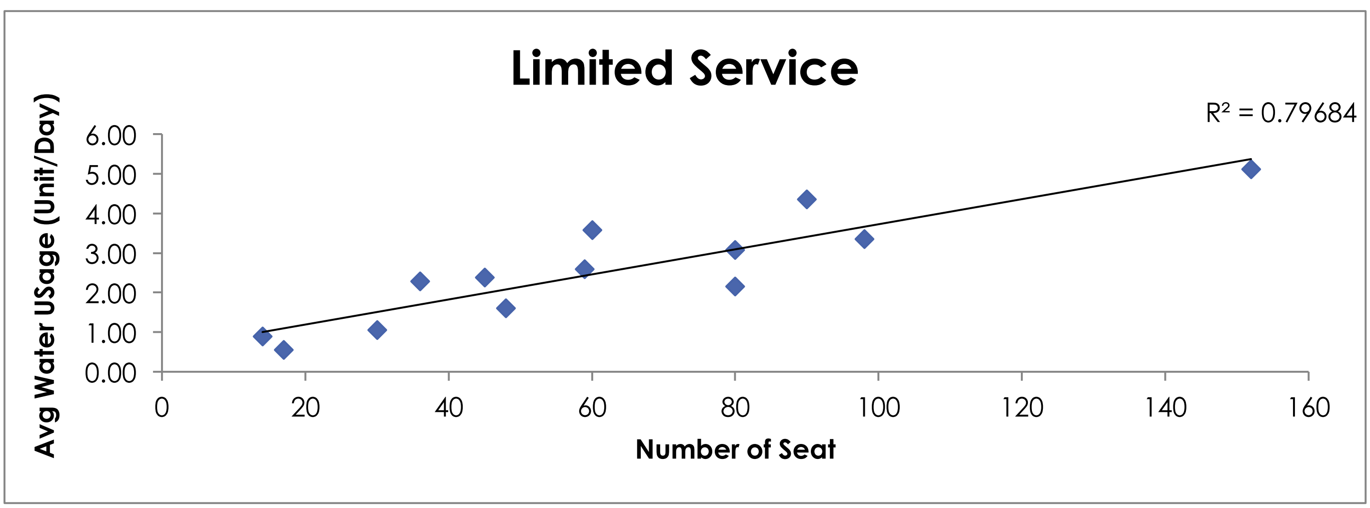

Figure B-8: Correlation between Number of Seat and Water Usage for Filtered Limited Service Restaurants Data

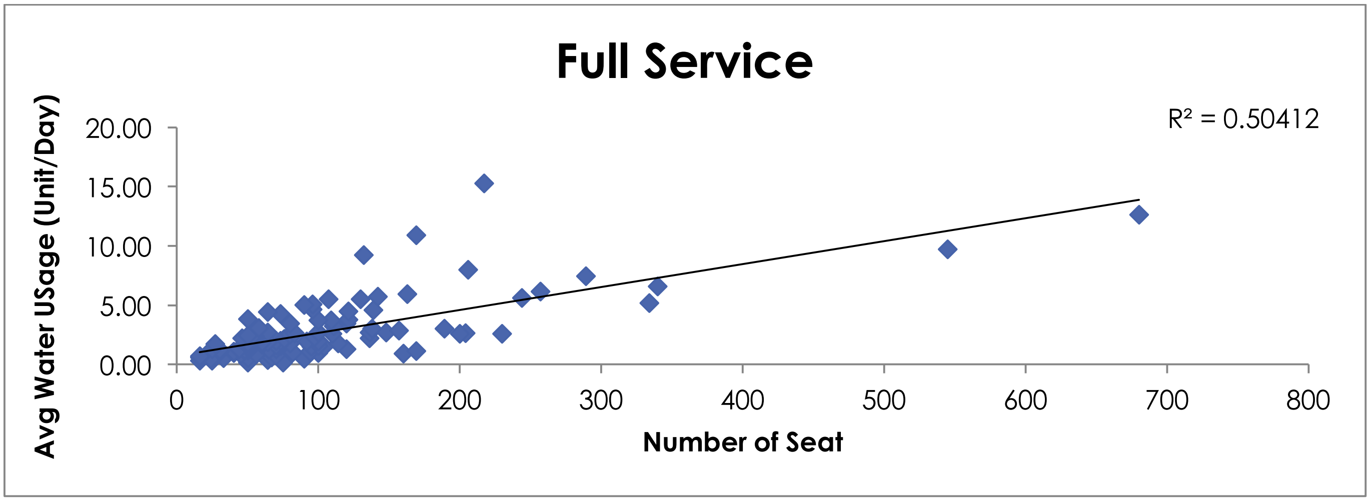

Figure B-9: Correlation between Number of Seat and Water Usage for Filtered Full Service Restaurants Data

