PREPOSITION OF WATER CONSERVATION SOLUTIONS IN SINGAPOREAN SCHOOLS

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Abstract

Singapore receives approximately 2340mm of rainfall per annum, well above the global average of 990mm. Yet as a country, Singapore is challenged with water issues. As a city-state on a small island, home to millions of inhabitants, Singapore has the dual problem of limited space for water harvesting and storage, and an increasing demand for water from the growing population. In order to secure sustainable sources of water, Singapore has relied upon innovative solutions through the "Four National Taps" which comprises of local catchment water, imported water, desalinated water and NEWater, a technology used to convert used water to drinking water. In addition, Singapore emphasizes on water conservation of demand for water through implementation of water efficient devices and encouraging good water saving habits. In line with Singapore's national agenda, this research project aims to explore ways to optimize the usage of potable water in a bid to alleviate the strains imposed on the national resource.

The study will focus on identifying water consumption patterns and attitudes towards water conservation, and henceforth design feasible solutions. The project will include: (1) assessing the current water usage through water audit in order to identify water usage patterns, (2) ascertaining areas which require improvements, and (3) formulating responses to tackle these areas of improvement through a. educating the student population, b. possible enhancement of the toilet facilities, and c. examine the possibility of using rainwater harvesting to complement the usage of non-potable water in the school premises.

With over 360 of them, schools form a significant influence in promoting sustainable water usage in Singapore. Having the intention to impact future water utilization in the city state positively, we hope that the outcome of our project may be transferrable to the other educational institutions, or encourage other students to come up with similar strategies for saving water and optimization of water usage. The issue of water sustainability and water security is a domestic concern, and at large, a global responsibility. Our project foresees that a concerted effort by all is imperative to complement innovative research with large-scale planning.

Keywords

Singapore, water, conservation, sustainability, schools

Table of Contents

1 Introduction

1.1 Singapore's Climate and Water resources

Singapore is a tropical country with a land size of 718km^2 located at 1°N, 104°E. The nation has a tropical rainforest climate with small temperature fluctuations and relatively high temperatures, humidity and rainfall throughout the year. With a 24-hour mean temperature of 26.6°C and annual relative humidity of 84.0%, it rains an average of 178 days a year, where rainfall is usually heavy and accompanied by thunder. Based on long-term records from 1869 to 2015, the mean annual rainfall total is 2331.2mm. Singapore's climate consists of two monsoon seasons; the Northeast Monsoon which occurs from December to early March, and the Southwest Monsoon from June to September. These two monsoon seasons typically cause thunderstorms in Singapore (Meteorological Service Singapore, 2015).

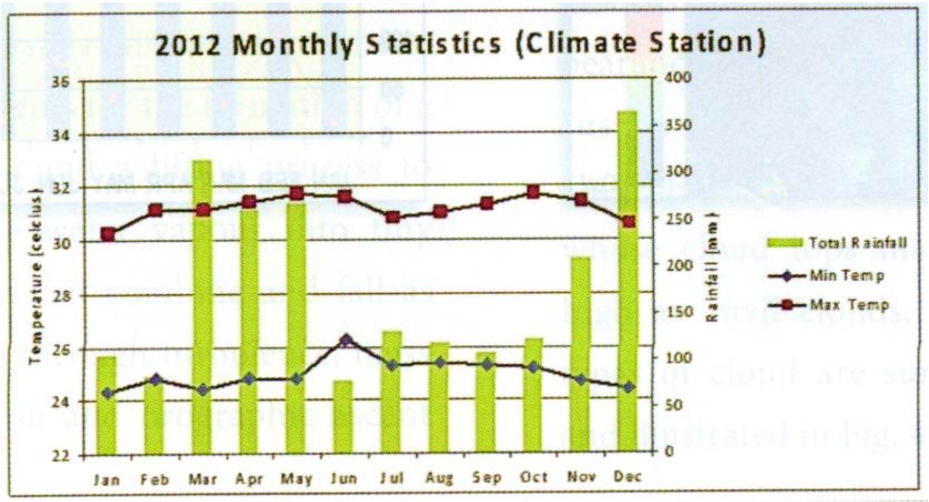

Figure 1: Climograph of Singapore (Oliver, 2015)

Figure 2: Singapore's rainfall distribution (Singapore, 2015)

Singapore is a small city state with a population of 5.4 million inhabitants. Due to its limited land size and small local catchment areas, the country faces water insecurity (Yong, 2015). Furthermore, due to rapid industrial, economic and social developments over the past 50 years, water consumption in domestic sectors increased exponentially. When the population was only 1.9 million in 1965, the demand for potable water was only 75 litres per capita per day. However, by 1994, when the population doubled, water demand had quadrupled to 175 litres per capita per day. Such disproportionate water demand growth placed a huge water stress on Singapore, given the country's lack of natural water supplies. The current water demand in Singapore is approximately 400 million gallons of water a day with 45%

belonging to the domestic at 151 litres per capita per day and 55% belonging to the non-domestic (Looi, 2014).

Singapore's water insecurities are further emphasized with Singapore's international ranking regarding fresh water availability. Singapore was ranked 170th among a list of 190 countries. Furthermore, according to a study conducted by World Resources Institute, Singapore was ranked 1st in terms of the top countries facing water stress, with a baseline water stress score of 5.00 (Paul Reig, 2013).

1.2 Water Management Strategies in Singapore

The Public Utilities Board (PUB), which is the statutory board under the Ministry of the Environment and Water Resources, is responsible for ensuring a sustainable and efficient water supply. PUB is in charge of Singapore's entire water supply system which comprises the water catchment and waterways, water reclamation plants, water treatment plant, water supply network and water reclamation network.

In order to cope with Singapore's increasing water demand, PUB focuses on developing sustainable water management strategies within both the water supply and demand aspects. PUB's strategies in the water supply aspects mainly comprises of developing new water sources through Four National Taps while strategies in the water demand aspects mainly comprises of regulating water demand in both domestic and non-domestic sectors as while as educating the general public of the importance of water conservation.

1.2.1 Water Supply Strategies

The definition of sustainability is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Education, 1987). This can be further clarified as ensuring sufficient water supply for both the present and future of Singapore. In order to ensure a sustainable water supply in Singapore, the Public Utilities Board (PUB), Singapore's official governmental agency in charge of water related issues, has adopted a two-pronged strategy. One half of the strategy is to develop new water sources through the Four National Taps, local catchment areas, imported water, NEWater (recycled water) and desalinated water.

The first national tap; local catchment water, relies on rainwater and plays an important role in ensuring Singapore's sustainable water supply. Local catchment areas have been increased from half to two-thirds of Singapore's land surface since 2011, with the completion of three additional reservoirs. Local Catchment areas can meet up to 10% of Singapore's water needs (Ghangga, 2015).

Singapore's imported water, her second national tap mainly comes from Johor, under two bilateral agreements. The first agreement was signed on October 1961 and expired in August 2011. The second agreement was signed on September 1962 and will expire in 2061. A maximum of 250 million gallons of water a day can be drawn from the Johor River under the agreement. Imported water can supply up to 60% of Singapore's water needs.

NEWater is produced from treated used water that is further purified using high end technologies such as ultra-violet disinfection and reverses osmosis technologies. Singapore's four NEWater plants can meet up to 30% of the nation's current water needs.

Lastly, desalination also plays an important role in ensuring Singapore's sustainable water supply. The two desalination plants in Singapore have a total capacity of 100 million gallons of water a day, and can meet up to 25% of Singapore's current water demand (Ghangga, 2015).

However, these four national taps do have instances in which they fail to produce desirable results. The first national tap can also fail us in events of dry weather. Singapore's weather patterns are becoming relatively unpredictable which reduce the catchment volume available. As for the second tap, it is not a long term solution for Singapore's attempt for a new water agreement beyond 2061 from Malaysia had not been successful (Kog, 2002). This becomes a worrying cause for imported water supplies up to 60% of Singapore's water supply. Singapore now faces a race against time, for she has to develop technologies that are able to supply up to 60% of her water supply by 2061. It may be challenging to do so. Desalination and NEWater processes, the third and fourth national taps, are highly energy-intensive (PUB, Public Utilities Board, 2013). It becomes questionable whether the cost of water will still remain affordable by the time it hits 2061, for the cheapest source of water; imported water, will no longer be made available. Singapore can only hope by 2061, technology is so advanced that water from desalination and NEWater becomes affordable. Under further examination, it is shown that the four national taps may not been as sustainable and robust as it is often put across. Thus, water demand strategies come into play (Looi, 2014).

Fortunately, rainwater harvesting is gaining popularity in Singapore who strives to become a green city which utilities green technology. There has been a preposition to construct a large scale underground storage system which mimics local catchment areas in the storage of rainwater. The system is able to capture an average of 4.6 million cubic metres per day, which is definitely sufficient to meet Singapore's needs of 1.5 million cubic metres per day. Despite its potential, the system's capital cost proves to be a setback and requires further cost-benefit analysis before it can be implemented (Yong, 2015). Other than large scales projects as discussed above, there has also been many smaller scale projects which involves rainwater harvesting. Currently, newer Housing and Development Board (HDB) flats (high-rise housing estates) are built to be eco-friendly. The HDB is the national public housing authority of Singapore. An example would be Tree Lodge HDB estates located at Punggol, in the North-east of Singapore. Tree Lodge consists of a rainwater harvesting system located at rooftops. The collected rainwater is treated and later used for washing of HDB amenities such as staircases and void decks. Rainwater harvesting could potentially supplement Singapore's water supply (Yong, 2015).

1.2.2 Water Demand Strategies

Water demand strategies are the second half of PUB's strategy in ensuring Singapore's water security. They mainly consist of educating the general public of the importance of water conservation as well as regulating water demand in both domestic and non-domestic sectors.

Water conservation education campaigns have started as early as 1970s. In 1971, the first "Water is precious" campaign was launched, and it succeeded in bring down 4.9% of water consumption in Singapore (Tan, 2009). Another example would be the "Turn it Off" water conservation campaign conducted in 1998. The campaign consists a wide variety of events, each specifically tailored to target different sectors of Singapore that consume water. Its multi-faceted nature was one of the root cause of its success, for it encouraged 93% of the respondents to save water (Bulter, 2004). Even till this day, water conservation campaigns, especially those commissioned by PUB are still widespread, with notable examples such as the annual World Water Day which takes place in Jurong Lake, Singapore, cooperating with students of nearby schools in educating the public of the importance of water conservation.

Additionally, PUB also developed structural or technical changes to save water. Since 1983, the installation of water-saving devices such as constant flow regulators and self-closing delayed action taps has been made mandatory in all non-domestic premises and common amenities areas of all private high-rise residential apartments and condominiums; bathtubs and jacuzzis larger than 250 litres in volume also require a water circulation system. Low-capacity flushing cisterns (LCFCs) make use of not more than 4.5 litres of water per flush have been installed in all new public housing units since 1992 which was later made mandatory for all new and on-going building projects in 1997. From 2009 onwards, dual-flush LCFCs which offer the option of half-flush, which uses not more than 3 litres of water, when full-flush, which uses not more than 4.5 litres of water, is not necessary, are made mandatory in all new developments and premises.

Since the water supply strategies, the four national taps, may not be very sustainable; more effort should be put into water demand strategies as well as rainwater harvesting which could potentially supplement Singapore's water supply. Thus our project focuses on the development of water demand strategies as well as the development of rainwater harvesting systems.

1.3 Aim and Objectives of Study

1.3.1 Aim

This project aims to study water consumption patterns and attitudes towards water conservation and evaluate if proposed solutions are feasible and transferable to other schools in Singapore.

Our proposed solutions comprise of:

- Proposed solution 1:
  Designing a simple yet cost effective rainwater harvesting system, a potential water supply strategy
- Proposed solution 2:
  Involve improvisations to public education, a water demand strategy
- Proposed solution 3:
  Installation and maintenance of water efficient amenities, a water demand strategy

1.3.2 Target group

Schools are chosen for our investigation site for they play an integral role in our local community with 369 educational institutes nation-wide as recorded in the Educational Statistics Digest 2014. The abundance of schools would amplify the benefits of water conservation throughout the nation. Students as well as school staffs have been engaged to take part in this study.

1.3.3 Objectives

A total of four types of investigation will be conduct for data collection:

1. A water audit,
2. Perception surveys on students
3. Interviews with school's staffs, and
4. Potential sites for constructing the rainwater harvesting system.

a) The water audit aims to investigate areas which require non-potable water usage in schools, and the water amenities in the school's toilets. The data collected will be used for the cost-effective analysis of the rainwater harvesting systems (proposed solution 1) and evaluation of the impacts of water efficient amenities in schools respectively (proposed solution 3).

b) The Global Positioning System (GPS) area tracking device will be used to calculate the potential rainfall the rainwater harvesting system is able to collect, which will be later utilized for the cost-effective analysis of the rainwater harvesting systems in schools, and hence the precursor for the designing of such a system.

c) The perception survey aims to investigate the student's views of the water demand and supply strategies, which will aid in the designing and evaluation of the various proposed solutions.

d) The interviews aim to investigate school staffs' views of the water demand strategies as well as the rainwater harvesting systems, which will aid in the designing and evaluation of the various proposed solutions.

1.3.4 Investigation Site: River Valley High School

River Valley High School (RVHS) was founded in 1956 and is widely regarded as among the top schools of Singapore, in the fields of academics, co-curricular achievements and leadership development. RVHS moved into its latest 7.64-hectare campus at Boon Lay Avenue in December 2009. Our investigation was conducted throughout the school, ranging from toilets to the canteen, to open spaces, in which the list is not exhaustive.

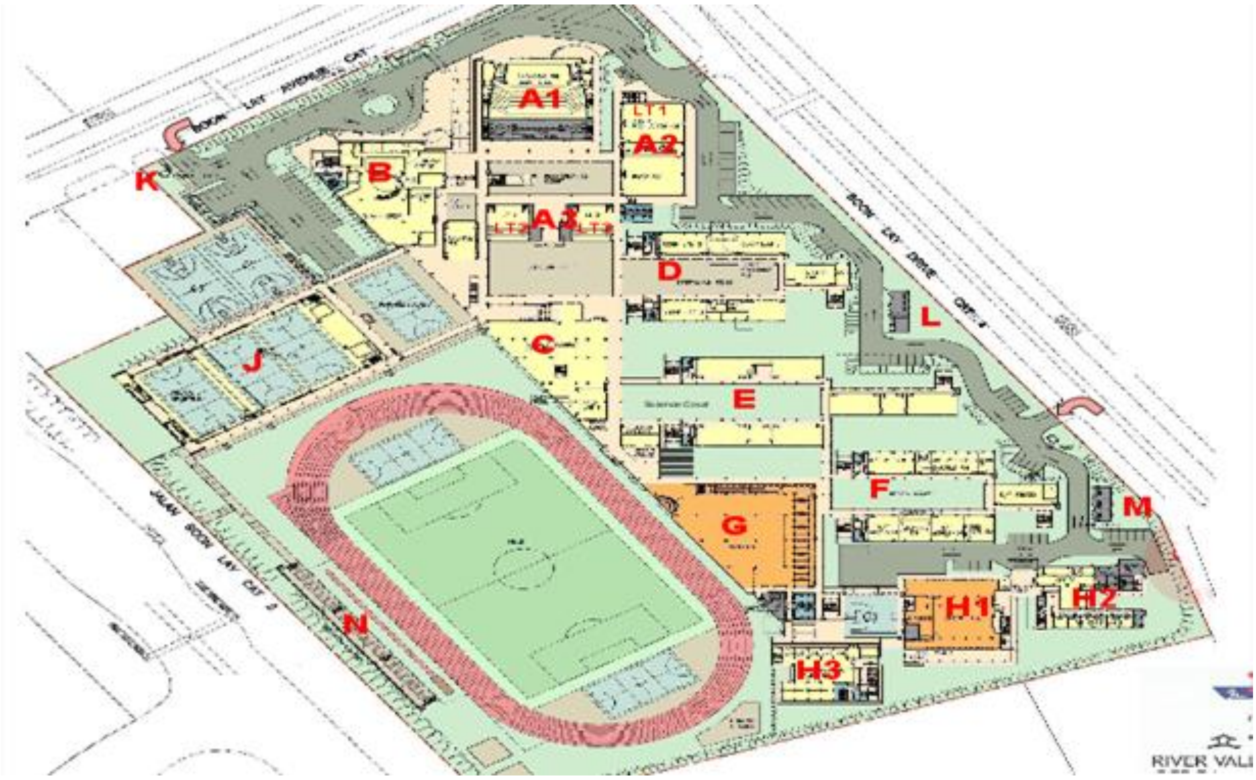

Figure 3: Floor Plan of River Valley High School

1.4 Literature Reviews

1.4.1 Rainwater harvesting in Singapore

Rainwater harvesting is a system that is used for the collection and storage of rainwater. It comprises of three components - the catchment area, collection device and conveyance system. Singapore has limited land resources and a rising demand for water. Almost 86% of its total population lives in high-rise buildings. A recent study of an urban residential area (about 742 hectare) put in place a model to determine the optimal storage volume of the rooftop cisterns, taking into consideration non-potable water demand and actual rainfall at 15-minute intervals. The savings in water, energy costs, deferred capital, and the cost of roof water collected culminates in a cost of S$0.96, which is smaller than that of cost of S$1.17/CuM which PUB charges for potable water (Appan, 2001).

