Update Report for UREC (4-03-2013)

West Wing Water Needs & Rainfall Harvest Potential (3WNRHP) Project[1]

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EXECUTIVE SUMMARY

This study is part of a suite of 6 water projects initiated by the Faculty of Science due to the frequent Water Shortage Days (WSDs) at NUS. This study set out to determine the roof area of Building A at the Mountainside so that we could calculate the volume of rainfall that we could harvest and store in water tanks in order to supplement our water needs (consumption rate) during the WSDs. It also looked at determining the water consumption rate at the West Wing of the NUS-IHE A-Building (WWNIAB). The results show that our consumption rate exceeds the amount of rainwater that we could harvest and store from the period this study took place (March – May 2012). However, the consumption rate determined so far, is too high - perhaps the 2minute urinal flushing time interval could be a cause that is pushing the consumption rate up. To find the actual consumption rate for WWNIAB, there is an urgent need to extend the urinal flushing time interval to one hour.

I. INTRODUCTION

This project is part of a larger Faculty of Science water project called Sustaining Healthy Quality Environments – Ensuring Running Water Systems Project (SHQEERWaSP). SHQEERWaSP is a suite of 6 projects which collectively investigated the real-life water shortage (RLWS) problem at NUS-IHE. SHQEERWaSP aimed to generate empirical findings and recommendations to inform the development of short term and long term strategies to sustain, at all times, a quality, healthy and professional work environment more generally at NUS but especially for the occupants of the West Wing of the NUS-IHE A-Building (WWNIAB). See Appendix 1 for more details about the SHQEERWaS Project.

This project however, the West Wing Water Needs and Rainfall Harvest Potential project - 3WN&RHP (or Project 4 of SHQEERWaSP), focused on determining the water consumption rate at the West Wing of NUS-IHE A Building (WWNIAB) as well as the rainfall harvest potential of the roof area of Building A.

II. PROBLEM STATEMENT

The West Wing Water Needs & Rainfall Harvest Potential project links to SHQEERWaSP through the determination of the water needs (consumption rate) at the WWNIAB whether it can be supplemented by rainwater harvested from the roof top of Building A and stored to be used during water shortage days (WSDs).

Due to the recurrent problem of WSDs at the NUS-IHE A-Building, we the academic staff of the Faculty of Science, as users of the toilets and wash basins as well as the hot water urn and sinks on the West Wing of Building A, are very concerned about the health and safety or OHS implications of these WSDs at our workplace on our health and general well being. More generally, the potential of rainwater harvest at NUS with its abundance of roof surfaces as a sustainable alternative water source in the long term and as a viable back-up water source during the increasingly more frequent SWA-initiated WSDs at NUS-IHE, needs to be empirically investigated for its feasibility as a realistic and practical means of assuring and sustaining a continuous supply of water on campus at all times.
More specifically, Project 4 or the West Wing Water Needs and Rainfall Harvest Potential (3WNRHP) project, chooses the West Wing of Building A at the NUS-IHE as a site for a case study of its water consumption and rainwater harvest potential. Collecting the relevant empirical data will enable the determination of the total water supply (in cubic metres) that is required to adequately meet our water needs at WWNIAB and at the same time determine whether the rainfall that could be

1. A UREC-funded project

harvested from the NUS-IHE A-Building rooftop is sufficient to meet our WWNIAB water demands as an alternative source of water during WSDs.

In summary, the 3WNRHP project is a pilot study of a unit block at the IHE Building A with water needs that are basic to a normal work environment. These basic needs are mainly for sanitary (i.e., flushing toilets/ urinal and washing hands) and drinking purposes.

Two metres were installed to measure the daily water usage or consumption rate for drinking/ sink use and for toilet use at the West Wing of Building A (i.e. for both the first floor and the ground floor). The readings were taken twice a day, at 9.00 am and 5.00 pm. Four First year degree students were selected to take the water metre readings during the course of the first semester, 2012, except the weekends where the lecturers took turns to note down the readings. Altogether there were 13 weeks of data being collected from the two meters. The readings from the meters are given in Table 1. This data was then plotted onto two graphs – one for the daily water usage (Graph 1) and the one for the weekly water usage (Graph 2) at the WWNIAB.

III. RESEARCH PURPOSE

The purpose of theW3NRHP project is twofold: (1) to determine the water consumption needs or water demand of the WWNIAB for a period of 3 months; and (2) to determine whether or not the rainfall capture capacity of, (or a possible rainwater supply from), the NUS-IHE A Building's roof surfaces is able to meet the needs of WWNIAB during WSDs.

Main Objective

To determine the level of water consumption and rainwater harvest potential at the WWNIAB.

Specific Objectives

- To determine the average daily, weekly and monthly water consumption rate at the WWNIAB.
- To determine whether or not rainwater harvest at WWNIAB is sufficient to meet the WWNIAB's water demand during WSDs.

IV. LITERATURE REVIEW

Water availability is decreasing all over the world (Ghisi, *et al*, 2006) including Samoa, yet water is an essential resource for the sustenance of life. In fact 75% of the human body is made up of water (Campbell & Reece, 2007). So apart from our essential biological need for water which is catered for, by drinking potable water, our domestic water-use practices also add to our demand for water. These daily domestic water-use practices include cooking, cleaning, washing (of dishes, utensils, cars, etc.), gardening, showering (including hot water), flushing and for laundry. Samoa being an island nation with limited water resources needs to begin an effective water conservation campaign to change the water-use practices of its inhabitants. This project emerged out of FoS staff members' concerns about occupational heath and safety implications of being exposed to the increasingly frequent WSDs at our workplace. That is no water for sanitary and drinking purposes. At the same time, this project is a step in the right direction to begin the long journey towards linking our water-use practices with the reality of water scarcity.