FLOOR AREA

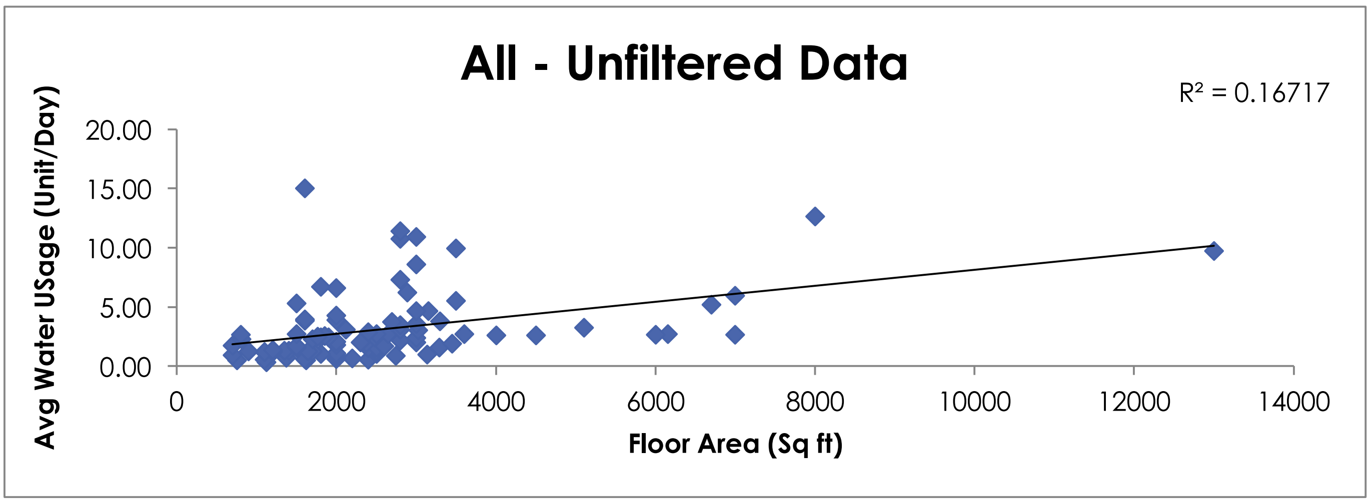

Figure B-10: Correlation between Floor Area and Water Usage for Unfiltered All Restaurants Data

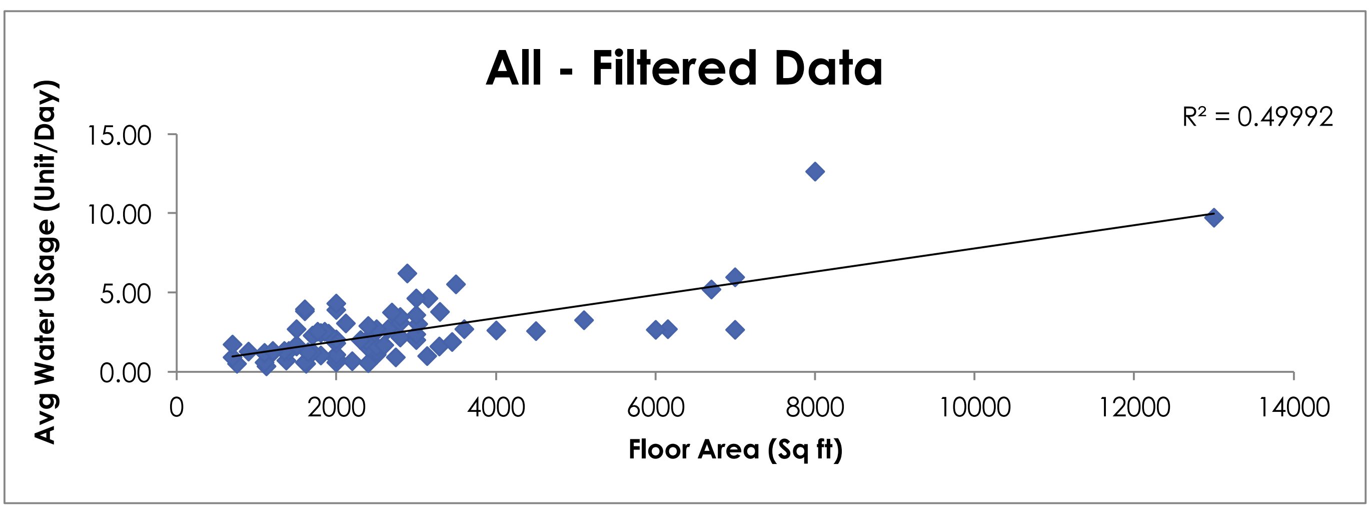

Figure B-11: Correlation between Floor Area and Water Usage for Filtered All Restaurants Data

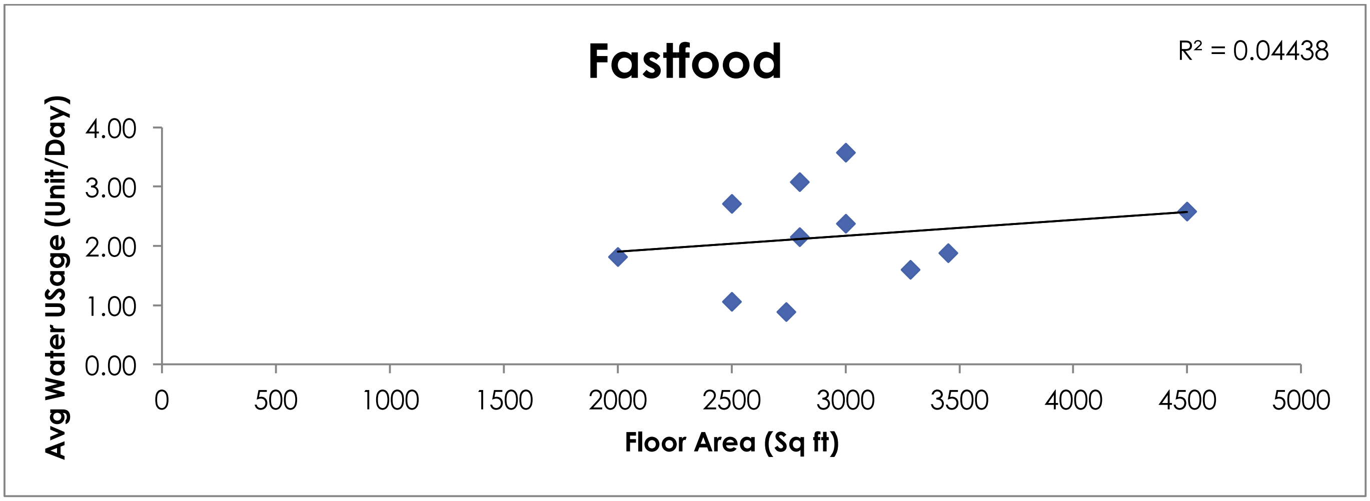

Figure B-12: Correlation between Floor Area and Water Usage for Filtered Fast Food Restaurants Data