Case Study 1: Rainwater harvesting system in Changi Airport

In the Singapore Changi Airport, storm water is captured at the Changi Airport Nursery and landscaped areas through rainwater harvesting. (Atlas, 2012). It accounts for 28-33% of the total water usage, saving approximately S$390,000 per annum. Development of a simple computer programme as well as preparation of nomogram were used to relate the roof area, tank size and roof water available to be collected (United Nations Environment Programme, 2004). The recycled water from rainwater is used for irrigation of plants in the nursery.

Case Study 2: Rainwater Harvesting System in Treelodge Punggol

This rainwater harvesting system is one which is located within a Housing and Development Board (HDB) residential district named Punggol. The SIF Technologies' proprietary DPA water technology is utilized for the inaugural chemical free rainwater harvesting system in Treelodge@Punggol – Singapore's green mark platinum award public housing project developed by the HDB. Rainwater is retained and purified by natural elements such as surrounding plants before it is channeled into the water pathway, as part of Punggol and Serangoon reservoirs (Ko, 2014).

1.4.2 Public Education in Singapore

D. Howarth and S. Butler's (2004) "Communicating water conservation: how can the public be engaged?" reviewed many instances of water conservation campaigns, including England, Singapore, and Denmark, et cetera. The study concluded that for a communication programme to be successful it has to move people through a five stage process: from ignorance to awareness to interest to desire to action. The above approach would allow the formation of a more comprehensive perception survey for the public.

Also the study has also reviewed Singapore's "Turn it Off" water saving campaign in 2001. The campaign was a huge success, as it managed to influence 93% of its respondents to conserve water. Some of the success factors include the cessation of water conservation to be an abstract concept, causing it to be more relatable to the general public. Also the general public was highly exposed to PUB's attempts to educate them, especially through television advertisements. Lastly, there were many other organisations that supported water conservation campaigns other than PUB, allowing such campaigns to flourish. Another interesting finding would be on how people support vague generalities but would escape from the reality of taking action. The above findings of the social behaviour of the general public towards water conservation allow us to have a better idea of the general mindsets of our sample respondents, hence allowing us to devise a more comprehensive and detailed perception survey (Bulter, 2004).

1.4.3 Installation and maintenance of water efficient amenities in Singaporean schools

There are mainly two schemes that encourage the use of water efficient amenities in Singaporean schools, namely the Water Efficiency Labelling Scheme (WELS) and the Water Efficient Building Certification.

They both go hand in hand, where WELS offers advice as to which products to use, and WEB offers recognition to the school's efforts in water conservation.

In 2006, PUB introduced the voluntary Water Efficiency Labelling Scheme (WELS) for water-efficient water fittings and appliances. This allows consumers to make informed and better choices on the water efficiency of a product while making purchases and raises public awareness on water conservation and encourages more water-efficient products in the market (PUB, 2016).

The Water Efficient Building (WEB) Certification launched in 2004 encourages businesses, industries, schools and buildings from the non-domestic sector to include water efficient measures in their premises.

The WEB (Basic) Certification is achieved through the installation of water efficient fittings and adopting water efficient flow rates/flush volumes as shown in the figure below. In general, a certified water efficient building can save about five per cent of their monthly water consumption (PUB,2015).

Product/Fittings	Flow Rate/ Flush Capacity Requirements		
	Good ✓	Very Good ✓✓	Excellent ✓✓✓
Shower Taps and Mixers	> 7 to 9 litres/min	> 5 to 7 litres/min	5 litres/min or less
Showerheads	> 7 to 9 litres/min	> 5 to 7 litres/min	5 litres/min or less
Basin Taps and Mixers	> 4 to 6 litres/min	> 2 to 4 litres/min	2 litres/min or less
Sink/Bib Taps and Mixers	> 6 to 8 litres/min	> 4 to 6 litres/min	4 litres/min or less
Dual-Flush Low Capacity Flushing Cisterns	> 4 to 4.5 litres (full flush) > 2.5 to 3 litres (reduced flush)	> 3.5 to 4 litres (full flush) > 2.5 to 3 litres (reduced flush)	3.5 litres or less++ (full flush) 2.5 litres or less (reduced flush)
Urinals and Urinal Flush Valves	> 1 to 1.5 litres	> 0.5 to 1 litres	0.5 litres or less** or waterless urinals
Clothes Washing Machines	> 12 to 15 litres/kg	> 9 to 12 litres/kg	9 litres/kg or less

Figure 4: Water Efficiency Labels for different water amenities

Case Study 1: Riverside Secondary School

Riverside Secondary School (RSS) actively educates their students to uphold water conservation values by reminding them to report faulty fittings or leaks immediately.

Their water-saving measures include training staff on the proper use of high-jet machines, using high pressure jets for washing when necessary. The school was certified Water Efficient Building (Basic) in 2008. The school achieved a Water Efficiency Index (WEI) of 9.56 litres per person per day in 2012(PUB, Public Utilities Board, 2013).

Case Study 2: Sembawang Secondary School

Sembawang Secondary School installs all their taps with thimbles and checks on their water consumption daily. Posters are displayed prominently to encourage staff and students to report any leaks around the school. The school was certified Water Efficient Building (Basic) in 2011 and has achieved a Water Efficiency Index (WEI) of 10.20 litres per person per day. The school also harvests rain water to clean its corridors (PUB, Public Utilities Board, 2013).

1.5 Brief Overview of Project

Aim:

To study water consumption patterns and attitudes towards water conservation and evaluate if proposed solutions are feasible and transferable to other schools in Singapore.

Rationale:

Singapore faces water insecurity as a nation due to her limited land size as well as increasing water demand. Water supply solutions such as the 4 national taps are not as robust and sustainable as it is described to be under further examination.

Plan:

Focus on water demand solutions such as education and installation or maintenance of water efficient facilities. In addition, look into rainwater harvesting (water supply solution) which has the potential to supplement Singapore's water supply.

Solution 1: Designing a simple yet cost effective rainwater harvesting system; a potential water supply strategy	**Solution 2:** Involve improvisations to public education; a water demand strategy	**Solution 3:** Installation and maintenance of water efficient amenities
Water Audit: Investigate RVHS current water demand **GPS Area Tracing Device:** Calculate potential amount of rainfall to be collected Both sets of data above will be utilised to see if rainwater is able to supplement water usage in RVHS, thus aid in the designing of the system. **Perception surveys and interviews** collect opinions and concerns of various stakeholders which allow us to improve on our design.	**Perception Survey:** Investigate Students views towards PUB collaboration efforts with schools. **Interviews:** Investigate teachers views towards PUB collaboration efforts with schools Both sets of data allow us to evaluate the effectiveness of PUB's collaboration efforts with schools.	**Water audit:** Investigate the current conditions of water amenities in RVHS. **Interview** with operational manager: Allows us to have a better understanding of water facilities in RVHS. **Perception Survey:** Investigate the students' views towards this solution.
After Evaluation **FEASIBLE** / NOT FEASIBLE	After Evaluation **FEASIBLE** / NOT FEASIBLE	After Evaluation **FEASIBLE** / NOT FEASIBLE

2 Methodology

Table 1: Methodology involved in various solutions

	Water Audit	Perception Survey	Interviews with Teachers	Interviews with OM	GPS Tracking Device
Solution 1	✓	✓	✓	✓	✓
Solution 2		✓	✓		
Solution 3	✓	✓		✓	

2.1 Water Audit

The aim of the water audit is to assess the current water usage in the school premise of RVHS, so as to observe water consumption patterns to aid the team in coming up with feasible solutions for water conservation. The team focused the water audits in three areas – toilets, irrigation and the washing of amenities. Do you use a specific protocol for water audit?

The team did not look into water usage in 'Others' (non-categorical areas) such as the laboratory and art room taps, for little can be done to these amenities as they are heavily involved in the curriculum and requires specific guidelines which may not be water efficient but are necessary.

2.1.1 Water Audit in Toilets

Water audits conducted in toilets were mainly conducted for our proposed solution 3, where we investigate the flow rates of various water amenities such as taps and showerheads and thus determine their ratings. This would in turn allow us to calculate the savings of using water efficient amenities in RVHS and hence advocate for the installation and maintenance of such facilities. Additionally, it allows us to find faulty amenities which we will inform the OM in order to rectify the issue, doing an additional service for the school.

The water audit in toilets was carried out on 14th December 2015 and 16th December 2015. We used a water beaker and timer to measure the flow rate of half the number of taps/showerheads in each toilet. The locations of the all the toilets were identified and marked out on the school's floor plan as shown in Figure 4. RVHS has a total of 58 toilets. However, we only surveyed a total of 51 toilets as the other seven toilets were out of bounds due to students. There are four main types of toilets; female, male, disabled and staff toilets.

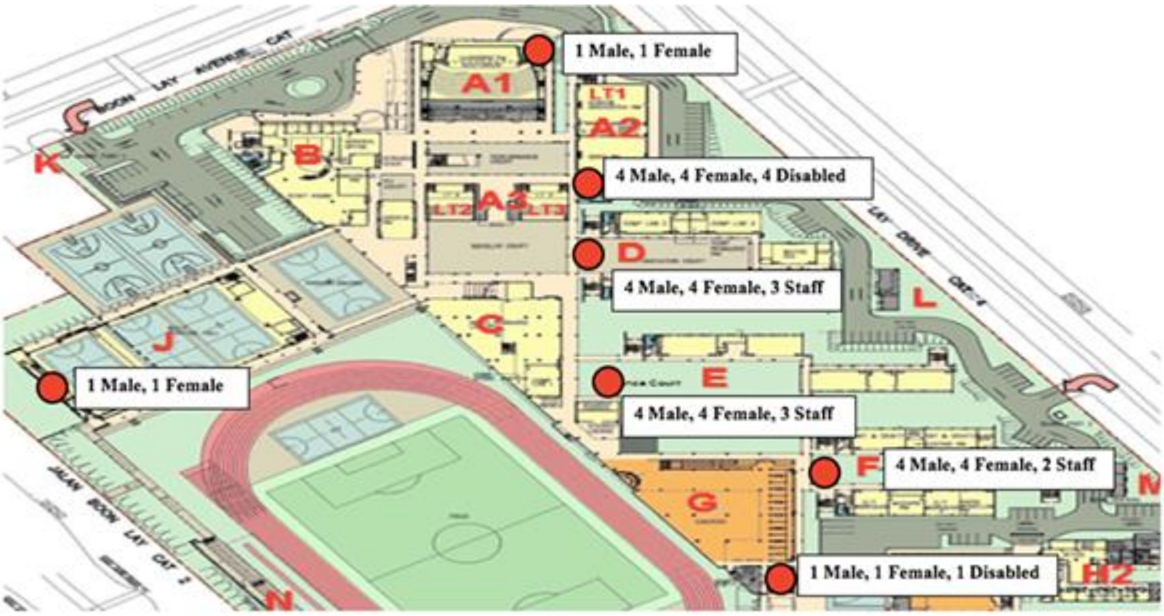

Figure 5: School's floor plan marked out with quantity and locations of toilets

The team also noted down the inventory of toilets which are the types of facilities used in each toilet. The flow rate of each toilet facility is derived from (Total Volume of Water/Minute). Following that, leakages of faulty facilities and malfunctioning taps or showerheads without thimble fittings were recorded.

Additionally, the team consulted the Operations Manager (OM) of RVHS, who provided us with a copy of the tabulation of water fittings in RVHS with WELS ratings. Along with these documents, the school's floor plans were also sent to the team to aid in the water audits.

2.1.2 Water Audit for Irrigation

Water audit for irrigation was mainly conducted for our proposed solution 1 (rainwater harvesting system). The investigation of RVHS's water demand in irrigation would aid us in the calculating the required amount of rainfall to be harvested, and the designing of the rainwater harvesting system by giving us a rough gauge of the sizing of the design. The volume of the rainwater collected should be complementary to the volume of water needed by the non-potable water usage in RVHS, which includes irrigation.

The water audit for irrigation was carried out on 14th December 2015. The team recorded sites within the school premise which require irrigation with the aid of the Operations Support Officer. Only locations of the potted plants were recorded since the school engages external vendors for irrigation of large grass patches and gardens in the school. Sites with potted plants were marked out on the school's floor plan. The OSO was interviewed regarding the amount of water used to water each potted plant and the regularity of irrigation on 14th and 21st December 2015.

2.1.3 Water Audit for Washing of Amenities

The water audit for the washing of amenities was conducted for the same purpose as the water audit for irrigation. On 14th December 2015, the team conducted the water audit for washing of amenities. The team interviewed a total of eight janitors regarding the amount of water used to wash each form of amenities and the regularity of each washing.

2.2 Perception Survey (Refer to Appendix A)

The aim of conducting perception survey amongst students was to find out their attitudes towards water conservation in schools through the assessment of awareness and behavioral level. The survey is used to identify the trends of student's awareness level and behaviors towards our three proposed solutions as well as collating feedback from these students, which allows us to further improve on our design. Students were asked about their feedback towards implementing rain water harvesting systems as well as their views towards the installation and maintenance of water efficient amenities. The bulk of the survey lies in their views towards PUB's collaboration in schools in order to promote water conservation, in which the data will be used to enhance PUB's current efforts.

Before the actual perception survey was conducted, the team conducted pilot surveys and surveyed 10 16-year-old students on 26 February 2016. The aim of creating a pilot survey was to gain feedback from these students regarding the structure of the survey questions and further improve on our perception survey. 16-year-old Singaporean students currently studying in River Valley High School was targeted in order to find out how has 4 years of education in RVHS increased their awareness in water conservation. 39 16-year old students were surveyed through Google forms.

2.3 Interviews (Refer to Appendix B and C)

The interviews aim to investigate the teacher's and operational manager's views of the proposed solutions. This allows the team to identify certain areas in which students are not aware of as well as take in valuable feedback from the professionals, which will ultimately aid in our evaluation of the proposed solutions.

2.3.1 Interviewing Teachers

The aim of the interviews was to assess the teachers' knowledge of water conservation measures and identify the gaps in their knowledge, proposed solution 2. Next was to enquire future probable measures and lastly, find out what they think of the rainwater harvesting system designed specifically for the school, solution 3. A total of 6 Geography teachers were interviewed from 7 March 2016 – 14 March 2016. Their responses were also collated for further analysis.

2.3.2 Interviewing School's Operations Manager (OM)

The aim of the interview was to find out what is the Operational Manager's find out actions taken by the school management in installation and maintenance of water efficient facilities, solution 3. Next is to learn his/her view towards rainwater harvesting system in schools in general and RVHS, solution 1.

2.4 Rainwater Harvesting System (Refer to Appendix E, F and G)

In order to calculate the potential volume of water to be collected using the proposed rainwater harvesting system, i.e. solution 1, mapping out of potential sites for the rainwater harvesting system to be put in place as well as weather data gained from Meteorological Services Singapore (MSS) were required. These data was utilized for the sizing of the rainwater harvesting system.

2.4.1 Potential Sites for Rainwater Harvesting in RVHS (Refer to Appendix E)

Potential sites in RVHS were identified and classified into two broad categories – shelters, smaller roofs and larger rooftop areas. A total of 11 rooftop areas have been mapped out using the Global Positioning System (GPS) application, TerraSync. The data recorded on the GPS application were transferred to the GPS PathFinder 5.30 on the computer. The results were mapped out on Google Earth using the "polygon" function.

2.4.2 Meteorological Data (Refer to Appendix H)

Meteorological data provided by Meteorological Services Singapore (Singapore, 2015) gave the team with the annual rainfall data as well as number of rainy days per year. This was used to calculate the potential amount of rainwater yield by using the proposed rainwater harvesting system.

2.4.3 Rainwater Harvesting Design

Sketchup, a three dimensional (3D) modeling software, was used to design the proposed rainwater harvesting system.

3 Data Analysis

The following results gathered are derived from a perception survey with a sample size of 39 respondents from the Year 4 cohort of students.

3.1 Solution #1: Rainwater Harvesting

Water consumption patterns from the water audit allow us to formulate a rainwater harvesting system that is able to supplement our water consumption patterns. Additionally, by studying attitudes of the student body from the perception survey, teachers and operational manager from interviews, we are able to obtain their concerns towards the construction of a rainwater harvesting system.