Rainwater has been shown as an effective alternative source of potable water to supplement the main water supply in many countries (Abdulla & Al-Shareef, 2009; Kahinda, Taigbenu & Boroto, 2007; Zang, *et al*., 2009). Appan (1999) for example, reported that Singapore's Nanyang Technological University (NTU) collects roof water (collection area of 20 ha) to supply toilets for their whole campus, which reduced their potable water consumption up to 12.4%. Ghisi, *et al*., (2006) reported potential potable water savings by using rainwater in residential sectors in Brazil as well.
Rainwater harvesting is defined as "*the small-scale concentration, collection, storage and use of rainwater runoff for productive purposes*" (Kahinda, Taigbenu & Boroto, 2007, p. 1050). However, for the purposes of this study, rainwater harvesting refers to the total amount of rainwater that could

be collected given the roof area of Building A and the calculated rainfall in mm for the NUS-IHE location.

According to the preliminary findings from SHQEERWaS Project 1 which dealt with the situational analysis of Building A, rainwater from the roof of Building A is not collected or stored anywhere in IHE but the rainwater from other Buildings of the IHE are collected, funnelled and stored under Building A in the 324 cubic-metres (or 32 x 10,000L) underground reservoir. Unfortunately, this reservoir is currently not utilised by NUS, hence our heavy reliance on SWA water and the constant Water Shortage Days (WSDs). According to the NUS Director of Physical Facilities – the reservoir under Building A is leaking. Project 1 of SHQEERWaSP has uncovered some other facts about our original backup water system from the blueprints that the Japanese Government had installed when they built the NUS Le-Papaigalagala Campus. (These will be discussed in another paper).
The importance of obtaining our WWNIAB water usage and the rainfall harvest data from the Building A roof top will allow us at the Faculty of Science to make an informed decision based on empirical evidence about the best alternative water supply to source our water needs during the increasingly more frequent WSDs at NUS-IHE

V. METHODOLOGY

Strategy

The 3WNRHP project used a single site research design to collect relevant empirical data to determine the water consumption and rainwater harvest potential at WWINAB. To collect water consumption data, two water meters from Acuflo NZ (i.e., size 1.5 inches (40mm) and the other 1.25 inches (32mm) were purchased and mounted on the feeder pipes upstairs and downstairs for the sinks and toilets at the WWNIAB. To determine the rainwater harvest potential at WWNIAB, NUS rainfall data from Project 2: RHANTE in conjunction with the roof surface area data from the NUS-IHE architectural plans were used. In addition, real time data on the actual occurrences of WSDs from Project 5: WaSINUS and data collected from the mounted Acuflo meters were used to determine the volume of water consumed by the WWNIAB facilities users during WSDs. A comparison of this estimate with potential rainwater harvest from the roof surfaces of NUS-IHE A-Building will address our second specific research objective.

Sample Site & Duration of Data Collection

As mentioned earlier, the site for the case study is the West Wing of the NUS-IHE A-Building which currently houses the water facilities that the FOS staff uses. This study was carried out over a period of 13 weeks or about three months. A follow up study is warranted to further test the validity of this pilot study and to mount more sub-meters to collect further empirical data to verify/ revise our daily/monthly water consumption rate and document our annual consumption rate from all NUS buildings.

Data Collection Procedures

Collecting the data to determine the WWNIAB water consumption was possible through the two mounted water sub-meters. Four first year degree students collected daily readings twice a day and the difference determined the amount of milli-Liters (mL) used per day. These readings determined the water consumption rate for the WWNIAB. The daily readings done twice a day – one in the morning at 9am and the other in the afternoon at 3pm, the 6 hours in between is considered the peak times for water usage by NUS staff and students. The two readings provided three sets of data as follows: 9am – 3pm; 3pm – 9am; plus data from 9am – 9am. Meter readers were given a water meter reading log book to record their daily readings plus the date and time of the readings. Two meter readers alternated on a weekly basis to take turns to read the morning and the afternoon readings each week. Meter readers were advised to make prior arrangements for an alternative reader when they could not take their scheduled reading. This was done well.

The 3WNRHP project used the roof area from the NUS architectural plans from Project 1 plus the rainfall data (both current NUS and 100+ years Apia Area) from Project 2: RHANTE to determine the amount of rainwater we could harvest during rainy days per month.

VI. RESULTS

A) Volume of Water from roof top of Building A

The annual volume of rainwater that we could potentially harvest based on the total roof area, the average annual rainfall and the runoff coefficient can be represented by the formula adapted from Abdulla & Al-Shareef (2009):

$$VR = R \times A \times C/1000$$

where ***VR*** is the annual volume of rainwater that could be harvested, ***R*** is the average annual rainfall for Apia (mm/yr), ***A*** is the total roof area (m^2), ***C*** is the runoff coefficient (non dimensional), and 1000 is the conversion factor from millimetres to metres (mm to m). The runoff coefficient is a value determined by a software or formula to take into account the fact that not all the water expected to fall on the roof area will be collected in the tank. Some may be lost via splashing of water as it hits the roof, or some lost via evaporation, gutter overflows, etc, even the first flush. The first flush of the roof water away from the tank before it is collected in the tank, removes most of the dust and bird droppings that would otherwise contaminate the water in the tank (Zang, *et al*., 2009).