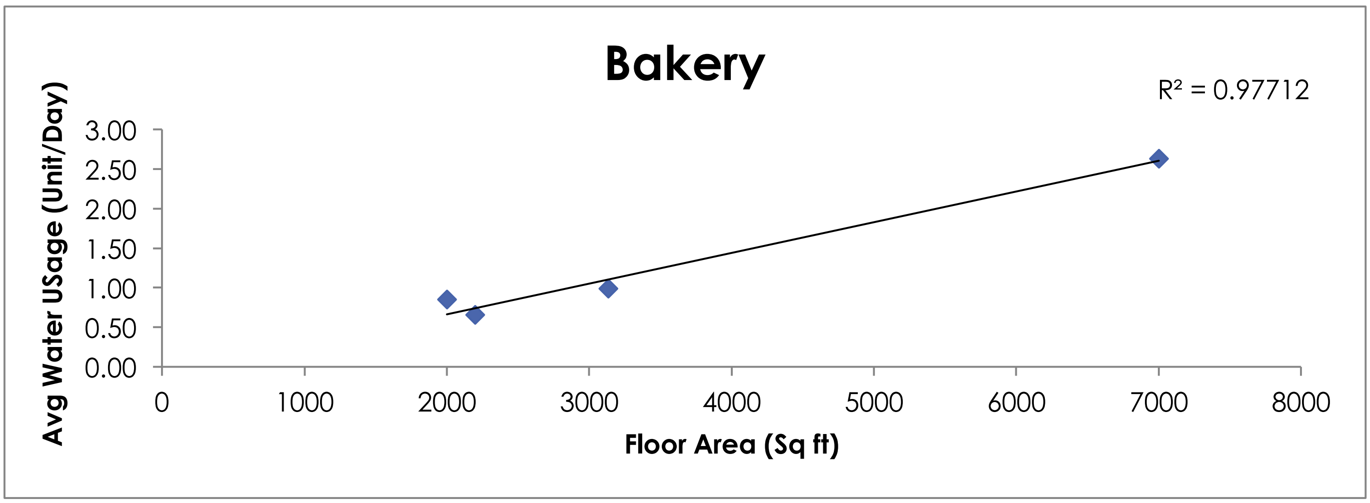

Figure B-13: Correlation between Floor Area and Water Usage for Filtered Bakery Restaurants Data

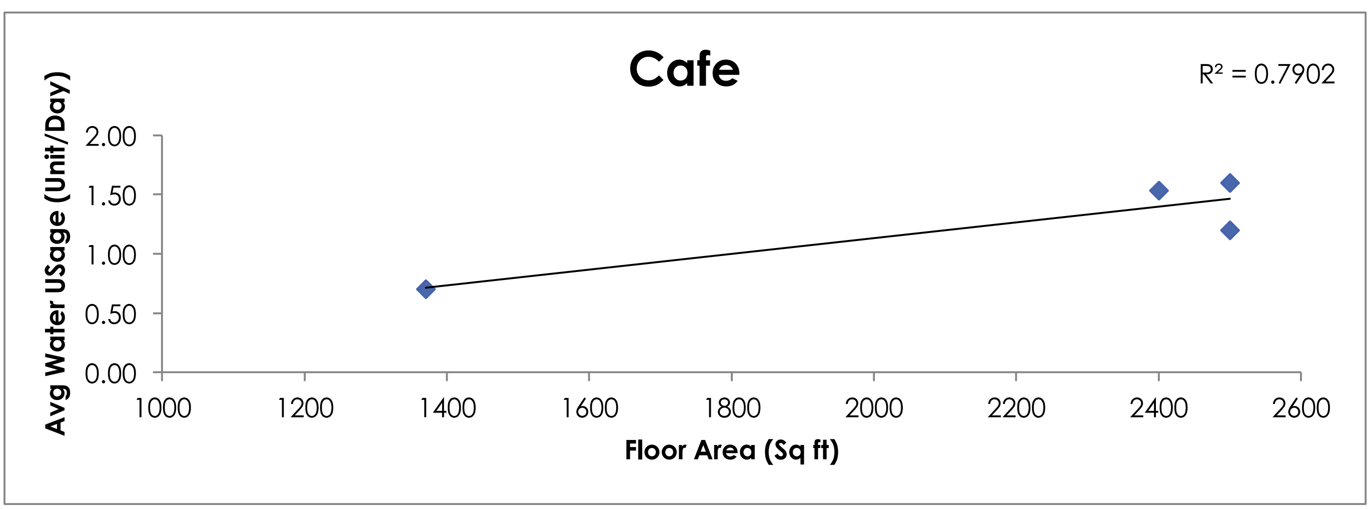

Figure B-14: Correlation between Floor Area and Water Usage for Filtered Café Data