3.1.1 Water Demand in RVHS

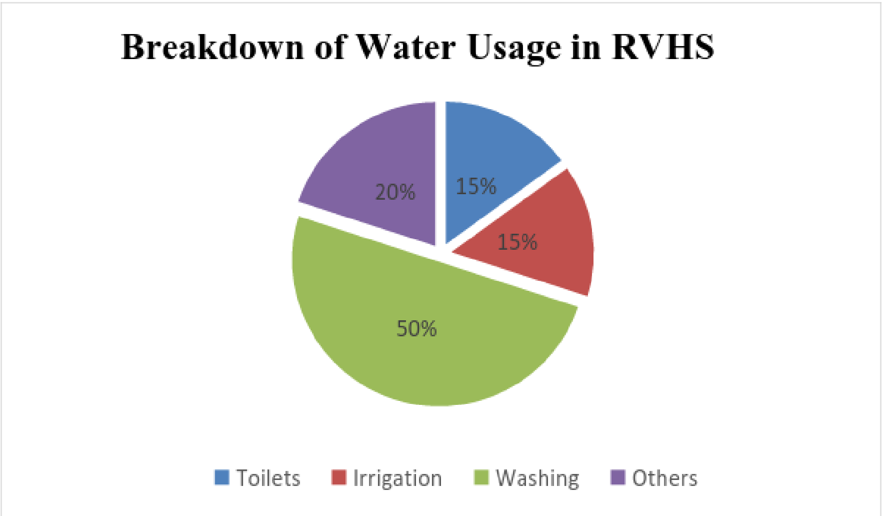

Figure 6: Breakdown of water usage in RVHS

RVHS spends 50% of its water on washing of amenities, 20% on toilets, 15% on irrigation and 15% on other uses irrigation. The non-potable usage of RVHS, which includes water used for irrigation and washing of amenities, accounts to a total of 65% of the total water usage. Since rainwater can only be used for non-potable purposes, it can potentially replace up to 65% of the water usage in RVHS, 932.17 CuM and almost $1090.63 of savings annually.

However for this project, we will only be focusing on the mopping aspect in the washing of amenities, since these activities can be done without the installation of a complex system of pipes which will not be discussed in our project. Refer to Appendix D for further breakdown of water usage of irrigation and the washing of amenities.

Table 2: Breakdown of non-potable water usage in RVHS

Purpose	Amount of water required weekly, l
Irrigation around the school	1200
Mopping of Canteen	1680
Mopping of Big Steps	60
Mopping of General Office and Good News cafe	420

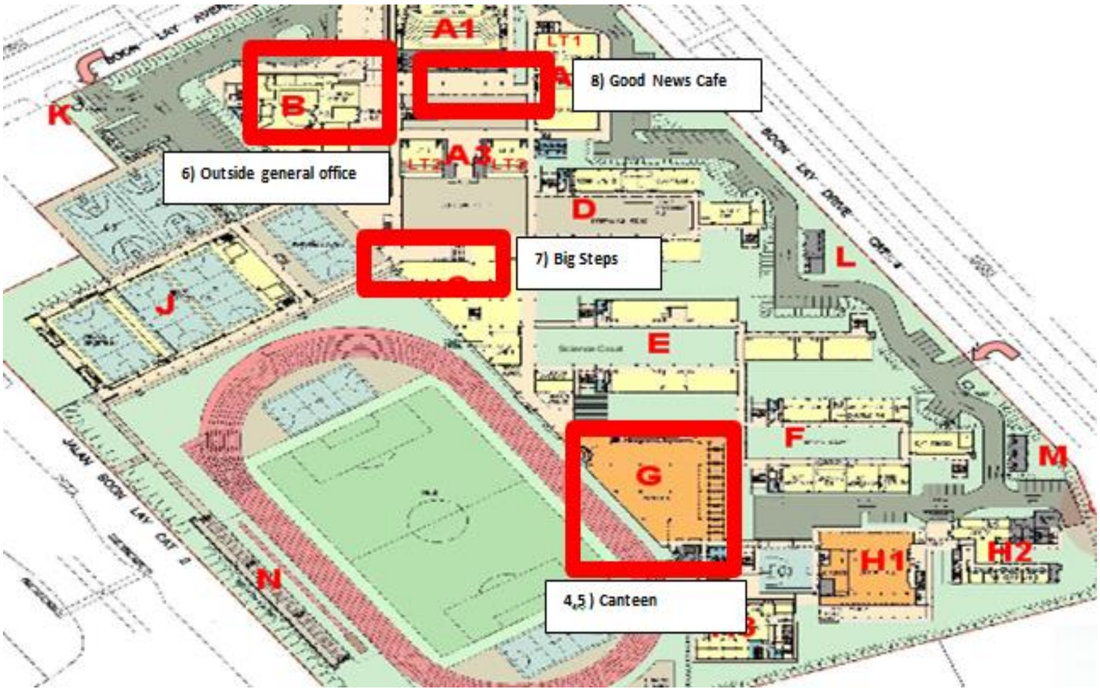

Figure 7: Areas in RVHS which requires mopping

3.1.2 Potential Rainfall Yield

Figure 7 shows the potential sites, which are mainly roofs due to their extensive areas and less invasive nature, where the rainwater harvesting system can be built. Refer to Appendix E for the exact areas of potential rainwater harvesting sites.

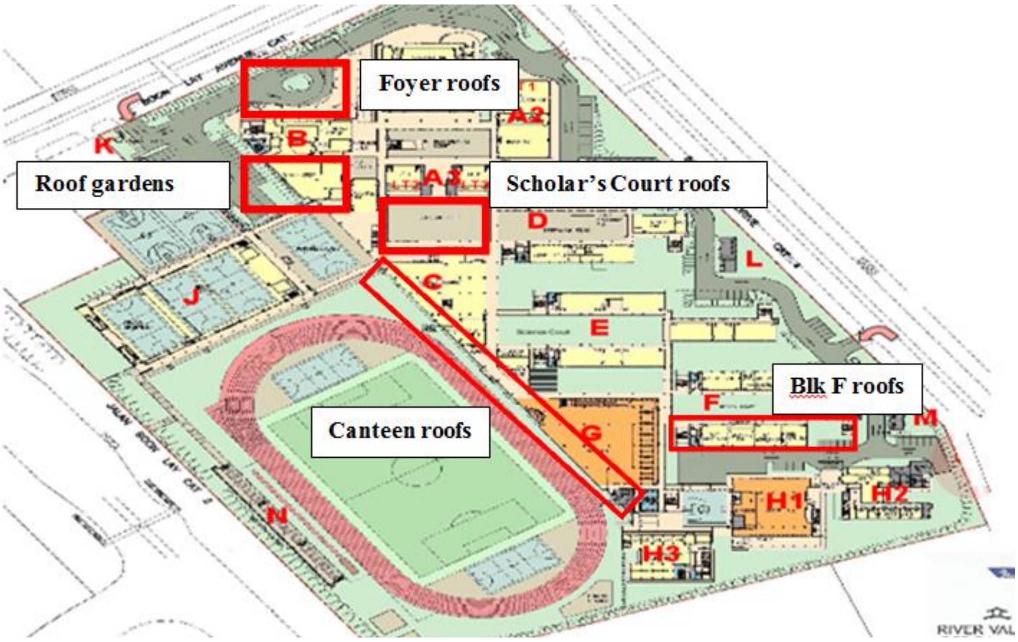

Figure 8: Potential rainwater harvesting sites

The potential rainfall yield can be calculated by using climate data provided by the Meteorological Services Singapore and by multiplying it with the area of potential investigation sites. We used an average rainfall if 194.3mm/month and 4 days of rain per week in our calculations. Refer to Appendix H for meteorological data used for calculations.

Table 3: Water demand of RVHS and potential amount of water that can be supplied from rainfall

Purpose	Amount of water required weekly, l	Sites	Amount of water collected from site weekly, l (MSS data x Area of potential sites)
Irrigation	1200	Scholar's Court's roof	5827
		Roof Garden's roof	29267
Mopping of Canteen	1680	Canteen roofs Blk F roofs	27511
Mopping of Big Steps	60		5222
Mopping of General Office and Good News cafe	420	Foyer's roofs	32116

From Table 3, it can be seen that water collected from rainwater harvesting is a lot more than the non-potable water demand of RVHS. Hence rainwater harvesting might just prove to be another water supply which has the potential to satisfy the school's water demand. Furthermore, if pipes (which will not be discussed in this paper) were to be built in the school to transfer rainwater for the washing and flushing of toilets around the school, it would definitely be sufficient. The data collected will be later used to determine the feasibility of building the rainwater harvesting system.

3.1.3 Students' perception of rainwater harvesting

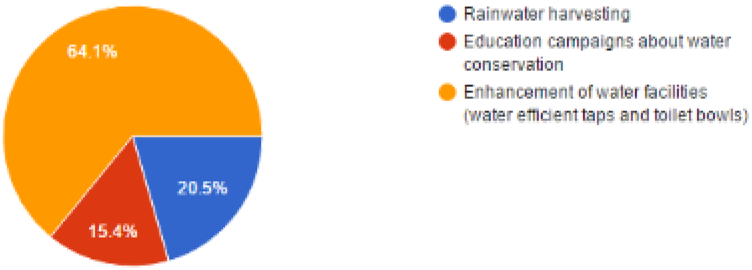

Figure 9: What students feel is the most effective method for water conservation

(Question: Among the suggestions below, which do you think is the best way to approach water conservation in schools?)

Only 20.5% of the respondents (8 students) pointed to rainwater harvesting system as the best approach. Such results might be due to the fact that rainwater harvesting is still a relatively new concept in Singapore; hence the students might not have much exposure towards it. Thus it is also noted that it is important to educate the students about the benefits of a rainwater harvesting system for such a development to garner support.

3.1.4 Teachers and operational manager's views

In the interviews with the Geography teachers in the school, most of them expressed interest in the rainwater harvesting system design and have provided input for us to improve on it.

Some also raised concerns about the severe dry spells which Singapore had experienced for the past few months due to El Nino Southern Oscillation (ENSO), which may impede on our rainwater harvesting progress. Consequently, during a wet season, there is a high possibility that an overflow will ensue. With its importance in play, the distinct seasonal rainfall patterns are an area that cannot be overlooked.

Others also questioned the system's self-sufficiency and its further implications. This gave rise to discussions about mosquito breeding and the quality of the filter system which will be used for the purification of the harvested water. Comments about the system's user-friendliness also provided insights as to how its level of convenience can be further enhanced.

3.2 Solution #2: Education

Improving education campaigns for the student body usually involves the school's cooperation with PUB to promote water conservation. However our data shows that such efforts may not have been very successful in the recent years.

3.2.1 Students' perception of water conservation in school

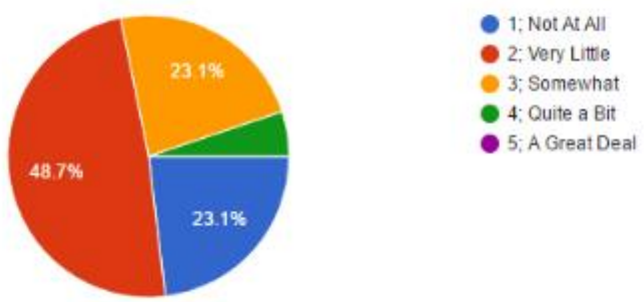

Figure 10: Students' views towards how water conservation efforts are introduced into RVHS's curriculum

(Question: In your opinion, do you think the concept of water conservation has been consciously brought into the school's curriculum?)

A total of 23.1% of the respondents (9 students) expressed that the concept of water conservation has not been consciously incorporated into the school's curriculum. Whereas, 48.7% (19 students) showed that it has 'very little' involvement, 23.1% (9 students) indicated that it has 'somewhat' involvement and the remaining (2 students) concurred that there is 'quite a bit' of involvement. Hence it can be inferred that there has been a lack of water conservation education in school.

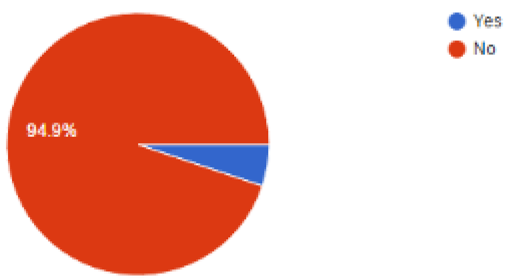

Figure 11: Students level of awareness of PUB's water conservation activities in cooperation with schools

(Question: Do you know of any water conservation implementations (i.e. practices, schemes, systems, etc.) in schools?)

When asked if they know of water conservation, only a few students could identify World Water Day and water conservation posters.

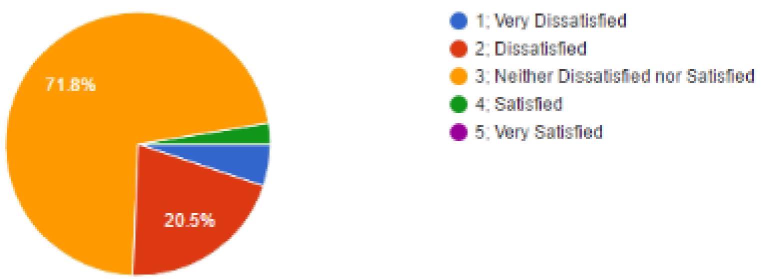

Figure 12: Students' satisfaction towards pro-activeness for Water Conservation in RVHS

(Question: How satisfied are you towards RV's pro-activeness for water conservation?)

A large proportion of the respondents (71.8%) (28 students) remain neutral towards the school's water conservation efforts. In addition, 20.5% of them (8 students) expressed that they are dissatisfied with the school's proactiveness. The remaining which constitutes a small proportion (3 students) expressed polarized views of either being very dissatisfied or satisfied with the school's proactiveness.

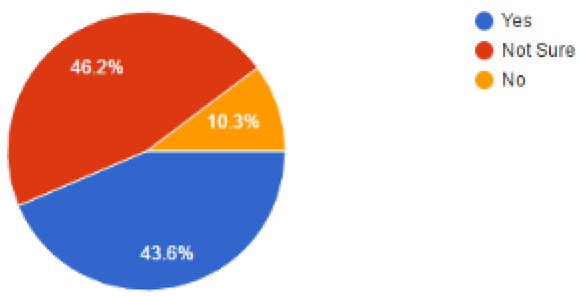

Figure13: Students' willingness to participate in water conservation efforts in school

(Question: Would you participate in water conservation campaigns (if any) if given a chance?)

Nearly half of the students (43.6%) (17 students) surveyed expressed interest in participating in water conservation campaigns when the opportunity arises. Most of the students (46.2%) (18 students) indicated that they are unsure of their participation, whereas 10.3% of them (4 students) are not interested in participating in water conservation efforts.

In general, students are optimistic towards the idea of taking part in water conservation campaigns which suggests that they are receptive towards the water activities planned by the school management and are willing to play their part in water conservation. Hence the promotion of water conservation in schools is beneficial.

3.2.2 Teacher's views of water conservation in school

The teachers mentioned that in schools, guest speakers are invited to engage students in a discussion on the topic of water sustainability and chapters of water resources are incorporated into the Year 1 geography syllabus. Apart from that, the school has consistently been conducting green (water) audits and receiving water awards on a yearly basis, which includes the Water Efficient Building Award given by PUB Singapore.

However, the teachers identified that the school is lacking in terms of monitoring students and staffs' usage of water. Also, the objectives of activities involving water conservation should be clearer and met with precision. One of them used the example of students having to balance water bottles on their heads and walk from one side to another side. In this case, the gaining effect was more on appreciation of water rather than ways to conserve water. Thus, it is difficult to assess a change in students' behavior and attitudes because most of the time, awareness does not mean action.

As a result, the teachers also recognized that these measures are insufficient to initiate an effective change in students' attitudes towards water conservation. It is noted with concern that there are minimal self-initiated efforts from the student body. They are; however, open to new water-saving solutions to mitigate the situation, such as the proposed rainwater harvesting system.

3.3 Solution #3: Enhancement of Water Facilities in RVHS

By conducting a water audit, we will be able to find out the current flow rates for taps and showerheads and determine if they are water efficient. Hence most of our investigations will be conducted in toilet. By conducting a cost-benefit analysis, we can hence suggest further improvements for future installations of water amenities in schools.