However, in ideal situations we would take the runoff coefficient C as very negligible, hence we will just use the formula without the C. So we determine the volume of water that could be harvested from the roof top of building A, by multiplying the surface area of the roof top with the average rainfall data recorded by the Weather Office at Mulinuu for the past 20 years.

Area surface of roof top of Building A	x	Average Rainfall data in the Apia	=	Volume of Water collected from the roof top

Area surface of roof top of Building A:

The surface area in square millimetres was calculated from the original architectural top plan for building A = **<u>1162088075 mm^2 OR 1,162.1 m^2</u>**

Rainfall data:

The average rainfall data in millimetres per month was obtained from the Weather Office at Mulinuu = (average rainfall for March **103.7 mm**, April **42 mm** & May **57.5 mm**)

The following table (Table 1) shows the number of 10,000 litre tanks that could be filled from harvesting the rainwater from the roof top of building A.

Table 1: Calculated Rainfall Harvest from Roof of WWNIAB from March – May 2012

Month	Calculated Rainfall Harvest from Roof of Building A	Water Tanks Needed to Store
March	**1,162,088,075 mm^2 103.7 mm = 1.21 x 10^{11} mm^3** **1.21 x 10^{11} mm^3** divided 1,000,000 mm^3 per L = **120508 Litres**	**12** x 10,000 L tanks
April	**1,162,088,075 mm^2 x 42 mm = 4.88 x 10^{10} mm^3** **4.88 x 10^{10} mm^3** divided by 1,000,000 mm^3 per L = **48808 Litres**	**5** x 10,000L tanks
May	**1,162,088,075 mm^2 x 57.5 mm = 6.68 x 10^{10} mm^3** **6.68 x 10^{10} mm^3** divided by 1,000,000 mm^3 per L = **66820 Litres**	**7** x 10,000 L tanks

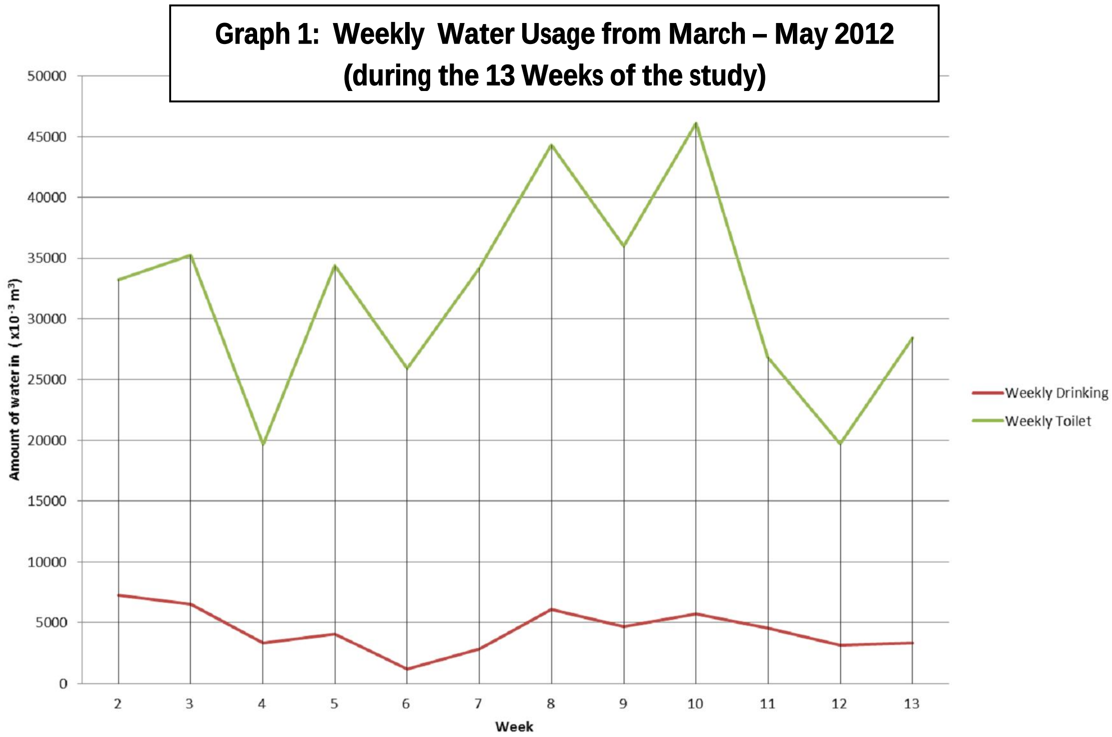
B) Water Consumption at West Wing of building A

Two water metres were installed at the West Wing of building A, to record water consumption for drinking and toilet. The next table (Table 2) shows the volume of water consume for each week in the same monthly period.