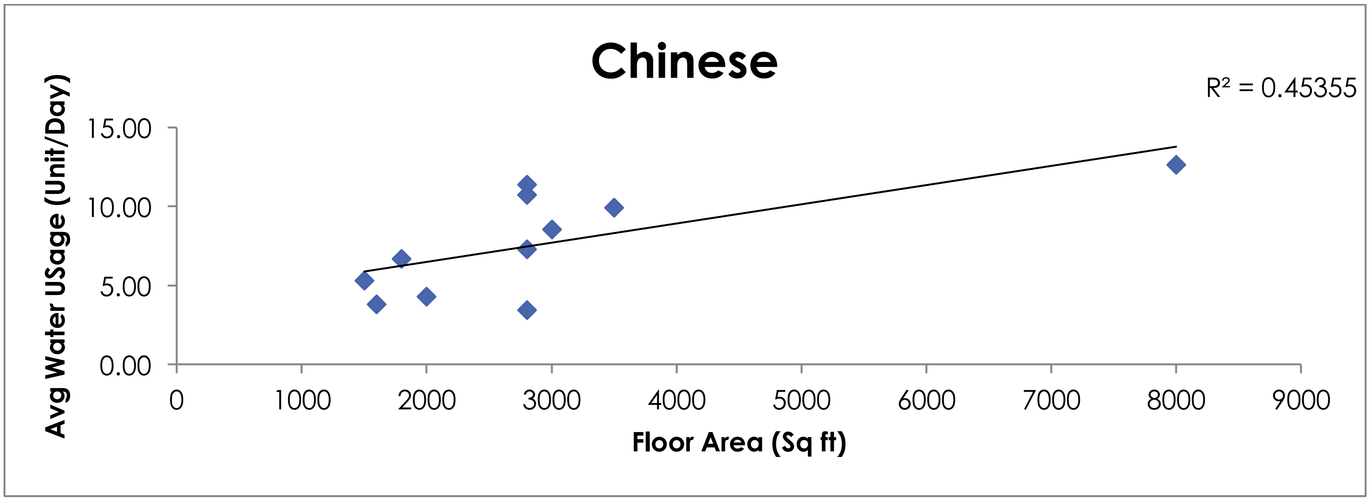

Figure B-15: Correlation between Floor Area and Water Usage for Filtered Chinese Restaurants Data

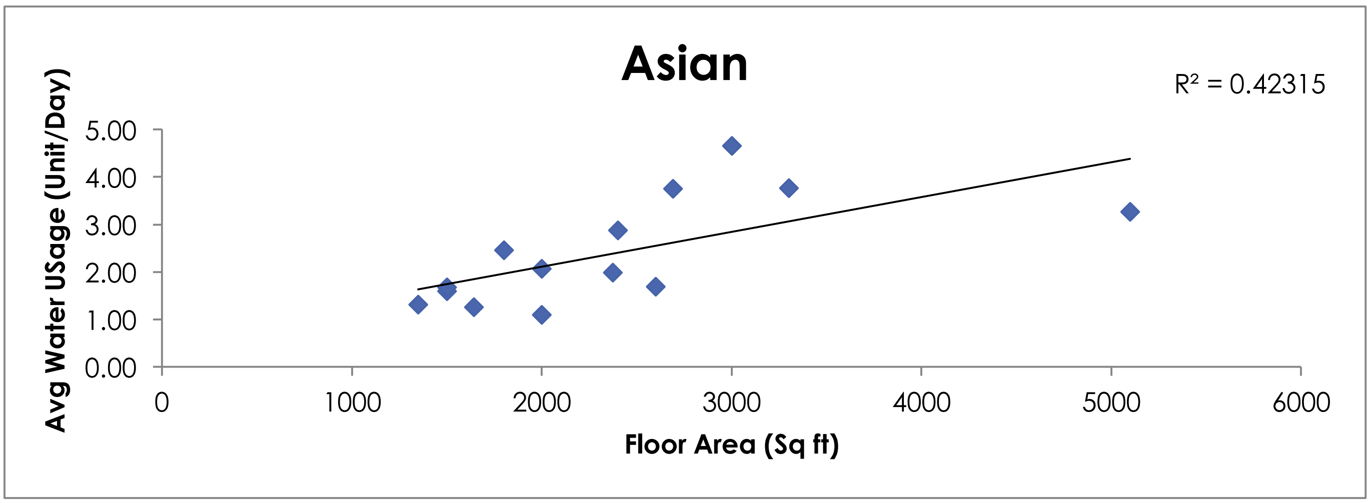

Figure B-16: Correlation between Floor Area and Water Usage for Filtered Asian Restaurants Data