3.3.1 Investigation Sites

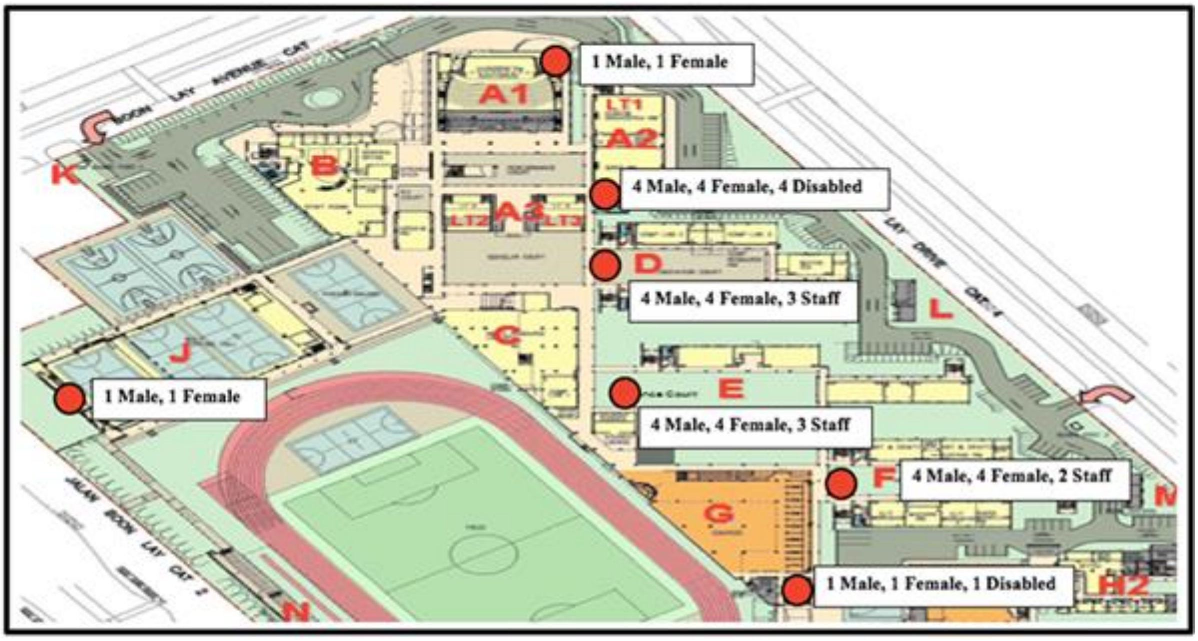

Figure 14: School's floor plan marked out with quantity and locations of toilets

RVHS has a total of 58 toilets. However, we only surveyed a total of 51 toilets as the other seven toilets were out of bounds due to students. There are four main types of toilets; female, male, disabled and staff toilets.

3.3.2 Classification of the flow rates of Water Amenities

Table 4: Quantity and WELS Ratings of Water Amenities

Ref	WELS rating	Total	Quantity of Fittings			
			Excellent	Very Good	Good	No rating
1	Showerheads	17	0	0	8	9
2	Basin taps	146	28	104	10	4
3	Sink/bib taps	6	4	0	1	1

Refer to Appendix I for further detail for the breakdown of flow rates of the different types of water amenities in toilets.

3.3.3 Statistics for Thimbles in toilets

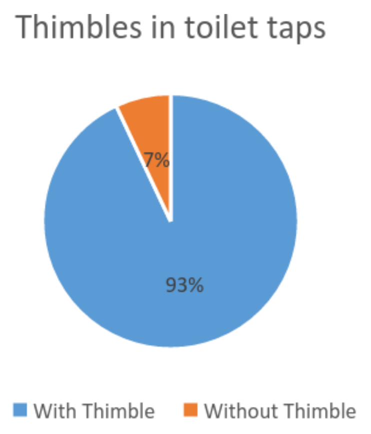

Figure 15: Thimbles in toilet taps

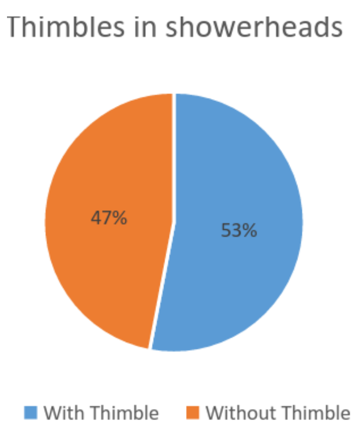

Figure 16: Thimbles in showerheads

Thimbles are devices designed to control the flow rate of water. Most taps in toilets are fitted with thimbles (93%), with only a minority not fitted with thimbles. However, almost half of showerheads are not fitted with any thimbles at all (47%), which is a worrying sign for showerheads undeniably spout more water that taps. Refer to Appendix J for the exact number of taps and showerheads with and without thimbles.

3.3.4 Statistics for Leakages in toilets

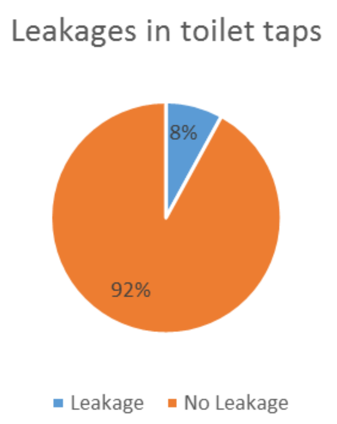

Figure 17: Leakages in toilet taps

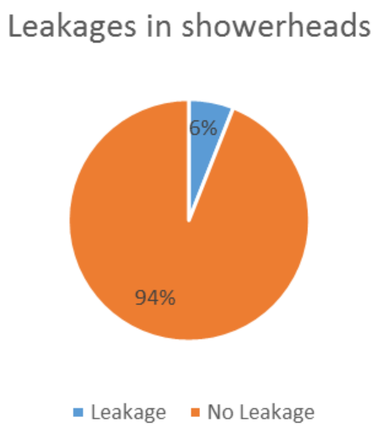

Figure 18: Leakages in showerheads

Over 90% of all water amenities are in good working condition, less than 10% were observed have leakages, which is a good sign.

3.3.5 Students' perception of managing water facilities in school

Majority of the respondents (64.1%) chose enhancement of water facilities to be the best approach to water conservation in schools. Nearly two-thirds of the students surveyed indicated that the enhancement of water facilities is the best solution in the management of water conservation. This is likely because these toilet facilities are used by everyone as part of their daily lives. Hence, the enhancement of facilities might be seen as the most direct approach and has the most immediate effect on water usage, with minimal need for them to change their behavioral patterns.

Figure 19: Students choice to report leakages in toilets

(Question: Do you report any leakages in toilet facilities?)

On the whole, students do not report leakages in toilet facilities. This constitutes 92.3% of the students who stated that they do not notice leakages, citing reasons such as they do not know who to report to and it is too troublesome to do so. Hence, only 7.7% of the students notice leakages and report it to the official personnel. This could come under improvements.

3.3.6 Operational Management's View

With regards to the actions taken by the school management in a bid to conserve water within the school compound, the Operations Manager of the school shared that the school has been actively working with PUB. The duo collaboration involved the replacement of all free flowing taps with plunger tap the addition of in flow restrictors (washers) to reduce flow rate to required limits, which enabled the school to achieve the Water Efficient Building status.

Faulty toilet flush valves or taps reported by staff, students, and cleaners are repaired accordingly and the watering of plants at ground level are also done using landscaping contractor's tankers instead of using free flowing water hoses.

However, he feels that the enhancement of water facilities is ultimately inadequate for water conservation. This is because despite the necessary measures in place for taps and flush valves, not a significant amount of water is conserved with these enhanced features. He stated that the main cause lies with the fact that school activities are always on the rise year by year, which causes the demand for water to increase accordingly. Moreover, given that water usage is on the rise every year, it is thus difficult to evaluate the effectiveness of these measures. In addition, the increasing focus on cleanliness and hygiene of environment will also constantly increase water consumption every year.

His data states that all the water amenities in RVHS are of "Excellent" and "Very Good" ratings. However our data shows that there are taps with "Good" ratings and even taps without any ratings present. This contrast might be due to the fact that his data was at least 6 years ago, while ours is collected in the present. Given that there is a lapse period involved, the most recent water audit conducted by our group may have surfaced some discrepancies. As such, there is a need to conduct water audits on a more regular basis to ensure the manageability of existing measures. Hence this further justifies the importance of maintenance of water amenities in schools, which can be another point for improvement.

4 Discussion

4.1 Discussion for Proposed Solution 1

4.1.1 Proposed Rainwater Harvesting System

The team has come up with a simplistic rainwater harvesting design to be incorporated into the current roof designs in the school premise. In the following section, the team aims to introduce our proposed rainwater harvesting system design, and evaluate the feasibility of our proposed rainwater harvesting system. Rainwater that runs off from the rooftop flows into the gutters located at the side of the roofs. Water will then travel down the gutter into the leaf eater and filtering mesh where debris and contaminants will be removed, then then into the column. There is an overflow pipe located at the top of the storage column, which is located directly above the drain. Such simple systems are already implemented in many parts of the world. (Centre, 1997).

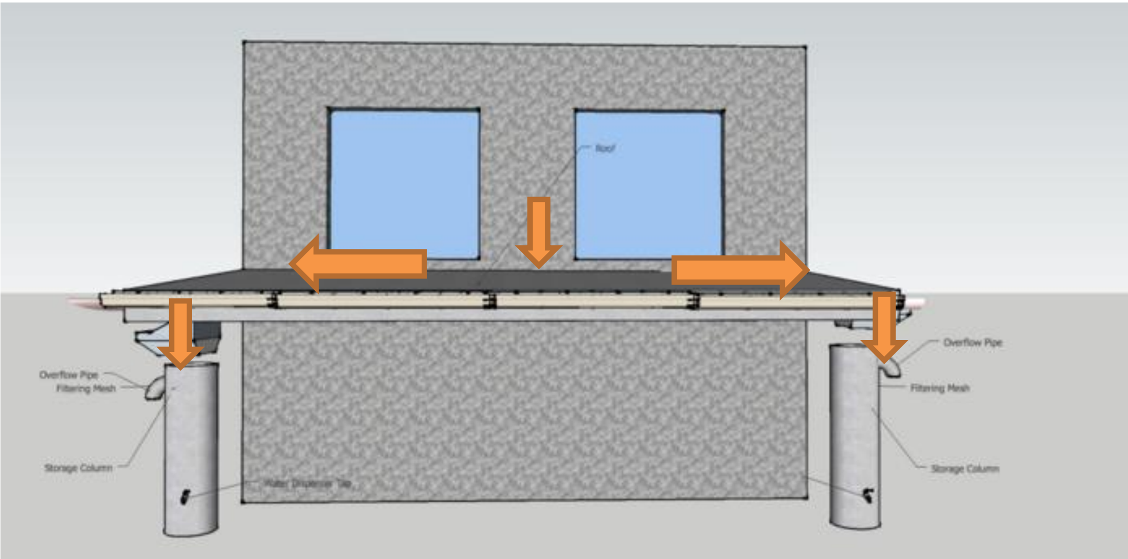

Figure 20: Front view of Propose Rainwater Harvesting System

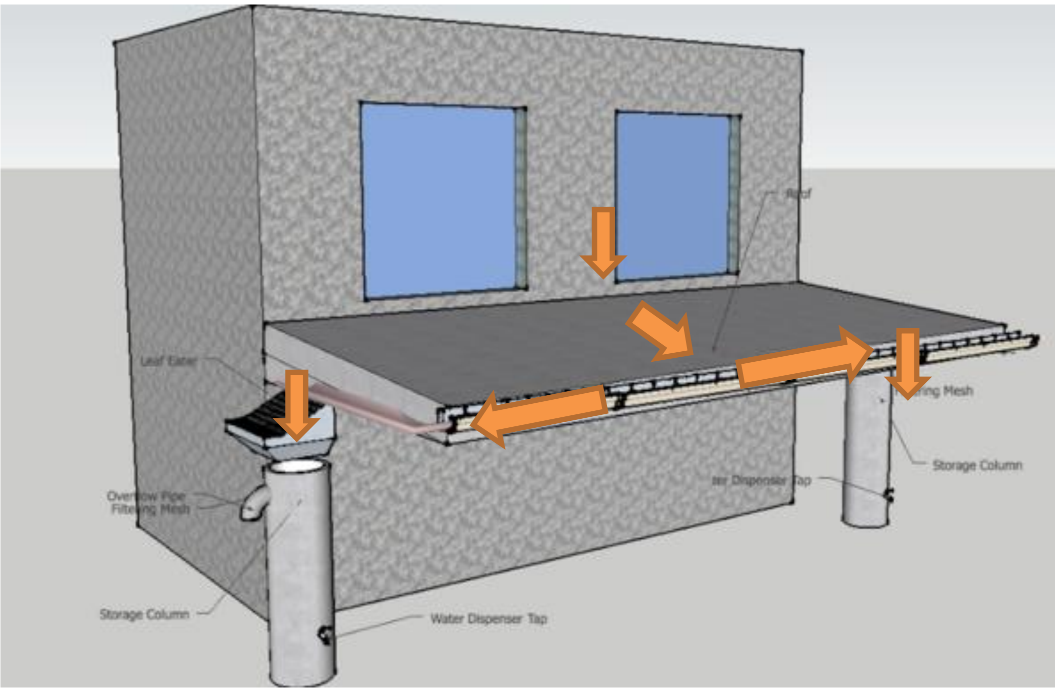

Figure 21: Angular view of Proposed Rainwater Harvesting System

4.1.2 Evaluation of Proposed Rainwater Harvesting System

As one of our solutions is to propose the conservation of a rainwater harvesting system in RVHS, we conducted a study on its manageability and sustainability in helping the school save water. Through these two aspects can feasibility of the proposed solution be concluded.

4.1.3 Manageability of Proposed Rainwater Harvesting System

To evaluate the manageability of the proposed rainwater harvesting systems, three different aspects; technical, economic and social manageability will be investigated. Overall, we found the rainwater harvesting system manageable to implement.

Table 5: Manageability of Proposed Rainwater Harvesting System

Technical Manageability	• There have been many companies that supply rainwater harvesting systems, which includes the tanks, pipes and taps. With current expertise available, it is not difficult to implement a system to harvest rainwater, so it technically can be done. Examples such as TreeLodge@Punggol as well as several secondary schools who received the WEB award have proven that the construction of rainwater harvesting systems is doable. • Furthermore, the water supplied from rainwater exceeds the water demand tremendously, where the total estimated amount of water required weekly in the potential sites for rainwater harvesting system in RVHS is 3360 liters, and the total estimated amount of water that could be collected through the proposed rainwater harvesting system is 99943 liters. • Thus building a rainwater harvesting system is manageable since it is already implemented in many other schools, as well as highly recommended since a tremendous amount of water can be harvested from the abundant rainfall RVHS receives.
Economic Manageability	• Building on existing structures which are roofs incur no additional cost incurred • Simplistic system which serves its purpose of complementing non- potable water usage, materials used are not overly expensive. • Thus it is economically manageable. Furthermore, when cost breakeven is conducted, • **Reduction in Utility Bills from water saved per week:** $0.00117* x 3360(amount of water saved) = $3.93 *Cost of water/liter with accordance to the water tariff in Singapore *Refer to Table 3 for the amount of water saved • **Reduction in Utility Bills from water saved per year (assuming that there are 4 weeks each month):**

	$3.9312 x 4 x 12 = $188.6976 RVHS can amount to a total of $188.70 of savings annually, which amounts to about 10% of her water bills, thus it is highly recommended to implement the rainwater harvesting system.
Social Manageability	• The use of roof as a key component of our design ensures that the system built is situated near irrigation sites/washing of amenities locations (multiple water storage tanks) for convenience sake. • At least 20.5% of the respondents pointed that building rainwater harvesting systems are the best approach, showing that there are people who support the implementation of the rainwater harvesting system. The remaining 79.95% are generally accepting of the idea but chose other options due to their lack of knowledge in this area, for it is still a relatively new concept. • Thus is it socially acceptable to build a rainwater harvesting system • Furthermore, it can directly be promoting the idea of water conservation amongst RVHS students as rainwater harvesting is a measure to conserve water in Singapore.It also has the ability to reduced flooding which occurs frequently due to the overwhelmed drainage system. Flooding has caused much trouble to the students and staffs of RVHS it floods pathways and renders them useless. Additionally, students have to wait for the tracks to dry before running, which will take a long time due to the flooding that occurs on the track from the canteen rooftops, where the drains are often overwhelmed. • Thus it is encouraged to implement a rainwater harvesting system.

4.1.4 Sustainability of Proposed Rainwater Harvesting System

We also used sustainability indicators from Woltersdorf, 2010 to evaluate the feasibility of our proposed solution. It is also important to note that sustainability refers to the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Education, 1987). The three pillars of sustainability are: environmental quality, economic performance and social suitability. Overall, we found the rainwater harvesting system sustainable to implement.