Table 2: Volume of Water Consumed at the WWNIAB (in 10,000 Litre tanks) from March – May 2012

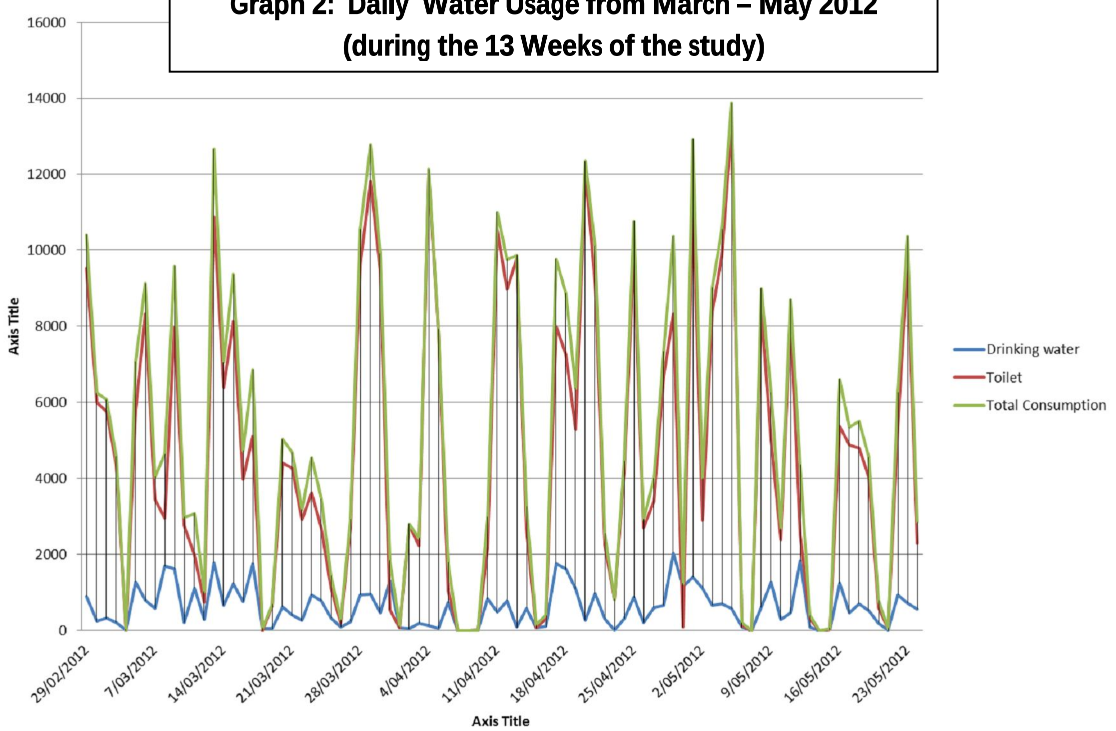
Months	Week	Number of tanks of 10,000 Litres consumed	Total Number of 10,000 litres tanks per month
March	2	4	14
	3	4	
	4	2	
	5	4	
April	6	3	16
	7	4	
	8	5	
	9	4	
May	10	5	17
	11	3	
	12	2	
	13	3	
	14	4	

Graph 1 below shows the weekly water usage data that was collected from the water meters for the West Wing toilets use and sinks use (drinking). The toilet use is high compared to the drinking water.



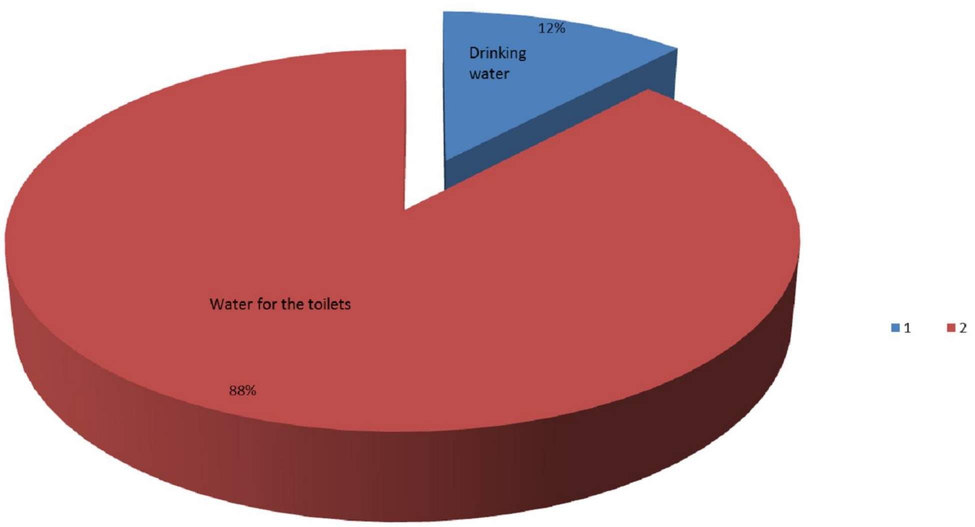
Similarly, Graph 2 below also shows that the daily water consumption is high for toilet use compared to sink / drinking use. The data show that the total daily consumption is almost the same as the toilet use. The pie graph that follows also reflects this.

Graph 2: Daily Water Usage from March – May 2012 (during the 13 Weeks of the study)



As alluded to earlier, Graph 3 vividly illustrates that the bulk of our water usage (80%) is lost through toilet use (which also includes the urinals), only 20% is through the use of the sinks either for washing or drinking. This data was collected from the 2 water meters that we mounted. One was mounted on the drinking water (sink use) and the other was mounted on the toilet use water supply.

Graph 3: Water Usage for 13 weeks of the study



VII. DISCUSSION

The data collected from our sub-water meters enabled us to determine the consumption rate for the WWNIAB toilets and sinks on a daily, weekly and monthly basis as per our project objective 1. Table 1 showed how we calculated the volume of rainwater that we could have harvested from the rainfall during the months of Mar – May 2012. Data from Project 1 such as the dimensions of the roof area from the Building A blueprints were used to determine the roof area of the WWNIAB. Data from Project 2 enabled us to proceed further with the calculation of the actual volume of rainwater we could harvest. This is in line with our project objective 2.