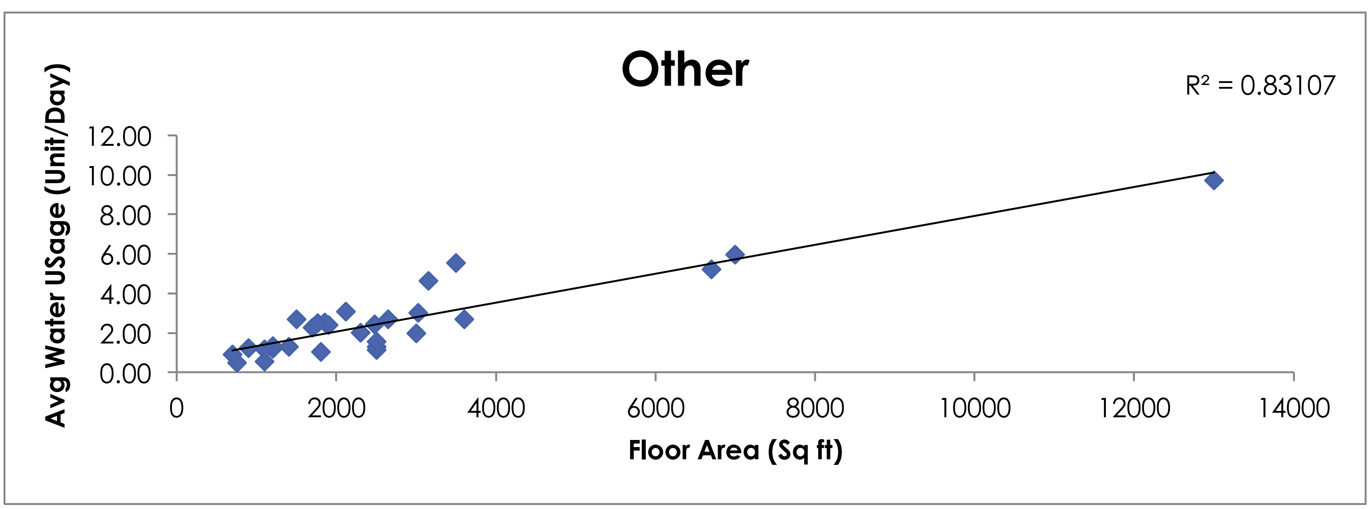

Figure B-17: Correlation between Floor Area and Water Usage for Filtered Other Restaurants Data

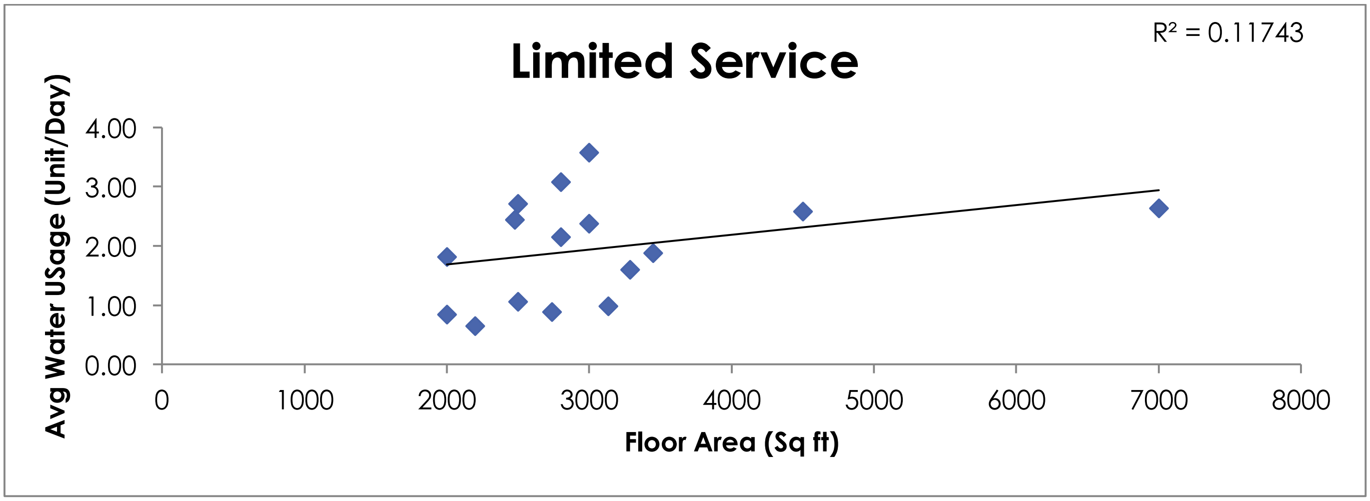

Figure B-18: Correlation between Floor Area and Water Usage for Filtered Limited Service Restaurants Data

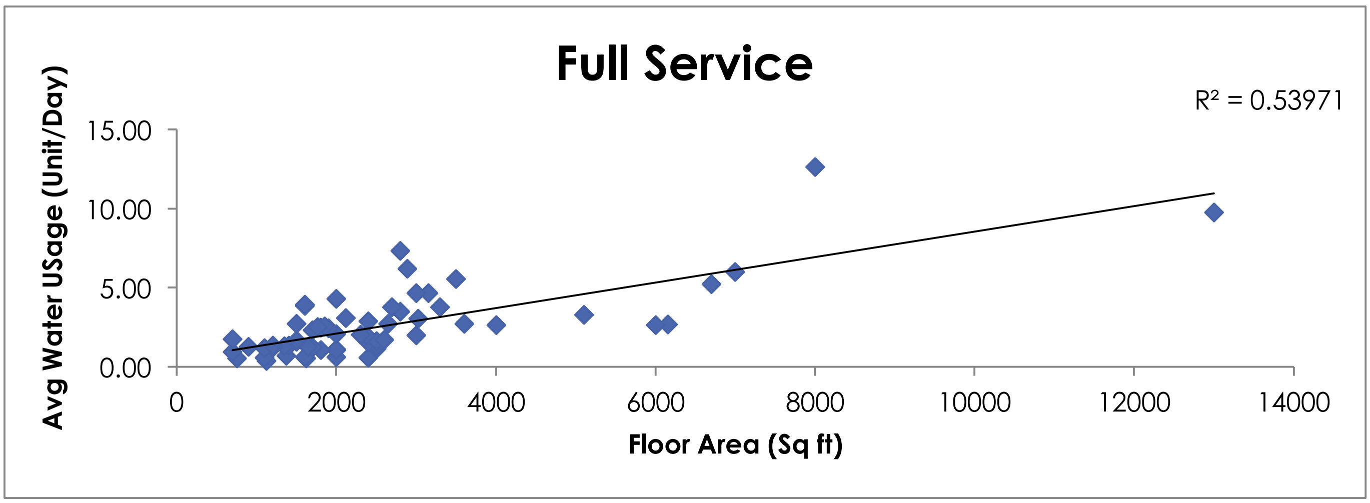

Figure B-19: Correlation between Floor Area and Water Usage for Filtered Full Service Restaurants Data