Table 6: Sustainability study of proposed rainwater harvesting system

Sustainability	Evaluation	Solutions (if any)
Environmental	The construction of the system does not involve clearing of land or affecting surrounding ecosystem since it is built on existing structure.	
Economic	The construction of the system sees returns after a period of 6 years and 7 months while negating the maintenance costs that arise alongside. **Cost Breakeven:**	

	1. **Total Material Costs:** $1236.40 (Refer to Appendix K for cost of individual materials.) 2. **Reduction in Utility Bills from Water saved per week:** $3.93 3. **Reduction in Utility Bills from Water saved per year (assuming that there are 4 weeks each month):** $188.6976 4. **Time taken for recovery (in years):** 6.55years ~ 6 years 7 months *Maintenance Cost: The cost breakeven calculation does not take into consideration the maintenance cost over time as the durability of each component of the rainwater harvesting system is non-uniform.	
	There could be an irregularity in the Singapore's rainfall, and this could affect the supply gained from the rainwater harvesting system, as well as the savings.	The proposed rainwater harvesting system is meant to complement the potable water usage of RVHS, not to fully substitute it, hence it is fine for people to complement the usage of rainwater with treated tap water. Besides that, rainwater harvested from the system far exceeds the water usage in irrigation and washing of amenities in the school *(refer to Table 3)* the irregularity in the nation's rainfall pattern will most probably not affect the amount of water harvested.
	Initial high cost from the manufacturing and the implementation of the rainwater harvesting system, which may lead to a long time before benefits are seen. (6 years)	Educate the public on other roles it serves rather than just focusing on the economic aspect of saving water. It serves as flood management as well as an education source.
	Maintenance cost could exceed the reduction in school utility bills due to: • Possible damages to the rainwater harvesting system such as chemicals or animal dropping seeping into the system	Regular maintenance is needed, therefore our system is designed in such a way that it is easy and cheap to maintain.

	• Breeding of Mosquitoes, spread of dengue	Regular checks have to be done to ensure that the chlorine dispenser is functioning well to ensure that the water is not stagnant which prevents breeding of mosquitos.
	• Clogging of filter	The filters will be taken out of the rainwater harvesting system regularly (about once in a week) to be washed. This will be done more regularly during the rainy seasons.
	• Misuse by students.	The school needs to seek the cooperation of the students not to misuse the rainwater harvesting system in order to reduce misuse of the system by students.
Social	The school staffs and students need to be educated on the proper usage of the rainwater harvested.	Users must be warned of the potential health risks when they drink the harvested rainwater; the water quality of rainwater harvested is not up to drinkable water standards and the water is chlorinated. They should also be told that non-compliance to the rules will lead them to facing undesirable consequences.
	It must be ensured that future batches of users are also receptive towards the usage of rainwater for irrigation and mopping.	Users (janitors/gardeners) must be questioned if they are receptive towards the usage of rainwater for irrigation and mopping purposes before they are hired.

4.1.4 Conclusion for Solution 1: Rainwater Harvesting

Our team has decided to look into a rainwater harvesting system in school as the system is not prevalent in Singapore schools. We are also looking at how this proposed feature could be transferred to other schools in Singapore. In order to do so, we propose that the key features of the system be kept (filtering system, leaf eater, and chlorine dispenser).

For Singapore, the nation receives sufficient amount of rainfall which serves as a fundamental basis for rainwater harvesting. In terms of economic sense, the initial installation fees will be covered after a stipulated time frame when cost breakeven occurs. In the social aspect, education is key in ensuring that users adhere to the safety regulations of the system, are receptive to the idea of using rainwater to complement potable water for non-potable usages. The rainwater harvesting system proposed will be a physical feature which does well to showcase its ability to conserve water for our nation in the school premise. This will serve as a constant reminder for everyone to do their part in the water conservation efforts.

Overall feasibility:
Feasible/ Not Feasible

4.2 Discussion for Proposed Solution 2

4.2.1 Evaluating current water conservation efforts in schools by PUB
In order to equip the younger generation with the mindset and knowledge to tackle this water scarcity in Singapore, education serves as an empowering tool. Although this solution may not garner immediate effect, it is a long-term strategy given that these individuals are the users of water and will be the ones securing the water resources which the world currently enjoys, therefore is a successful water demand strategy. From the data collected, PUB's partnerships with schools are commendable and can be further enhanced.

As shown in Figure 10, many students expressed that the concept of water conservation has not been emphasized in their syllabus. However, this could be due to the fact that the students were Secondary 4 students, their batch had not undergone the change in their syllabus which did not include the topic of Water Supply. In light of the interview conducted with the teachers, the topic about water sustainability has recently been incorporated into Secondary 1 Geography curriculum since 2014. The curriculum mainly focuses on reducing water consumption through pricing and public education, increasing water supply through the Four National Taps and conservation through protection of water resources. Therefore, through the new change in the curriculum, teachers could open discussions with their students about the existing water programs and hard measures promoting water conservation in Singapore such as the ABC Water Programme. This would raise the students' awareness of the measures implemented in Singapore and an informal session to give their inputs on the matter.

Furthermore, students are willing to participate and plan water conservation events in schools but few platforms are presented or given by the school and PUB. According to Figure 13, nearly half of the students are positive towards the notion of generating solutions for water conservation efforts and are keen on promoting this cause. However, as shown in Figure 12, at least 20.5% of the students were not satisfied towards pro-activeness for water conservation in RVHS, claiming that there were few opportunities for them to participate in such activities. Many students recognize that water scarcity is a prominent challenge which Singapore faces and are well-versed with the measures taken to mitigate its effects. By understanding the current state of Singapore's water stability, they are more conscious of the need for them to play their part in water conservation and innovation. However, on a student level, there are few opportunities for student-led events apart from those catered to the school's environmental club itself, which is still minimal. However, it is also noted that such a lack of outreach can also be due to the lack of the students' initiative to collaborate with PUB. Additionally, PUB does not have the time and resources to advise the 300 over schools in Singapore personally on water conservation activities. The student's initiative to approach PUB thus plays an important role to ensuring such opportunities are given to the general student body. Thus to effectively rally water conservation efforts in schools, it is crucial to harness students' proactiveness in organizing their self-initiated activities, or for students to take the initiative to actively seek out opportunities and assist PUB in their existing events.

4.2.2 Suggestions to improve Water Conservation Efforts in Schools
To improve PUB's overall outreach to students, there should be an interest-based feedback survey conducted on a yearly basis for students across all schools in Singapore. By receiving direct input from the beneficiaries of the measures, this would facilitate the agency in the identification of key areas which require more in depth focus. A different set of rubrics can be designed to cater to the involvement level of

primary schools, secondary schools and junior colleges. With this yardstick to gauge the success rate of PUB's measures, the agency will be able to review its plans and make more informed improvements in the following year.

PUB can enhance water conservation education by requesting for Operations Managers of each school to keep the student body informed about the water status of their schools by educating them about the overall water usage in the primary areas of (a) toilets, (b) washing of amenities and (c) irrigation. This would enhance the students' understanding of water conservation and their role to play as a user of these water resources. Also, a simplified version of conducting a water audit of school facilities can be developed and taught to the students so as to involve them in a hands-on learning experience of conserving water practically.

Additionally, by borrowing the concept of the annual "earth hour" exercise, on World Water Day, the water supplies in schools (eg. taps, water coolers etc.) will be cut off for duration of one hour. By engaging the entire student population, in this simulation, it serves as a reminder for students to treasure the current precious water resources they utilise, whilst displaying the importance of the rainwater harvesting system as the rainwater harvesting system will come in handy when there is a water shortage. Hence the rainwater harvesting system serves an alternative when there is lack of water supply.

To provide more opportunities for students, PUB can involve students in the planning and execution of such events, since students are generally positive towards the idea of taking part in water conservation campaigns and are willing to play their part in water conservation. They may be more inclined to participate and join the planning of the event as it is not a long-time commitment. Even though they are only involved for a short period of time, there are learning outcomes through this process of planning and this is value-added learning through their experience. This can be accomplished through various Value in Action (VIA) Projects in the water conservation domain for students to practice service learning and equip themselves with a broader understanding of this issue. PUB can also provide logistical support to student led initiatives as well as grants to schools who are actively involved in water conservation efforts, which will result in an increase of student/school led initiatives.

Lastly, PUB should widely publicize their current initiatives for schools by creating a incentivized system whereby schools which participate in a certain number of events will receive incentives or grants. On a more personal level, awards should be given to students who demonstrate a strong passion for water conservation and displayed exemplary actions for this cause.

Overall, PUB's efforts can be further enhanced to bring about more effective changes in educating the student body about water conservation. These enhancements are manageable given PUB's authority as a governmental agency in Singapore. Thus such improvements are feasible and we believe that with these enhancements, the student population will definitely be more aware of water conservations efforts in Singapore.

Overall feasibility:
Feasible/ Not Feasible

4.3 Discussion for Proposed Solution 3

In addition to the rainwater harvesting system as well as suggestions for education for water conservation in schools, our team has investigated the flow rates of various water amenities in RVHS to estimate the potential volume of water that could be saved if current taps are replaced by water-efficient taps according to the water efficiency guidelines from PUB. (‘Good’, ‘Very Good’ or ‘Excellent’). Through the investigation, it allows us to advocate for the maintenance and installation of water-efficient amenities in RVHS.

The cost of water in Singapore is as follows: (PUB, 2016)
Water Tariffs: 1CuM = $1.17, 1L =$0.00117
Water Conservation Tax: 1CuM= $0.35, 1L = $0.000350
Total Cost of 1L of water: $0.00152

4.3.1 Benefits of using excellent water efficient amenities at a marginal basis

Table 7: Benefits of excellent water efficient amenities

Types	Volume of water saved per tap per minute	Cost of water saved per tap per minute	Potential cost of water saved around the school per minute if current taps in RVHS are replaced by ‘Excellent’ taps
Basin Taps Total number: 146	Net Savings for ‘Excellent’ compared to ‘Very Good’: 2L ‘Excellent’ compared to ‘Good’: 4L	Net Savings for ‘Excellent’ compared to ‘Very Good’: $0.00304 ‘Excellent’ compared to ‘Good’: $0.00608	Assuming all current taps are ‘Very good’ : $0.444 Assuming all current taps are ‘Good’: $0.888
Sink Taps Total number: 6	Net Savings for ‘Excellent’ compared to ‘Very Good’: 2L ‘Excellent’ compared to ‘Good’: 4L	Net Savings for ‘Excellent’ compared to ‘Very Good’: $0.00304 ‘Excellent’ compared to ‘Good’: $0.00608	Assuming all current taps are ‘Very Good’: $0.0182 Assuming all current taps are ‘Good’: $0.0365
Total cost of water that can be saved per minute of continuous flow:		Assuming all current taps are ‘Very Good’: $0.462 Assuming all current taps are ‘Good’: $0.925	

Considering that most taps in RVHS are of very good requirements, the saving of $0.35 per minute is thus more realistic. (71%) This is further substantiated by the fact that there is a high human traffic of 2400 students and 80-100 staff members who frequent the toilets on a regular basis. Having able to save $0.35 for every minute of continuous flow of water from taps would as a result accumulate to be a significant amount to be saved.

4.3.2 Disadvantages of not using thimbles at a marginal basis

Thimbles play an important role in water conservation by regulating the flow rates of taps.

Taps with thimbles can save up to 5% more water than taps without thimbles. (PUB, 2015) Typically, taps and showerheads without thimble exceed the ratings given by PUB and have no ratings at all, as there flow rates are simply too much, causing water wastage. Most taps with thimbles fall under 'Excellent' or 'Very good' range, seldom under 'Good' range.

Table 8: Disadvantages of not using thimbles

Types	Volume of water lost compared to taps with thimbles	Cost of water incurred per tap compared to taps with thimbles	Total cost incurred
Basin taps w/o thimbles Total number: 10 Percentage: 7% out of total basin taps	'Excellent': 4L 'Very Good': 2L	'Excellent': $0.00608 'Very Good': $0.00304	'Excellent': $0.0608 'Very Good': $0.0304
Sink Taps w/o thimbles Total number: 2 Percentage: 33% out of total sink taps	'Excellent': 4L 'Very Good': 2L	'Excellent': $0.00608 'Very Good': $0.00304	'Excellent': $0.0122 'Very Good': $0.00608
Showerheads w/o thimbles* Total number: 8 Percentage: 47% out of total showerheads	'Excellent': 15L 'Very Good': 13L	'Excellent': $0.0228 'Very Good': $0.0198	'Excellent': $0.182 'Very Good': $0.158
Total cost incurred:		'Excellent': $0.255 'Very Good': $0.194	

Basin Taps and Sink Taps without thimbles mainly stay around 6 and 8 litres respectively, falling under the good category. However for showerheads, they exceed the ranges tremendously, mostly falling under 20 litres per minute.

4.3.3 Limitations involved and Methods of Improvement

In totality, RVHS is well-equipped with water efficient amenities which are in line with PUB's WELS protocol for schools. However, it is also noted that the process of water saving is hindered by the subsequent poor maintenance of water amenities. Our findings from the water audit has shown that by using these excellent labelled water amenities, $0.35 - $0.70 can be saved per minute of continuous water flow from taps and showerheads. Meanwhile, $0.15 - $0.20 can be saved per minute if thimbles are installed to taps and showerheads which lacked them. As a result, a total of $0.50 - $0.90 per minute of continuous water flow can be saved if enhancement of water facilities were to take place, which translates to a significant amount due to the high human traffic thus frequent usage of toilets in RVHS.

Overall, according to majority of the students identify toilets to be the area which uses the largest proportion of water. This is in line with their preference with enhancement of water facilities being the best solution for water conservation.

4.3.4 Improvements to be made to existing problems and strategies

Problem 1:
Based on the school's documentation it seems that all our water fixtures and appliances are of excellent rating (none fall under "Good" and "No rating" category). However when we re-conducted our water audit, we realised that in reality may be otherwise, there were some fixtures that are actually "good" and "no rating".

Suggestion 1:
WELS/WEB scheme can make it mandatory to check for the conditions of these water appliances i.e. leakages and presence of thimbles after a few years, instead of it being an ad hoc event.
PUB can also subsidise the costs of installation for 'Excellent' water amenities facilities as a significant amount of money can be saved from the installation. This will help us to monitor the effectiveness of these water saving devices and appliances, and get them replaced or repaired promptly.

Problem 2:
Although there were few leakages in the toilets as observed, more efforts is required from the student body prevent such leakages, which may result in the wastage of water.

Suggestion 2:
The school can further utilise the help of students to inform the school management about leakages instead of relying mainly on the school attendants. According to *Figure 19,* most students were unaware of such leakages and did not know who to report to when such cases arises. Therefore, the operation staff can first engage the help of students by being more observant and spotting leakages, and subsequently educating them on who they should report to, such as nearby cleaners. Such messages can be communicated through posters. Students should play an active role in maintaining the conditions of toilets given that they are the main users.

Overall, it takes both the efforts of the school management and student body to collectively manage the state of water amenities in toilets so as to effectively save water.

Overall feasibility:
<u>Feasible</u>/ Not Feasible

5 Conclusions

With the aim to study water consumption patterns and attitudes towards water conservation and evaluate if proposed solutions are feasible and transferable to other schools in Singapore in mind, the team used various methods: a water audit, conducted perception survey and interview, as well as designed a rainwater harvesting system to be situated in River Valley High School.

The solutions proposed were evaluated in this report, and the team deemed all 3 solutions as feasible. This study serves as an insight for other schools in Singapore to step up their water conservation efforts, possibly through the solutions proposed.

In light of future projects, the team recommends that future works could include a study on flooding of school premises due to the heavy rainfall that the nation receives. Students could possibly look into curbing flooding in school by altering the compositions of soil adjacent to concrete grounds to increase infiltration rate and reduce surface runoff.

6 Acknowledgements

This research project would not have been possible without the strong encouragement and willing assistance of many individuals. Henceforth, we would like to extend our utmost gratitude to the following.

We would like to thank River Valley High School's The Environmentally Sustainable Leadership Academy (TESLA) for providing us with this opportunity, as well as providing us with the site of investigation for our research project.

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8 Appendices

APPENDIX A*: Perception Survey for Year 4 Students of RVHS*

Students' Perception towards Water Conservation

Dear Year 4 students, thank you in assisting us in our research project. This questionnaire aims to **find out students' perception towards water conservation in schools through assessment of your understanding, attitudes and behaviours.** Responses are anonymous and the data collated is solely for research purposes, therefore we seek your help to answer the questions as truthfully as possible. Thank you once again!

Please fill in the following information:

A. SCHOOL:

B. AGE:

C. SUBJECT COMBINATIONS:

D. GENDER:

E. NATIONALITY:

The first segment of the questionnaire aims to assess students' perception towards water conservation by finding out your **understanding and attitudes** on this matter. Questions are set in the Singaporean and schools' context.

Singaporean Context:

1) Which of the following do you think is the key environmental issue in Singapore? (Please select only ONE of the options.)

- ☐ Air Pollution
- ☐ Water Pollution
- ☐ Noise Pollution
- ☐ Global Warming
- ☐ Deforestation
- ☐ Water Scarcity
- ☐ Waste Management
- ☐ Energy Efficiency

Others:_________________

2) On the scale of 1 to 5, how far do you agree that Singapore should put in more effort to conserve water?