Table 2 showed that the amount of water consumed per month during this study from March – May 2012 in terms of 10,000 Litre tanks were 14 in Mar, 16 in Apr, and 17 in May. Meanwhile, the amount of rainwater that we could only harvest from March – May 2012 in terms of 10,000 Litre tanks were 12, 5, and 7 respectively.

Hence if we used 14 x 10,000 L tanks of water in March and could only harvest 12 x 10,000 L tanks then we are short by 2 x 10,000 L tanks. Likewise, for Apr if we use 16 x 10,000 L tanks and could only harvest from the rain 5 x 10,000 L tanks, then we are very short by 11 x 10,000L tanks. Similarly, in the month of May, we use 17 x 10,000 L tanks of water and yet we could only harvest 7 x 10,000 Litre tanks of rain water, then we are short by 10 x 10,000 L of water.

This clearly shows that based on the data collected from March to May our water demand exceeded the rainfall harvest that we could have stored as an alternative water supply. In other words the consumption rate is too high and the bulk of it went to the toilets (see Graph 3), this was recorded by meter 2 that was mounted on the 32mm pipe for the toilets (See Appendix 4 for exact raw readings).

Now given the remote location of these toilet facilities, not many students and staff use them, hence the actual toilet usage in terms of water should be less. What was noticeable however during this study, is the fact that the full urinal reservoir empties every 2 minutes without any users using the urinal. These observations support the notion that our high WWNIAB toilet use is attributed to unnecessary urinal flushes. This will be the focus of another paper.

Overall, the empirical data from this project (3WNRH) clearly showed that the water needs (consumption rate) at WWNIAB cannot be supplied by the rainfall harvest during the months of the study. The consumption rate for toilet use is too high. It is so high that it is unrealistic hence there is an urgent need to delay the urinal flush time from every 2minutes to say every hour. This will enable us to determine a realistic water consumption rate for WWNIAB. In addition, a more comprehensive 12 months study is advocated to collect sufficient data during the wet and dry season months. The importance of dry season calculations should give us a baseline for the amount of water tanks that we could possibly fill given the average rainfall data for those months.

Hence the data so far can support a case for acquiring backup rainwater tank(s) nearby with a capacity that could meet the demands of the WWINAB during WSDs, provided that we take measures to delay the urinal flush time or control or lower our consumption rate to levels that are sustained by the amount of rainwater that we could harvest.

Our data so far can also be used as the basis to infer the water needs of similar facilities across the Mountain-side and the Ocean-side campuses. Seeking an alternative source of water supply at NUS, to meet staff's and students' needs during SWA-initiated WSDs is becoming a necessity not an option.

VIII. CONCLUSION

To conclude, our findings with respect to our objectives are as follows:

7.1 The daily and weekly consumption rate is fairly high especially for the toilet water supply compared to the sink/ drinking water supply.

7.2 The rainfall harvest during the 13 weeks of the study is insufficient to meet our water consumption rate during WSDs.

Other findings that we have discovered:

7.3 The high WWNIAB water consumption rate is unrealistic given that a bulk of it, is attributed to our toilet water use. Yet these toilet facilities are mainly for staff from FOS, SONHS, and some from FoA with MSS students and a few other students. In other words, the human traffic is not heavy, yet the toilet water usage is very high.

7.4 The WWNIAB urinals flush time interval needs to be extended from the 2 minute intervals during our study period to an hourly basis. (i.e. prolonging the urinal flush time intervals from 2 minutes to 1 hour). The 2 minute urinal flush intervals means that we are wasting a lot of water unnecessarily and we are literally flushing a lot of money down the urinal system.

IX. RECOMMENDATIONS

Although this study was not officially commissioned by the University, the empirical data collected and analysed has inspired us to list a few critical recommendations should NUS need to address this basic staff and student need.

8.1 Need to extend the urinal flush time intervals from 2 minutes to 1 hour in order to obtain our actual consumption rate.

8.2 Need to take this study further in order to get a clear full picture of our consumption rate for each building by installing sub-meters for every building on campus and taking daily readings to be collected for a period of 12 months.

8.3 Need to apply to MNRE to install a permanent rain gauge on campus that the Meteorology Office could monitor on a daily basis, this will also allow us to determine our own average rainfall data on campus.

8.4 If the current urinal's flush interval time cannot be extended to an hour then there is a need to replace the existing urinal system with 3 or 4 single urinal units in order to reduce water usage.

8.5 Fix the existing Building A underground reservoir back-up system. If this was up and running, there would be no need for water tanks to store rainwater to supplement our actual consumption rate during SWA induced Water Shortage Days (WSDs) at NUS.

REFERENCES

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APPENDIX 1: Sustaining Healthy Quality Environments – Ensuring Running Water Systems (SHQEERWaS)

SHQEERWaS is a Faculty of Science project which collectively investigated the real-life water shortage (RLWS) problem at NUS-IHE. SHQEERWaS aimed to generate empirical findings and recommendations to inform the development of short term and long term strategies to sustain, at all times, a quality, healthy and professional work environment more generally at NUS but especially for the occupants of the West Wing of the NUS-IHE A-Building (WWNIAB).