Appendix C Restaurant Seasonal for T-Test

SEATING CAPACITY

Table C-1: Paired T-Test for Winter and Spring with Seating Capacity Metric

	Winter (Read Pd 1- Read Pd 2)	Spring (Read Pd 3- Read Pd 4)	Comment
Mean	3.0928	3.0655	
Variance	8.7120	8.2337	
Observations	141	141	
Pearson Correlation	0.9583		
Hypothesized Mean Difference	0		
df	140		
t Stat	0.3841		t Stat < t Critical, accept the null hypothesis
P(T<=t) one-tail	0.3507		
t Critical one-tail	1.6558		
P(T<=t) two-tail	0.7015		p – value > 0.05, accept the null hypothesis
t Critical two-tail	1.9771		**There is no significant difference in the means of winter and spring**

Table C-2: Paired T-Test for Winter and Summer with Seating Capacity Metric

	Winter (Read Pd 1- Read Pd 2)	Summer (Read Pd 5- Read Pd 6)	Comment
Mean	3.0928	3.5614	
Variance	8.7120	11.2789	
Observations	141	141	
Pearson Correlation	0.9317		
Hypothesized Mean Difference	0		
df	140		
t Stat	-4.5134		t Stat > t Critical , reject the null hypothesis
P(T<=t) one-tail	0.0000		
t Critical one-tail	1.6558		
P(T<=t) two-tail	0.0000		p – value ≤ 0.05, reject the null hypothesis
t Critical two-tail	1.9771		**There is significant difference in the means of winter and summer**

Table C-3: Paired T-Test for Spring and Summer with Seating Capacity Metric

	Spring (Read Pd 3-Read Pd 4)	Summer (Read Pd 5-Read Pd 6)	Comment
Mean	3.0655	3.5614	
Variance	8.2337	11.2789	
Observations	141	141	
Pearson Correlation	0.9656		
Hypothesized Mean Difference	0		
df	140		
t Stat	-6.2021		t Stat > t Critical, reject the null hypothesis
P(T<=t) one-tail	0.0000		
t Critical one-tail	1.6558		
P(T<=t) two-tail	0.0000		p – value ≤ 0.05, reject the null hypothesis
t Critical two-tail	1.9771		**There is significant difference in the means of spring and summer**

FLOOR AREA

Table C-4: Paired T-Test for Winter and Spring with Floor Area Metric

	Winter (Read Pd 1-Read Pd 2)	Spring (Read Pd 3-Read Pd 4)	Comment
Mean	3.0404	3.0249	
Variance	8.7000	8.1407	
Observations	92	92	
Pearson Correlation	0.9498		
Hypothesized Mean Difference	0		
df	91		
t Stat	0.1606		t Stat < t Critical, accept the null hypothesis
P(T<=t) one-tail	0.4364		
t Critical one-tail	1.6618		
P(T<=t) two-tail	0.8727		p – value > 0.05, accept the null hypothesis
t Critical two-tail	1.9864		**There is no significant difference in the means of winter and spring**

Table C-5: Paired T-Test for Winter and Summer with Floor Area Metric

	Winter (Read Pd 1- Read Pd 2)	Summer (Read Pd 5- Read Pd 6)	Comment
Mean	3.0404	3.4048	
Variance	8.7000	10.4023	
Observations	92	92	
Pearson Correlation	0.9313		
Hypothesized Mean Difference	0		
df	91		
t Stat	-2.9727		t Stat > t Critical, reject the null hypothesis
P(T<=t) one-tail	0.0019		
t Critical one-tail	1.6618		
P(T<=t) two-tail	0.0038		p – value ≤ 0.05, reject the null hypothesis
t Critical two-tail	1.9864		**There is significant difference in the means of winter and summer**

Table C-6: Paired T-Test for Spring and Summer with Floor Area Metric

	Spring (Read Pd 3- Read Pd 4)	Summer (Read Pd 5- Read Pd 6)	Comment
Mean	3.0249	3.4048	
Variance	8.1407	10.4023	
Observations	92	92	
Pearson Correlation	0.9628		
Hypothesized Mean Difference	0		
df	91		
t Stat	-4.0175		t Stat > t Critical, reject the null hypothesis
P(T<=t) one-tail	0.0001		
t Critical one-tail	1.6618		
P(T<=t) two-tail	0.0001		p – value < 0.05, reject the null hypothesis
t Critical two-tail	1.9864		**There is significant difference in the means of spring and summer**