- ☐ 1, Strongly Disagree
- ☐ 2, Disagree
- ☐ 3, Neutral
- ☐ 4, Agree
- ☐ 5, Strongly Agree

If you agree on this (4-5), why? (You may select more than one option.)

- ☐ Lack of Water Resources
- ☐ Limited Catchment Area
- ☐ Dependence on Foreign Imports for Water
- ☐ Growing Population
- ☐ Cost of Water
- ☐ It is an Environmental Friendly measure
- ☐ Others: _______

If you disagree/remain neutral on this (1-3), why?

- ☐ Sufficient existing water supply
- ☐ No pressure to conserve water at the moment, not a serious issue
- ☐ Water shortage issues do not affect me
- ☐ There is little I can do so why do anything, let governmental agencies such as PUB handle it
- ☐ There are other more pressing environmental issues
- ☐ Others: _______

3) Do you know of any water conservation efforts by PUB in Singapore? (e.g. Water Efficiency Labelling Scheme, ABC Waters, etc.)

- ☐ Yes
- ☐ No

If yes, please state it/them: ___________________________

4) On a scale of 1 to 5, how has the water conservation efforts by PUB increased your awareness?

- ☐ 1; Not At All
- ☐ 2; Very Little
- ☐ 3; Somewhat
- ☐ 4; Quite a Bit
- ☐ 5; A Great Deal

School Context:

1) In your opinion, to what extent should schools work on water conservation? (On the scale of 1 to 5).

   - ☐ 1; Not At All
   - ☐ 2; To a Small Extent
   - ☐ 3; To Some Extent
   - ☐ 4; To a Moderate Extent
   - ☐ 5; To a Large Extent

2) Are you supportive of students' water conservation efforts in schools?

   - ☐ 1; Not Supportive At All
   - ☐ 2; Not so Supportive
   - ☐ 3; Neutral
   - ☐ 4; Supportive
   - ☐ 5; Strongly Supportive

3) Do you know of any water conservation implementations (i.e. practices, schemes, systems) in schools?

   - ☐ Yes
   - ☐ No

   If yes, please state it/them: ___________________________

4) In your opinion, do you think the concept of water conservation has been consciously brought into the school's curriculum?

   - ☐ 1; Not At All
   - ☐ 2; Very Little
   - ☐ 3; Somewhat
   - ☐ 4, Fairly
   - ☐ 5; Largely

5) Which of the following platforms did you learn more about water conservation from?

   - ☐ In school curriculum
   - ☐ Extra-curriculum activities
   - ☐ External sources (e.g. family and friends)
   - ☐ Social media platforms (i.e. Facebook, Instagram, Twitter, etc.)
   - ☐ Newspapers/Magazines
   - ☐ Others: __________________

6) Given that our school's water usage can be classified into
   a. Toilets
   b. Irrigation,
   c. Washing of Amenities,
   d. Others

Rank the respective level of water usage (from the highest to the lowest).

- ☐ Toilets, Irrigation, Washing of Amenities, Others
- ☐ Irrigation, Washing of Amenities, Others Toilets
- ☐ Washing of Amenities, Others, Toilets, Irrigation
- ☐ Others, Toilets, Irrigation, Washing of Amenities

7) Are you aware that potable (drinkable water) is used for irrigation, washing of amenities and even flushing of toilet bowls?

- ☐ Yes
- ☐ No

8) How supportive are you of using potable water for the above uses? (e.g. Irrigation etc.)

- ☐ 1; Not Supportive At All
- ☐ 2; Not so Supportive
- ☐ 3; Neutral
- ☐ 4; Supportive
- ☐ 5; Strongly Supportive

9) Among the suggestions below, which do you think is the best way to approach water conservation in schools?

- ☐ Rainwater Harvesting
- ☐ Education campaigns about water conservations
- ☐ Enhancement of water facilities (water efficient taps and toilet bowls)

The second segment of the questionnaire aims to assess students' perception towards water conservation by finding out your **behavioral patterns** in this matter. Questions are only set in RV's context.

School Context:

1) In your opinion, how often does RV provide opportunities for students to step up in water conservation efforts? (On a scale of 1 to 5)

- ☐ 1; Always
- ☐ 2; Very Frequently
- ☐ 3; Occasionally
- ☐ 4; Rarely
- ☐ 5; Never

2) How satisfied are you towards RV's pro-activeness for water conservation? (i.e. You can assess the pro-activeness through initiatives, events planned, etc.)

- ☐ 1; Very Dissatisfied
- ☐ 2; Dissatisfied
- ☐ 3; Neither Dissatisfied nor Satisfied
- ☐ 4; Satisfied
- ☐ 5; Very Satisfied

Could you list some of your suggestions? ______________________________

3) Would you participate in water conservation campaigns (if any) if given a chance?

- ☐ Yes
- ☐ Not Sure
- ☐ No

4) To what extent are you conscious of being water-savvy in school whenever possible? (e.g. Avoid flushing the toilet unnecessarily, avoid turning on the taps excessively when washing hands, spread the words of conserving water to fellow school mates, etc.)

- ☐ 1; Not At All
- ☐ 2; To a Small Extent
- ☐ 3; To Some Extent
- ☐ 4; To a Moderate Extent
- ☐ 5; To a Large Extent

5) Do you make use of the dual flush toilet system in order to save water?

- ☐ Yes
- ☐ No
- ☐ I do not know how of the existence of the dual flush system
- ☐ Dual flush toilets are faulty
- ☐ Others:___________________

6) Do you report any leakages in toilet facilities?

- ☐ Yes
- ☐ No; I do not notice leakages
- ☐ No; I do not know who to report to when there are leakages
- ☐ No; It is too troublesome for me to do so

APPENDIX ***B: Interview Questions for RVHS Teachers***

TESLA Interview Questions (For teachers)

Aim: To serve as a bridge between teachers and students and assess the current water conservation measures in RVHS.

Main points to cover during interview:

- Assess teachers' knowledge of water conservation and identify their gaps of knowledge
- Their current measures in incorporating the topic of "water conservation" into the school's curriculum
- Assess the effectiveness of current measures
- Enquire about possible future measures
- Their thoughts about rainwater harvesting

1. Do you know of any water conservation efforts done by PUB in Singapore?
   Yes/No
   If yes, please state a few: ____

2. Do you know of any water conservation implementations in RVHS done by PUB?
   Yes/No
   If yes, please state a few: ____

3. What measures have you done to incorporate the concept of water conservation into our school's curriculum? Please elaborate.

4. On a scale of 1 to 5, 5 being the highest and 1 being the lowest, rate the effectiveness of these measures? (Please circle the corresponding number)

   1 2 3 4 5

5. What is your basis of your rating for the effectiveness of these measures? (e.g. Change in student behaviour/ attitude towards water conservation)

6. (Only applied to ratings 1 to 4)
   How do you think you can further improve on these measures?

7. Knowing the limitations of pre-existing measures, what are the possible future measures to incorporate water conservation into our school's curriculum?

8. Among the following suggestions, which do you think is the best way to approach water conservation in schools?
   - Rainwater harvesting
   - Education campaigns about water conservation
   - Enhancement of water facilities (water efficient taps and toilet bowls)
9. (Explain our current plan for rainwater harvesting)
   What are your views about our current idea of rainwater harvesting? What improvements can be made?

10. Being the direct link to students, what message would you want us to put across to the students during education campaigns about water conservation?

APPENDIX ***C: Interview Questions for Operational Manager of RVHS***

<u>Interview Questions</u>

Aim: To find out what is the Operational Manager's understanding, behaviours, and attitudes towards water conservation in schools*.
*some questions are targeted specifically in RV's context

Main points to cover during interview:

- Assess **OM's knowledge of water conservation** and **identify gaps in knowledge**
- Find out **actions taken by the school management** in water conservation
- Assess the **effectiveness of current measures**
- **View towards students' initiatives/projects on water conservation**
- **View towards rainwater harvesting system** in schools/RV
- Ask about **thoughts on possible future measures**

1. Do you know of any water conservation efforts done by PUB in Singapore?
   Yes/No
   Please state a few: ____

2. Do you know of any water conservation implementations in RVHS done by PUB?
   Yes/No
   Please state a few: ____

3. What are the actions taken by the school management in a bid to conserve water in RV?

4. How effective are the measures? (any statistical data to prove that they have been effective/ineffective?)

5. What do you think are other viable solutions that the school management can implement to facilitate water conservation in RV? (top-down approach)

6. Among the following suggestions, which do you think is the best way to approach water conservation in schools (or specifically in RV)?
   - Rainwater harvesting
   - Education campaigns about water conservation
   - Enhancement of water facilities (water efficient taps and toilet bowls)

7. How far do you support student-led initiatives/projects involving water conservation in schools/ specifically in RV?

8. (follow-up on Q4) What are some of the positive outcomes as well as limitations that students face? (*What is the school's stance on issues like water conservation?)

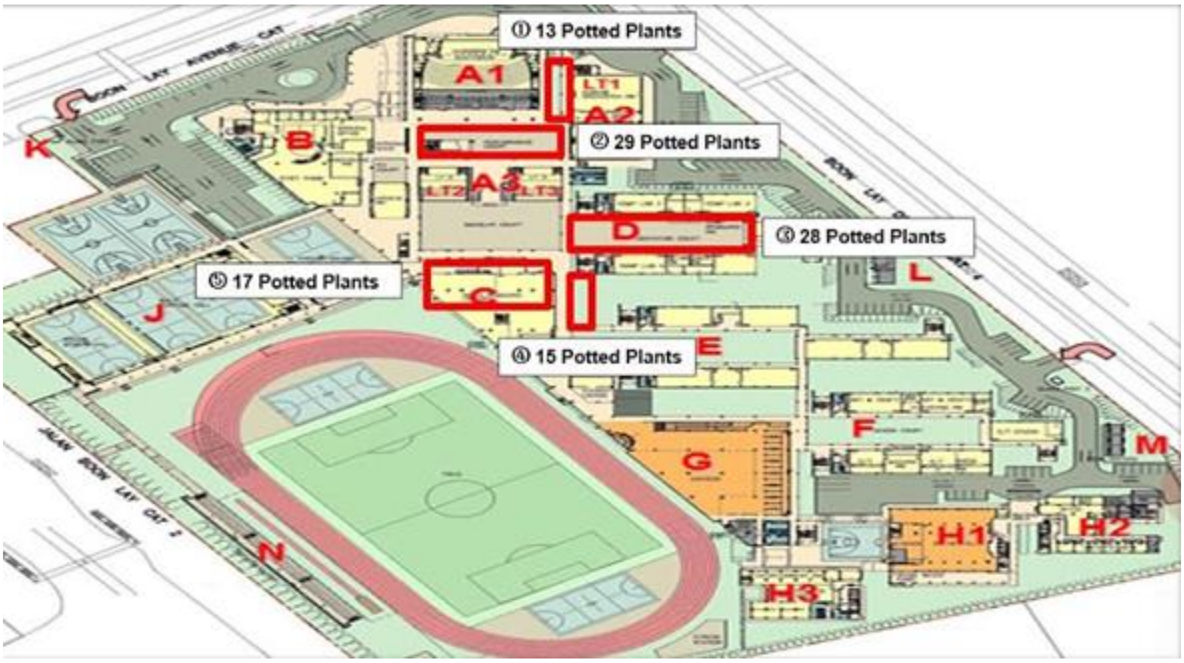
9. (Please refer to the another document attached in the email)
   What are your views about our current idea of rainwater harvesting? What improvements can be made?

10. What message/information do you wish to put across to the students during the education campaign (if we have one) about water conservation? (i.e. educating the students about the water efficient taps and toilet bowls we have in school)

11. Do you think it is a good idea that we implement guidelines for students to follow when they observe leakages in toilets, or find there to be breakdowns of the water facilities in schools? (e.g. faulty flushing system resulting in unnecessary flushing of toilet bowls causing wastage of water)

APPENDIX D: Water Usage for Irrigation and Washing of Amenities in RVHS

Water Usage for Irrigation in RVHS



Location of irrigation sites in RVHS

No.	Venue	Description of vegetation (pictures)	Amount of water used per round (litres/ l)
1.	Outside CO room, near Auditorium	Small potted plants	20
2.	Performance court	Medium-sized potted plants	100
3.	Innovation court	Medium-sized potted plants	100
4.	In front of library	Rectangular potted plants	80
5.	In front of Year 5 and 6 tutorial rooms	Rectangular potted plants	100
Total amount of water used per round:			400400
Total number of cans used for irrigation: 20 cans each time Total amount of water used for irrigation 2014: 15% x 1222.03CuM = 183.30CuM			

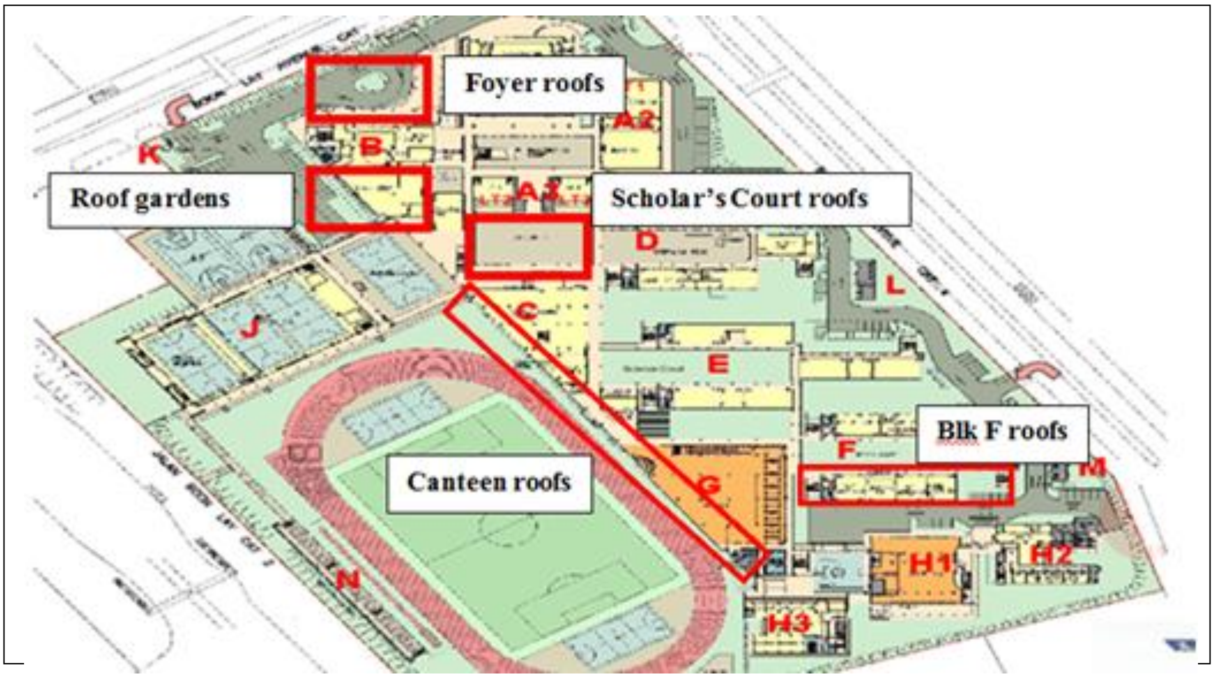
Method	Pouring the pail of water over to the soil, scooping up with smaller container

Regularity	At least twice a week without rain, days with hot weather
Remarks	Plants gets scorched easily under hot sun, hence necessary for frequent irrigation

Water Usage for Washing of Amenities in RVHS

No.	Venue	Description of washing	Amount of water used per round (litres/ l)	Regularity of washing
1.	Big Toilets (12)	Hose flushing (20mins) Mopping (10L)	400 + 30 (5160/day)	Hose Flushing: Once daily Mopping: Thrice daily
2.	Small Toilets (24)	Hose flushing (15mins) Mopping (10L)	300 + 30 (7920/day)	
3.	One room toilets (14) (Staff/ Disabled)	Hose flushing (10mins) Mopping(10L)	100 + 30 (1820/day)	
4.	Canteen	Mopping	120 (240/day)	Twice daily
5.	Canteen Tables	Wiping	10	Once daily
6.	Outside General Office	Mopping	30	Once daily
7.	Big Steps	Mopping	30 (9/day)	Twice weekly
8.	Good News Café	Mopping	30	Once Daily
Total amount of water used daily:			15219	
Total amount of water used for Washing of Amenities 2014: 50% x 1222.03CuM = 611CuM				