More acceptable and sustainable alternatives need to be explored and researched instead of the status quo where staff and students are expected to seek their own individual solutions (by going outside campus and/or forced to cope with the consequences of water shortage days (WSD) on campus.

Three forces drove our suite of 6 Sustaining Healthy Quality Environments - Ensuring Running Water Systems (SHQEERWaS) Projects at NUS-IHE. The first one is broadly an occupational health and safety issue but more specifically the occupational health hazards we, as professionals, are exposed to during days in which there is no running water available at our NUS workplaces. In the last 12 months there has been a marked increase in the frequency of notices about water shortage days (WSD), a problem which appeared to be directly linked to the capacity of the Samoa Water Authority (SWA) to reliably supply NUS with running water, most importantly, during working hours.

The second driving force is the need to enhance and innovate the delivery of our teaching so that our students are actively engaged with:

- learning experiences that make meaningful connections between classroom learning and real-life situations (authentic, meaningful learning);
- learning experiences whose design and development has been informed by current empirical research with Samoan students and current trends in educational philosophies and theories (research-based teaching and learning);
- solving real-life problems that are environmentally, culturally, and socially situated within the Samoan context (relevance and real-life problem-solving); and
- collaborative research projects with academic staff as supervisors/mentors to develop undergraduate students' skills in the conduct of empirical research and in writing research reports (i.e., problem-solving, research & reporting skills), graduate attributes that are highly recommended for the workplace and for post-graduate studies.

The third driving force is linked to the university's expectations for academics to deliver in terms of finite research publications, quality teaching performance and substantive contributions to the university, community and discipline.

Collectively, the three driving forces as delineated above merged to birth an idea to turn an authentic, problematic situation at NUS-IHE to an opportunity to engage with empirical scientific, mathematical and social research to seek positive, evidence-based solutions to an increasingly worsening real-life situation within our work environment. Consequently, engaging with these projects to generate the required empirical data to inform the development of evidence-based strategies aligns perfectly with one of NUS strategic goals of being responsive to the needs of our community with research-based solutions as published in our NUS Calendar Mission Statement and Strategic Plan.

SHQEERWaS' Problem Statement

The real-life water shortage (RLWS) problem at NUS, generated by the increasing frequency of WSD, created a significant and valuable real-life opportunity for a group of Faculty of Science (FOS) academics to engage with applied research, using their collective expertise and experiences, to address the RLWS problem that was impacting on the sustainability of a quality, healthy and professional work environment more generally at NUS but especially at the West Wing of the NUS-IHE A-Building (WWNIAB).

SHQEERWaS' Main Research Questions

As a consequence of this collective and collaborative effort, a suite of 6 SHQEERWaS Projects was designed and developed to address 6 different aspects of this RLWS problem concurrently with separate, independent data collections but with triangulation of findings at the interpretation-of-data stage to provide a range of evidence-based possible solutions to the following 8 main research questions.

a. What is the existing situation with the running water systems at NUS-IHE and the likely causes of the frequent water shortages? (**Project 1**)
b. What is the nature and status of the Rainwater Catchments or Reservoirs at NUS-IHE? (**Project 1**)
c. What is the nature of the SWA water supply to NUS-IHE? (**Project 2**)
d. What are the existing capacity and potential capacity of rainwater catchments at NUS-IHE? (**Projects 1, 2 & 6**)
e. What is the quality of the water at WWNIAB? (**Project 3**)
f. What is the level and nature of water needs and demands at WWNIAB? (**Project 4**)
g. What are the real and perceived impacts of water shortage days on the occupants of the WWNIAB? (**Project 5**)
h. What is the impact of participating in innovative, authentic mathematical investigations on some undergraduate students' mathematical competence and attitudes towards mathematics? (**Project 6**)

Update on SHQEERWaSP

Project 1	**C**urrent Running **W**ater **S**ystems and **R**ainwater **H**arvesting at NUS-IHE (**CRWSRH**) **– *Team***: *Jonathan Yoshida & Faafetai Kolose*	**Status:** @ the Final Write Up Stage
Project 2	**R**ainwater **H**arvesting **Al**ternative at **N**US-IHE: **T**he **E**quilibrium (**RHANTE) - *Team:*** *Leala Fitu and Aperaamo*	**Status:** Unknown
Project 3	**B**acteriological **Q**uality of **P**otable **W**ater **S**upply at the National University of Samoa (**BQPWS**) – ***Team***: *Faainu Latu, Patila Malua-Amosa*	**Status:** @ the Final Write Up Stage
Project 4	**W**est **W**ing **W**ater **N**eeds & **R**ainfall **H**arvest **P**otential (**3WNRHP**) - ***Team***: *Desmond Lee Hang & Faafetai Kolose*	**Status:** @ the Final Write Up Stage
Project 5	Water Shortage Impacts at NUS (**WaSINUS**) - ***Team***: *Foilagi Maua- Faamau & Elisapeta Mauai*	**Status:** Unknown
Project 6	**S**tudent Teachers' **A**uthentic **M**athematical **I**nvestigations and the **I**mpact on their Mathematical **C**ompetence & **A**ttitudes **(SAMIICA) - *Team:*** *Professor Karoline Afamasaga-Fuata'I & Lumaava So'oa'emalelagi*	**Status:** Completed Write Up. Already published

APPENDIX 2: Background Information on Researchers

The principal researcher, Dr Desmond Lee Hang's research experience is confined to the projects he has undertaken as part of the requirements for his higher education qualifications. He is currently a lecturer in biology at the Faculty of Science and his interest in this project emanates from his biology background and hobby as a handyman at home.