Appendix D Beer Production-Water Use Correlation for Microbrewery

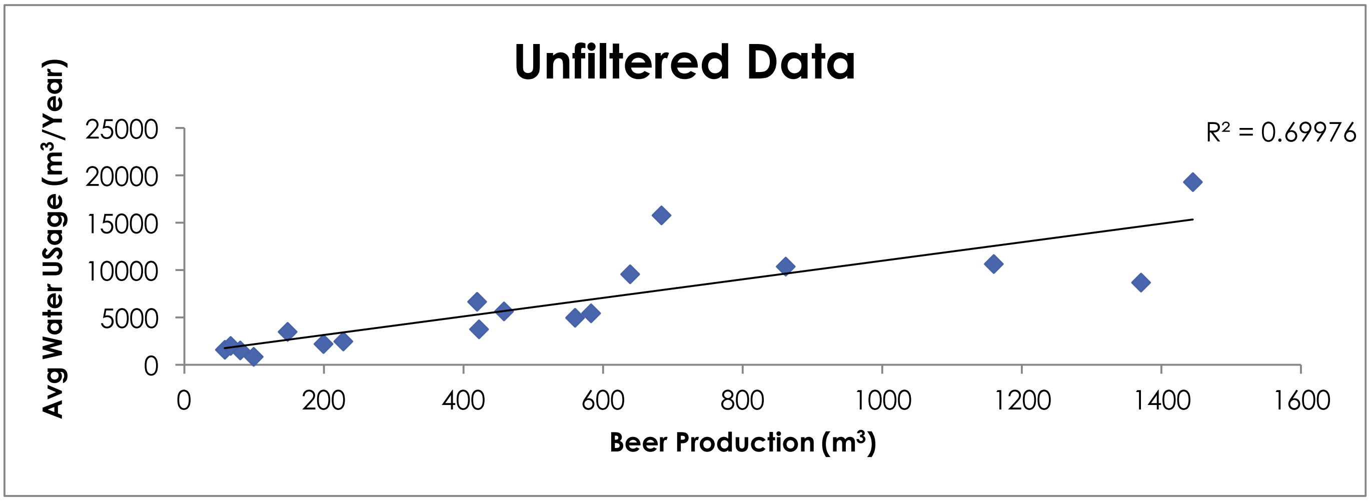

Figure D-1: Correlation between Beer Production and Water Usage for Unfiltered Microbreweries Data

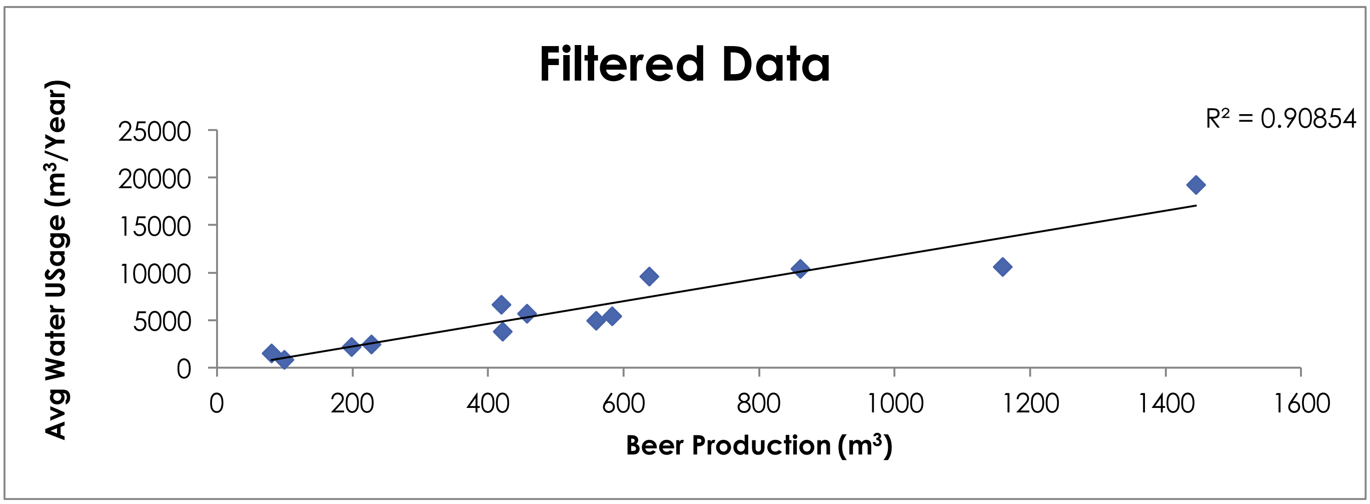

Figure D-2: Correlation between Beer Production and Water Usage for Filtered Microbreweries Data