APPENDIX E: Pictures of Potential Rainwater Harvesting Sites



Blk F roofs	Scholar's Court roofs
	

Canteen roofs	Roof garden shelters
	 
Foyer roofs	
	

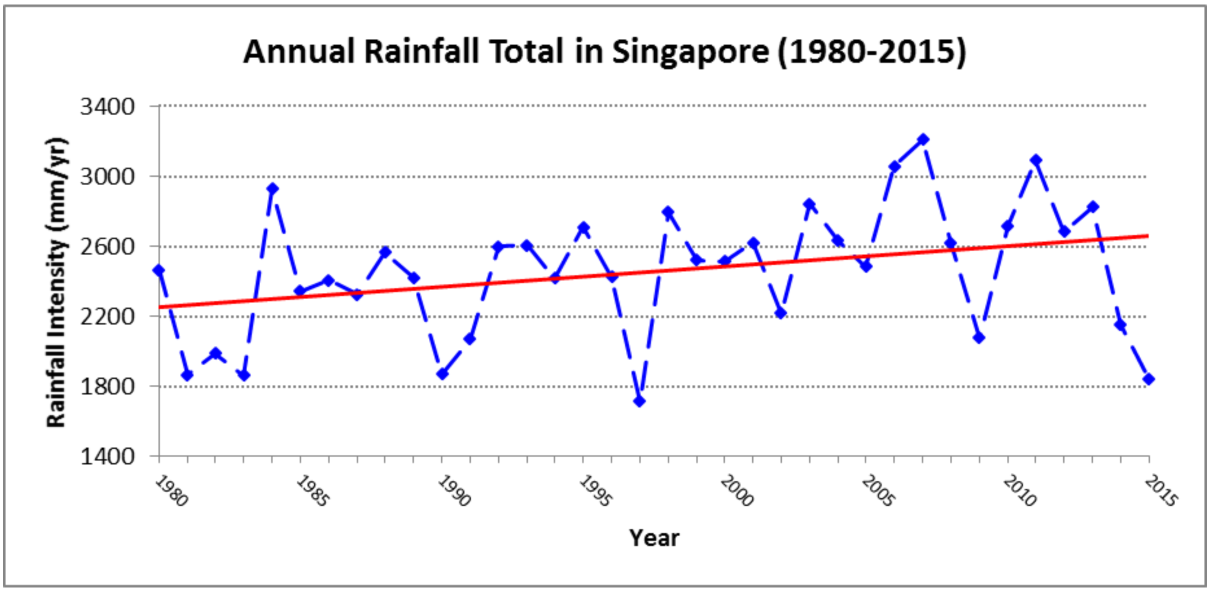
ANNEX F: Areas of the Investigation Sites

Investigation Site	Map Out on Google Earth
Foyer	Using Polygon Data: Area: 661.18m^2
Scholars Court	Using Polygon Data: Area: 119.96m^2
Roof Garden roofs	Using Polygon Data: Area: 602.53
Canteen Roofs	Using Polygon Data: Area: 566.38m^2
Block F 2nd floor shelters	Using Polygon Data: Area: 107.51m^2

APPENDIX G: Global Positioning System (GPS) Device

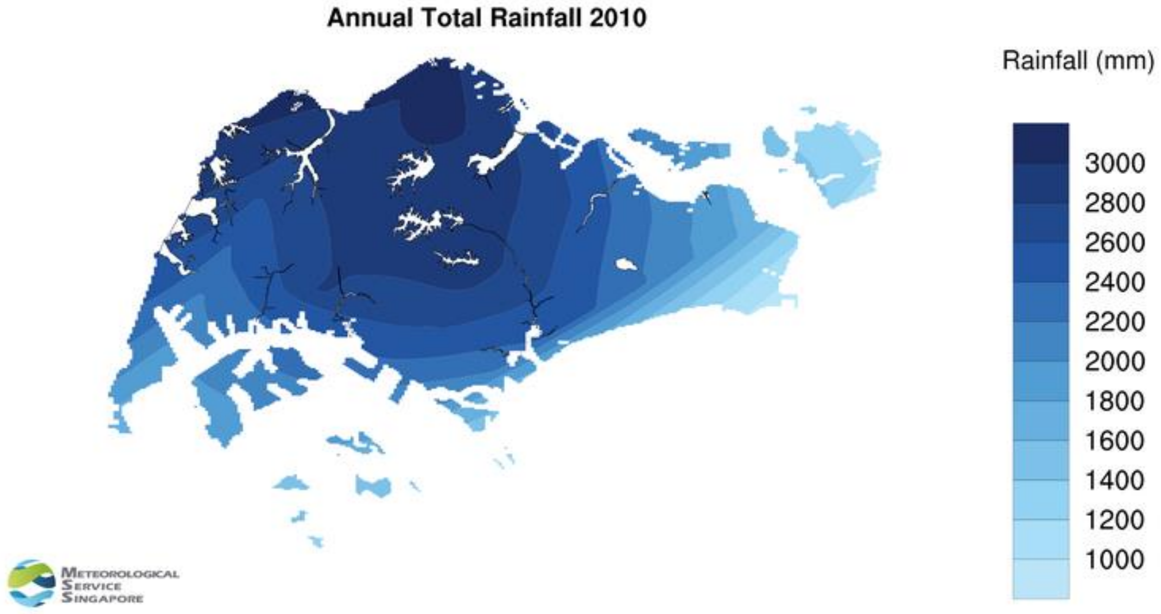
Trimble Juno 3B

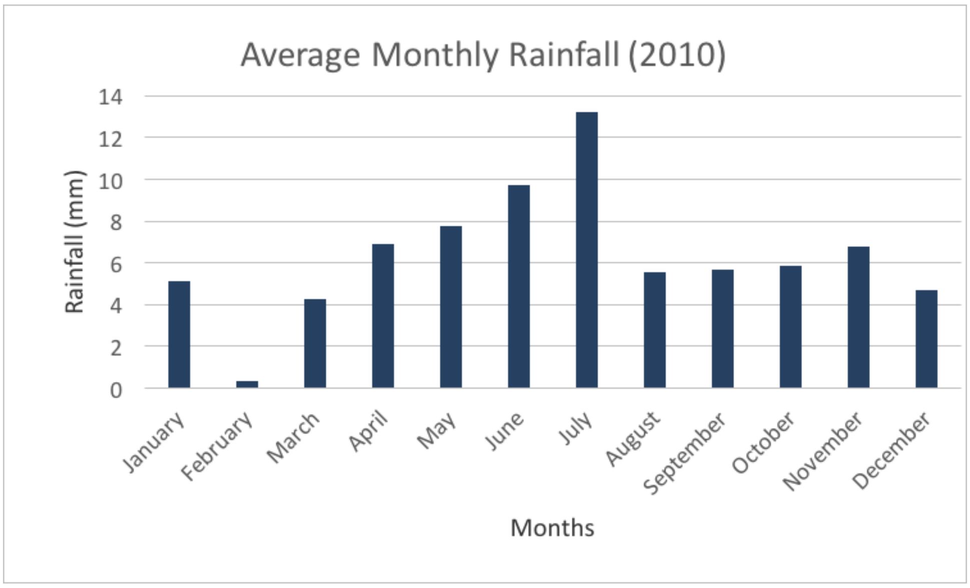
APPENDIX H: Meteorological (MET) Data



Location: Jurong West
Latitude: 1.3455 N
Longitude: 103.6806 E

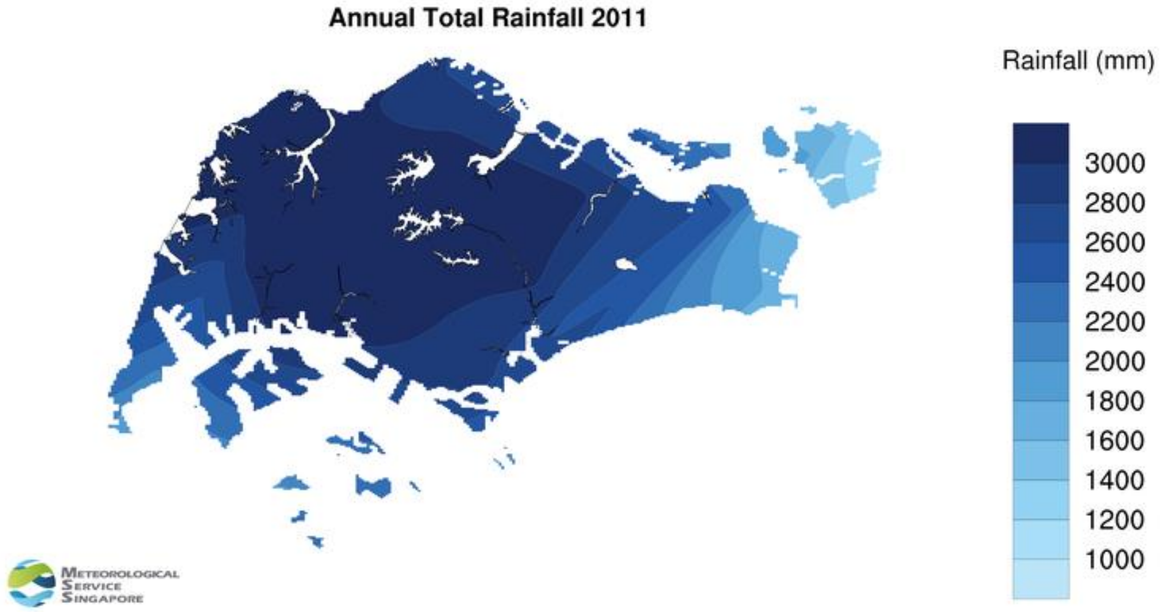
<u>Year 2010</u> (Year when RVHS Campus at Boon Lay is built)