The associate researcher, Faafetai Kolose has done research for his undergraduate degree final year courses. He was also involved in a UREC-funded renewable energy research as an associate researcher. His involvement in that study has led to his current interest in wind as a renewable energy resource. Currently, the associate researcher is a lecturer in physics at the Faculty of Science.

APPENDIX 3: Limitations of the Study

The rainfall data is based on a monthly basis and this is misleading because it could be that in one or two days of that month it poured so much water that is reflected in the data but on other days no water at all. Hence there is a need to obtain the actual daily amount of rainfall.

This is a case study hence the data we collected from our meters is only for a short period of time (13 weeks).

The data was only collected from the West Wing of Building A (WWINAB) not including the other toilets and sinks around Mountainside or Oceanside. Hence, the consumption rate is more than the one we determined from our empirical data and we know this from the utility water reports that are tabled at VCC.

Rainfall data we used is that of Apia which was collected at Mulinu'u but the actual rainfall at Le Papa-i-galgala campus may well be very different from Mulinu'u.

The rainfall harvest values calculated have uncertainties due to local environmental factors that contribute to the loss of water such as evaporation rate, absorption rate, rainfall intensity, effective surface area and wind (Appan, 1999).

APPENDIX 4: Actual Water Meter Readings Collected

Table 1: Daily Reading for Water Usage for Drinking and Toilet

				Meter 1 Pipe size (40 mm)	Meter 2 Pipe size (32 mm)
Week	**Day**	**Date**	**Time**	**Drinking Water**	**Toilet Water**
1	Sunday	26/02/2012	N/A	N/A	
1			N/A	N/A	
1	Monday	27/02/2012	4.35 pm	5856	136456
1			N/A	N/A	
1	Tuesday	28/02/2012	8.52 am	6112	138343
1			4.48 pm	6893	145774
1	Wednesday	29/02/2012	9.04 am	7011	147862
1			4.50 pm	7170	152584
1	Thursday	1/03/2012	9.08 am	7254	153862
1			4.39 pm	7503	158271
1	Friday	2/03/2012	9.13 am	7571	159615
1			4.37 pm	7748	163919
1	Saturday	3/03/2012	9.00 am	7786	163971
1			5.00 pm	7796	163977
2	Sunday	4/03/2012	9.00 am	7796	163977
2			5.00 pm	7799	163977
2	Monday	5/03/2012	9.00 am	9063	169782
2			5.00 pm	9307	174771
2	Tuesday	6/03/2012	10.40 am	9851	178119
2			5.05 pm	9981	181072
2	Wednesday	7/03/2012	9.05 am	10438	181571
2			4.30 pm	11714	183350
2	Thursday	8/03/2012	9.07 am	12130	184519
2			5.00 pm	13571	191141
2	Friday	9/03/2012	9.05 am	13741	192502
2			4.42 pm	13941	195244
2	Saturday	10/03/2012	9.00 am	13954	195264
2			5.00 pm	15065	197228
3	Sunday	11/03/2012	9.00 am	15069	197228
3			5.00 pm	15074	197228
3	Monday	12/03/2012	9.00 am	15353	197957
3			5.00 pm	16204	199057
3	Tuesday	13/03/2012	9.00 am	17137	208839
3			4.45 pm	17522	214436
3	Wednesday	14/03/2012	9.10 am	17802	215226
3			5.00 pm	18718	221776
3	Thursday	15/03/2012	8.44 am	19032	223361
3			4.40 pm	19243	226441
3	Friday	16/03/2012	8.43 am	19789	227332

3			4.30pm	20637	230281
3	Saturday	17/03/2012	10.00 am	21540	232447
3			6.30 pm	21569	232447
4	Sunday	18/03/2012	9.30 am	21598	232447
4			6.00 pm	21615	232447
4	Monday	19/03/2012	9.00 am	21641	233090
4			4.00 pm	21894	235833
4	Tuesday	20/03/2012	9.30 am	22265	237491
4			4.10 pm	22469	240169
4	Wednesday	21/03/2012	9.00 am	22661	241768
4			4.35 pm	22879	243722
4	Thursday	22/03/2012	9.25 am	22921	244680
4			4.15 pm	23208	246721
4	Friday	23/03/2012	10.13 am	23846	248307
4			4.20 pm	24548	249893
4	Saturday	24/03/2012	9.25 am	24622	250993
4			6.15 pm	24954	252093
5	Sunday	25/03/2012	9.26 am	24954	252093
5			6.25 pm	24954	252093
5	Monday	26/03/2012	9.10 am	25047	252283
5			4.45 pm	25234	254685
5	Tuesday	27/03/2012	8.45 am	25277	254979
5			4.50 pm	25863	260477
5	Wednesday	28/03/2012	9.10 am	26218	264592
5			4.47 pm	26659	272996
5	Thursday	29/03/2012	8.57 am	27168	276422
5			4.46 pm	27533	283011
5	Friday	30/03/2012	9.00 am	27632	285870
5			4.38 pm	28492	285980
5	Saturday	31/03/2012	10.15 am	28933	286413
5			5.25 pm	28996	286474
6	Sunday	1/04/2012	9.15 am	28996	286474
6			6.15 pm	28996	286474
6	Monday	2/04/2012	10.00 am	29039	289232
6			5.30 pm	29154	290345
6	Tuesday	3/04/2012	9.00 am	29234	291467
6			5.00 pm	29299	295678
6	Wednesday	4/04/2012	9.00 am	29365	303466
6			6.00 pm	29409	308768
6	Thursday	5/04/2012	9.35 am	29421	311341
6			6.00 pm	29637	312391
6	Friday	6/04/2012	10.00 am	30151	312391
6			5.20 pm	30151	312391
6	Saturday	7/04/2012	9.00 am	30151	312391
6			5.00 pm	30151	312391
7	Sunday	8/04/2012	9.00 am	30151	312391