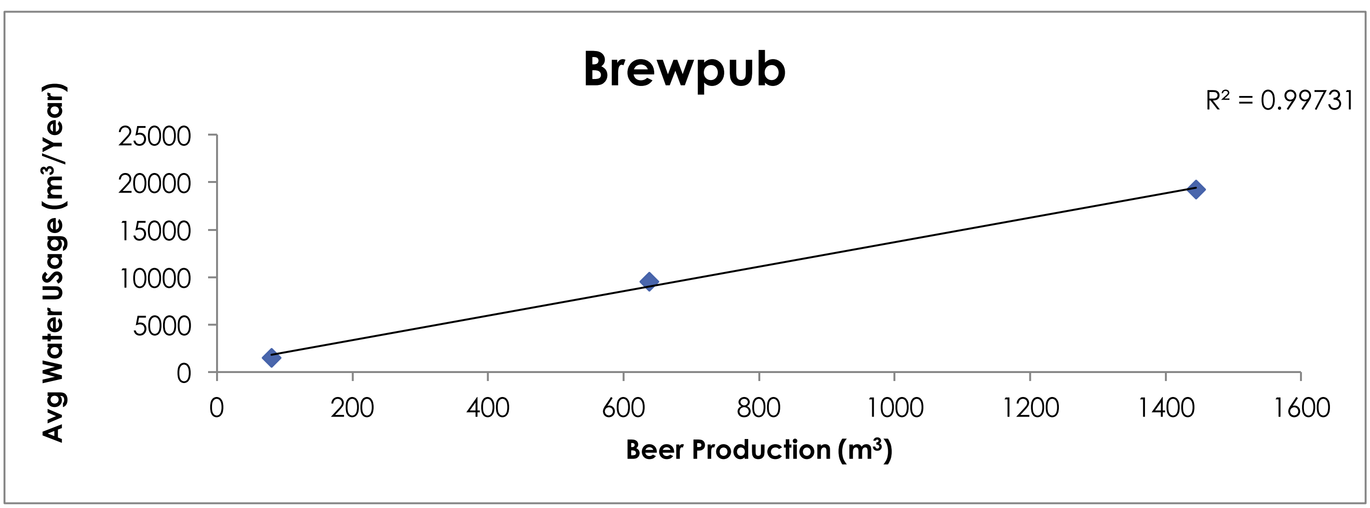

Figure D-3: Correlation between Beer Production and Water Usage for Filtered Brewpub Sub-Category Data

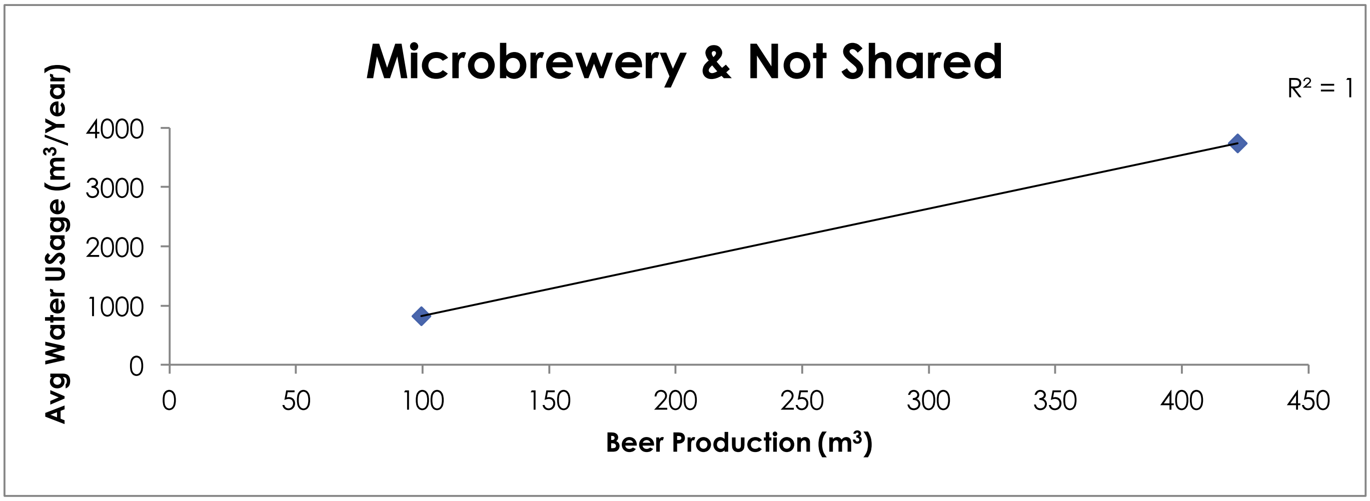

Figure D-4: Correlation between Beer Production and Water Usage for Filtered Microbreweries and Not Shared Sub-Category Data

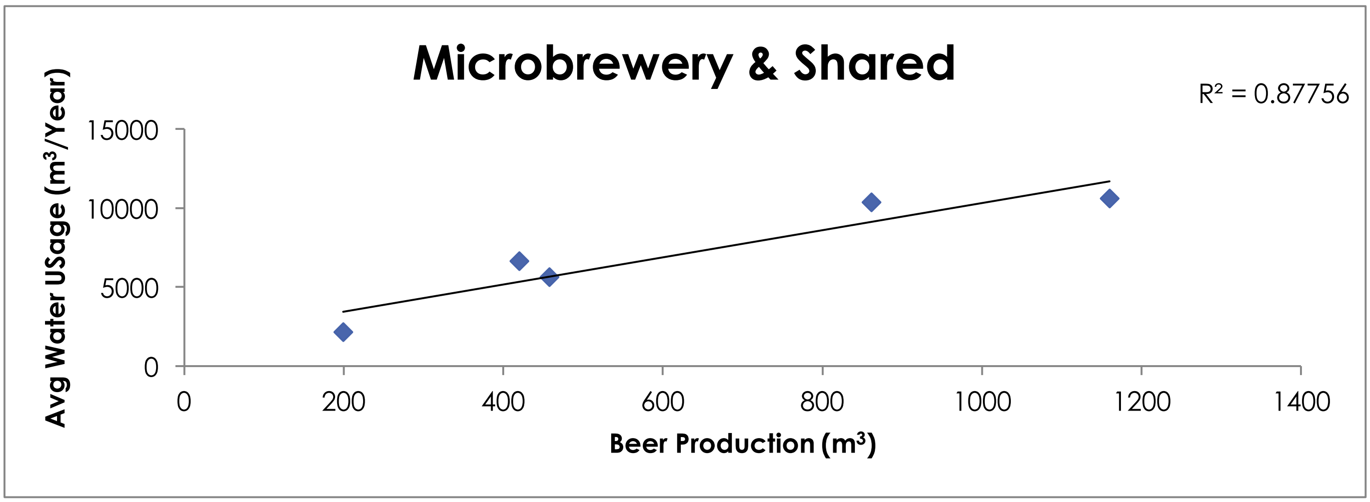

Figure D-5: Correlation between Beer Production and Water Usage for Filtered Microbreweries and Shared Sub-Category Data