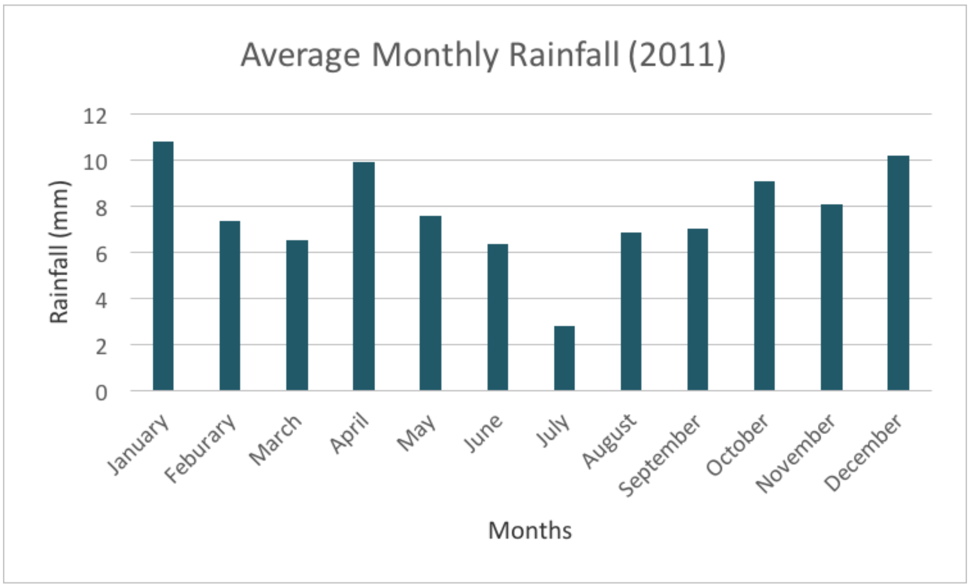




Total rainfall in 2010: 75.95mm

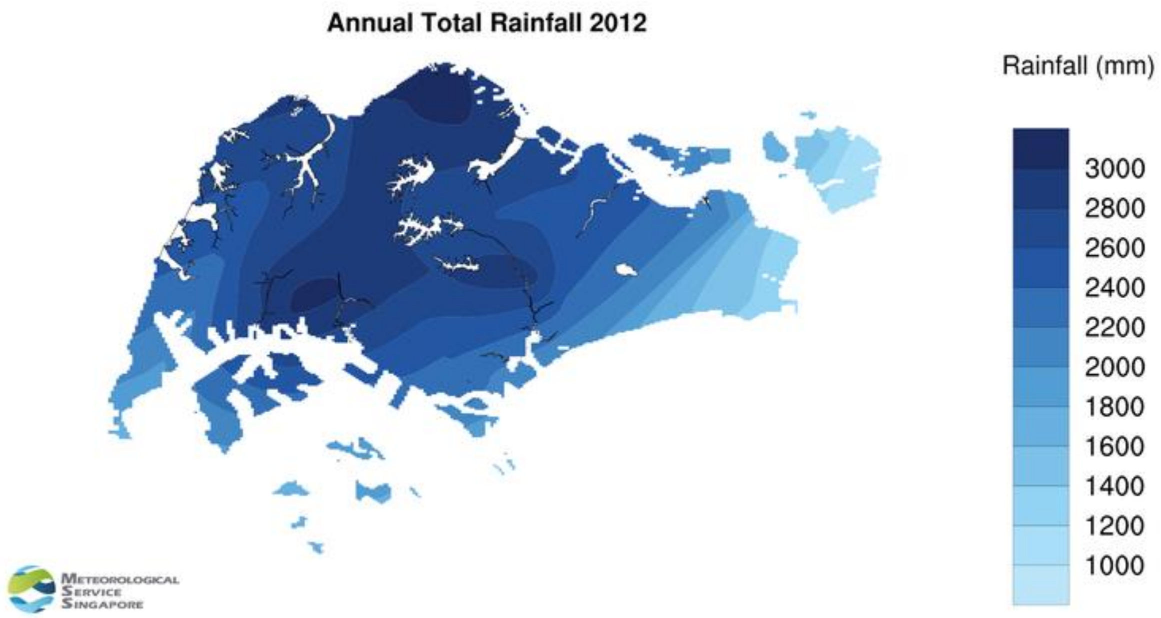
Year 2011

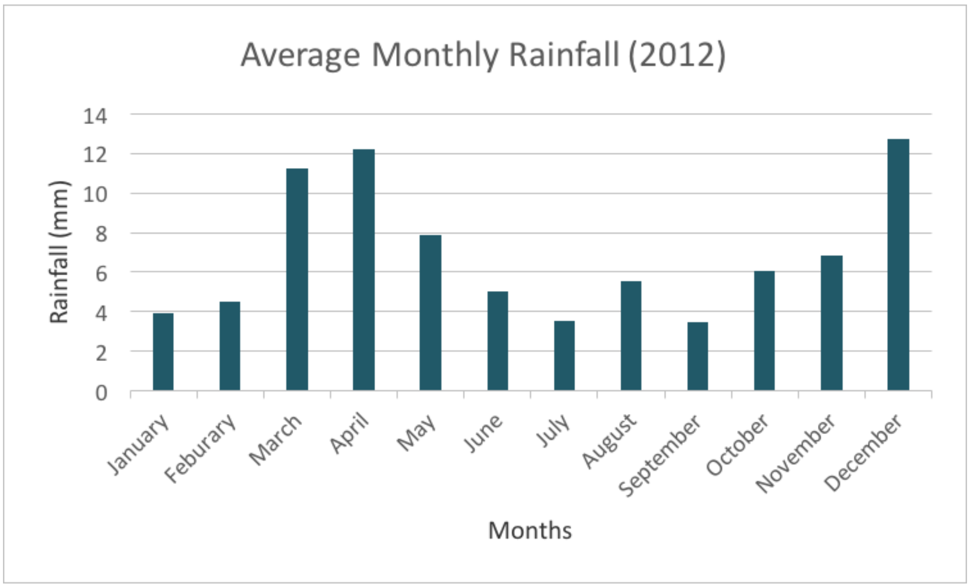




Total rainfall in 2011: 92.7mm

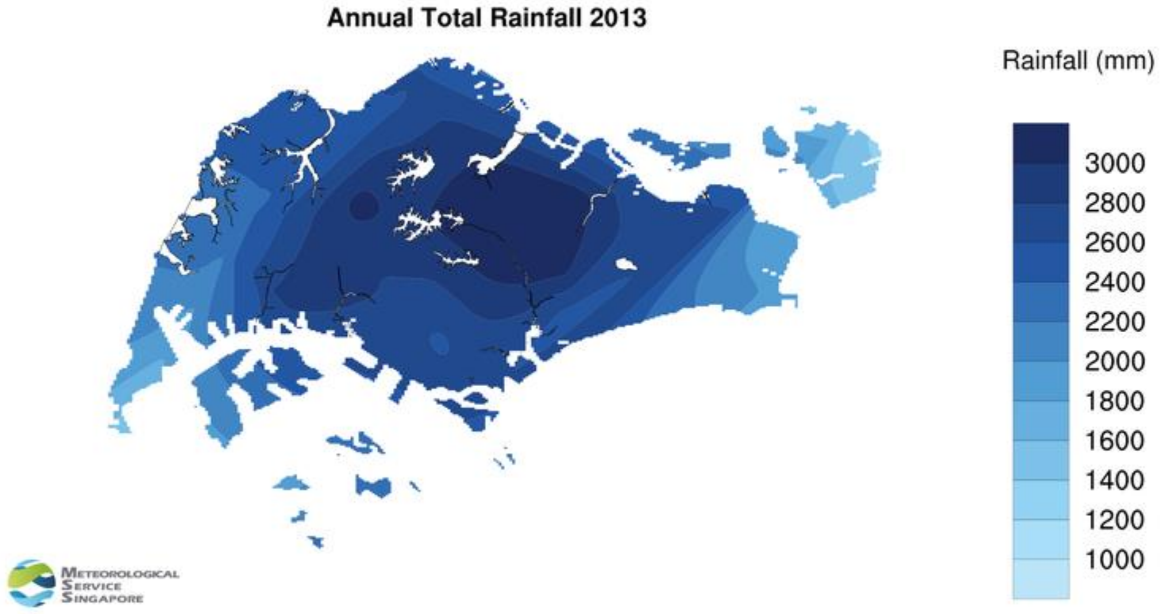
Year 2012

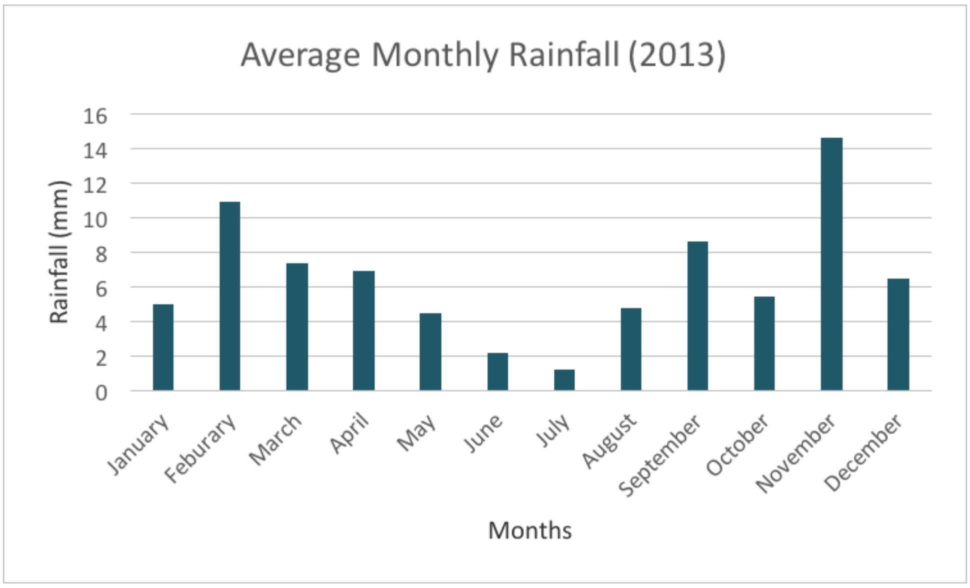




Total rainfall in 2012: 83.15mm

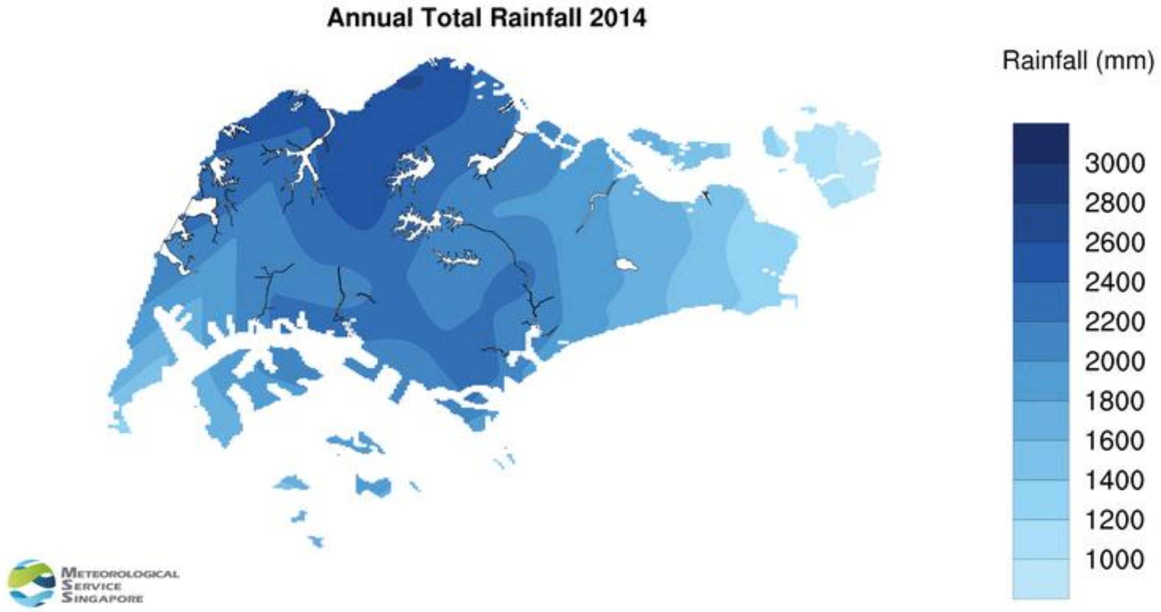
Year 2013

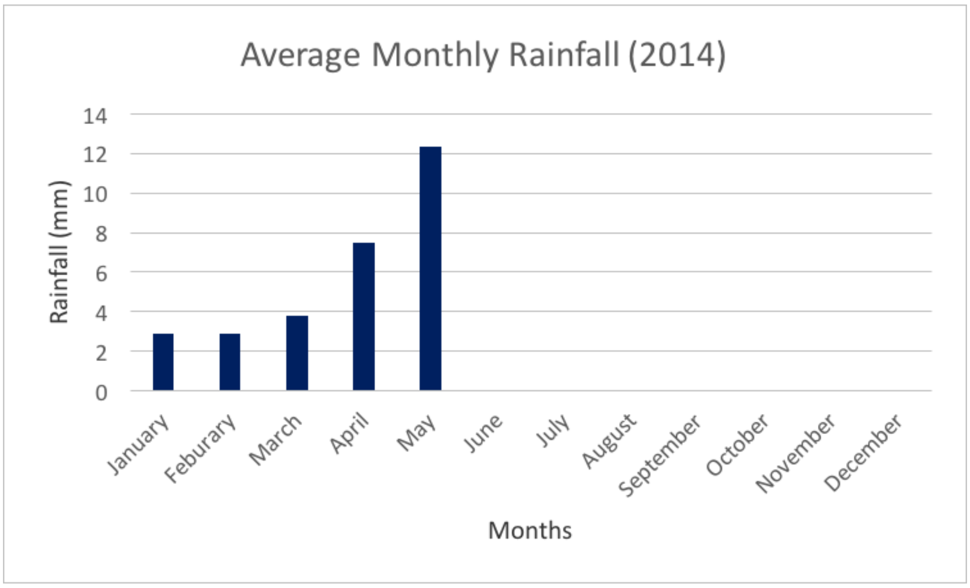




Total rainfall in 2013: 78.01mm

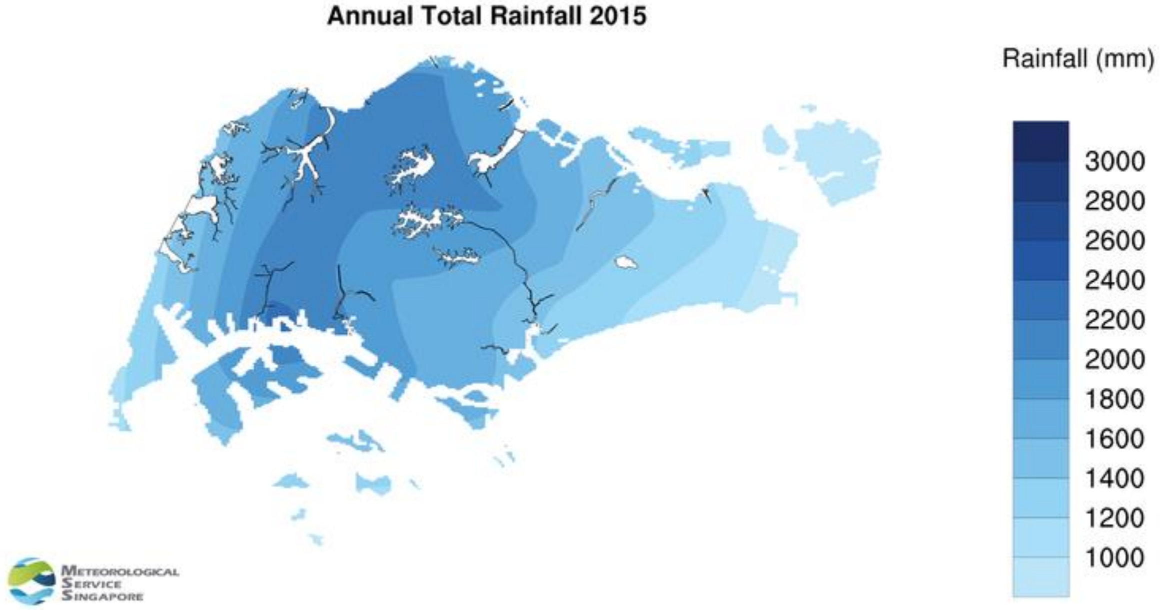
Year 2014

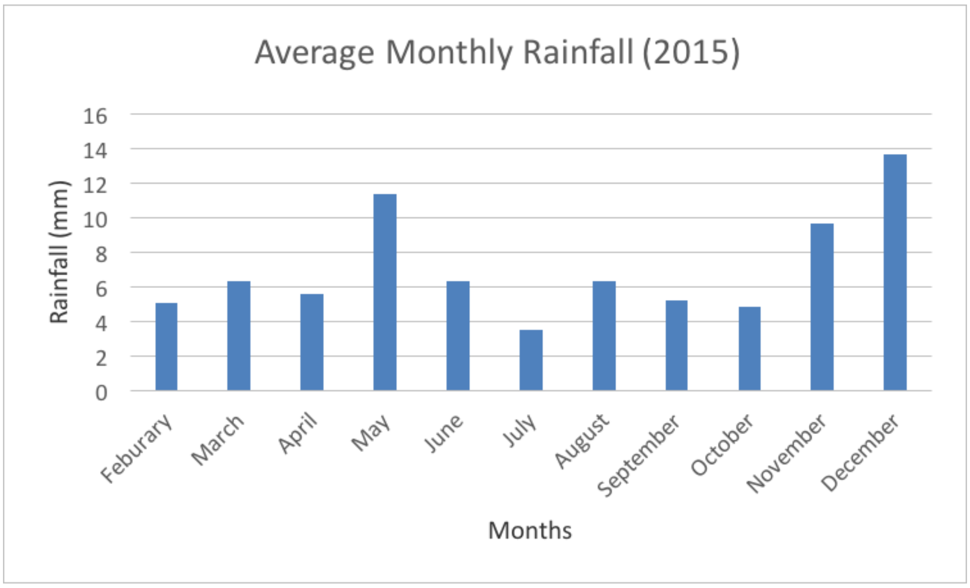




Total rainfall in 2014: Data on website is not complete

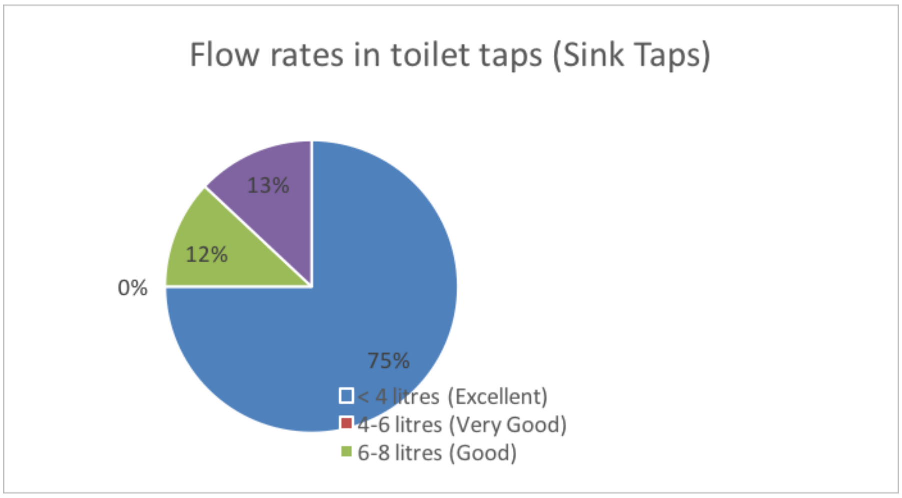
<u>**Year 2015**</u>

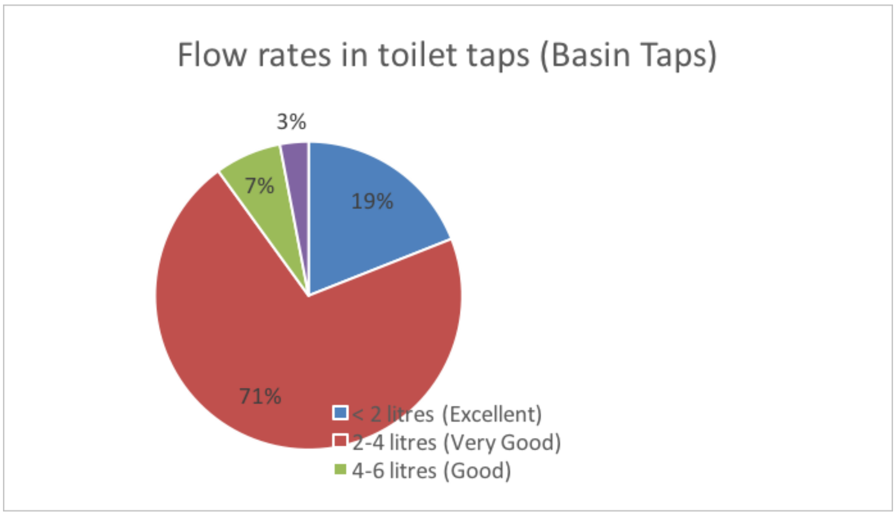




Total rainfall in 2015: Data on website is not complete

APPENDIX I: Flow Rates of Taps and Showerheads





APPENDIX J: Thimble Fixtures in Toilet Taps and Showerheads

Thimbles in Toilet Taps	
With thimble	142
Without thimble	10
Total:	152 taps

Thimbles in Showerheads	
With thimble	9
Without thimble	8
Total:	17 showerheads

APPENDIX K:

Components of Proposed Rainwater Harvesting System	Purpose
Leaf Eater	To prevent leaves from clogging at the filter system of the rainwater harvesting system which may block the flow of water through the polyethene tube.

Filtration System (Filtering Mesh)	Purify the harvested water to improve its quality for usage by students and school cleaners
Storage Column	Direct the flow of water through the tube and collects rainwater at the bottom of the tube during rainy days.
Horizontal Planks (on the slanted roof)	The internal storage column in slanted in such a way to direct the rainwater into the polyethene tube by gravitational force so that the potential for rainwater storage by the polyethene tube can be maximised.
Water Dispenser Tap	Users can collect the rainwater for non-potable usages such as irrigation and washing of facilities.
Overflow pipe	If incoming rainwater exceeds the storage capacity of the polyethene tube, the overflow pipe diverts the water flow away from the storage columns into the drains.
Chlorine Dispenser	Prevents the breeding of mosquitoes, hence preventing potential dengue cases.

Components	**Dimensions**	**Cost**
Polyethene Pillar Tanks Diameter: 700mm = 0.7m Height = 6m	Volume of each pillar tank $= (\frac{0.7}{2})$ x π x 6 = 2.3 m^3 = 2300 litres	$13.80 per pipe Total number of pipes being installed: 10 Total cost: $138
Water Dispenser (Taps)		$7.00 per piece Total number of taps

	N.A	being installed: 10 Total cost: $70
Chlorine Dispenser	N.A	$27.84 per float Total number of chlorine dispensers: 10 Total cost: $278.40
Filtration System (Filtering Mesh)	Area of each filter unit $= (\frac{0.7}{2})^2 \times \pi$ $= 0.385m^2$	Gravel Mesh: $7.70/piece Sand Mesh: $9.60/piece 'Netlon' Mesh: $4.00/piece Geotextile Cloth: $0.360/piece Leaf Eater: $1.93/piece Total number of filter units needed: 10 Total cost: $235.90
Horizontal PVC Planks	Area of each horizontal plank $= 107.51m^2$	$41.93/piece Total number of horizontal planks needed: 10 Total cost: $419.30
Overflow PVC Pipes	Volume of each overflow pipe: $= (\frac{0.7}{2}) \times \pi \times 6$ $= 2.3\ m^3$ = 2300 litres	$9.48/piece Total number of overflow pipes needed: 10 Total cost: $94.80