7			5.00 pm	30152	312392
7	Monday	9/04/2012	9.00 am	30152	312392
7			5.00 pm	30465	313445
7	Tuesday	10/04/2012	9.00 am	30978	314558
7			5.00 pm	31389	321086
7		11/04/2012	9.00 am	31452	325089
7			4.41 pm	31689	331979
7	Thursday	12/04/2012	8.41 am	32237	334069
7			4.31 pm	32298	342796
7	Friday	13/04/2012	8.50 am	32324	343844
7			4.42 pm	32885	346237
7	Saturday	14/04/2012	9.00 am	32913	346512
7			5.00 pm	32978	346589
8	Sunday	15/04/2012	9.00 am	32978	346589
8			5.00 pm	32978	346589
8	Monday	16/04/2012	9.00 am	33078	346887
8			5.00 pm	33542	349955
8	Tuesday	17/04/2012	9.45 am	34844	354886
8			5.32 pm	35566	359663
8	Wednesday	18/04/2012	9.00 am	36459	362133
8			5.00 pm	37152	364558
8	Thursday	19/04/2012	9.10 am	37542	367421
8			3.02 pm	37690	372981
8	Friday	20/04/2012	9.01 am	37813	379502
8			5.00 pm	38069	382767
8	Saturday	21/04/2012	9.30 am	38777	388649
8			5.00 pm	39089	390894
9	Sunday	22/04/2012	8.15 am	39089	390894
9			5.20 pm	39089	390894
9	Monday	23/04/2012	8.58 am	39101	391703
9			4.39 pm	39371	395068
9	Tuesday	24/04/2012	8.36 am	39410	395855
9			4.43 pm	40179	402773
9	Wednesday	25/04/2012	8.40 am	40274	405761
9			4.30 pm	40432	407269
9	Thursday	26/04/2012	8.52 am	40483	408468
9			4.47 pm	41029	410520
9	Friday	27/04/2012	9.11 am	41087	411867
9			5.00 pm	41567	414632
9	Saturday	28/04/2012	9.00 am	41753	418547
9			5.00 pm	42043	425781
10	Sunday	29/04/2012	9.00 am	43789	426874
10			5.00 pm	43789	426889
10	Monday	30/04/2012	9.00 am	44941	426955
10			4.25 pm	46024	436487
10	Tuesday	1/05/2012	9.45 am	46354	438471

10			4.00 pm	46901	439608
10	Wednesday	2/05/2012	9.05 am	47472	441360
10			3.30 pm	47868	444705
10	Thursday	3/05/2012	9.10 am	48130	449728
10			4.20 pm	48285	455344
10	Friday	4/05/2012	9.00 am	48833	459575
10			5.00 pm	49015	461275
10	Saturday	5/05/2012	9.00 am	49412	472879
10			5.00 pm	49496	472998
11	Sunday	6/05/2012	9.00 am	49496	472998
11			5.00 pm	49496	472998
11	Monday	7/05/2012	8.45 am	49496	472998
11			4.45 pm	49993	479544
11	Tuesday	8/05/2012	8.50 am	50106	481392
11			4.40 pm	51055	483806
11	Wednesday	9/05/2012	9.00 am	51380	486387
11			4.07 pm	51562	488019
11	Thursday	10/05/2012	9.00 am	51671	488769
11			4.40 pm	51958	493341
11	Friday	11/05/2012	10.00 am	52130	497021
11			4.45 pm	52335	499215
11	Saturday	12/05/2012	9.00 am	53956	499546
11			5.00 pm	54045	499712
12	Sunday	13/05/2012	9.00 am	54053	499845
12			5.00 pm	54053	499845
12	Monday	14/05/2012	9.00 am	54053	499845
12			5.00 pm	54054	499866
12	Tuesday	15/05/2012	9.20 am	54083	499868
12			4.05 pm	54202	503275
12	Wednesday	16/05/2012	9.05 am	55327	505231
12			8.26 pm	55542	507589
12	Thursday	17/05/2012	9.15 am	55784	510113
12			5.00 pm	55946	511256
12	Friday	18/05/2012	9.10 am	56490	514909
12			5.00 pm	56975	518432
12	Saturday	19/05/2012	9.00 am	57015	518946
12			5.00 pm	57205	519542
13	Sunday	20/05/2012	9.00 am	57205	519542
13			5.00 pm	57205	519542
13	Monday	21/05/2012	9.15 am	57213	519588
13			4.58 pm	57711	523365
13	Tuesday	22/05/2012	8.42 am	58155	524911
13			4.58 pm	58680	531415
13	Wednesday	23/05/2012	9.02 am	58878	534552
13			4.53 pm	59134	536266
13	Thursday	24/05/2012	9.01 am	59440	536844

13			4.52 pm	60239	540293
13	Friday	25/05/2012	8.45 am	60464	541331
13			4.01 pm	60532	547997
13	Saturday	26/05/2012		N/A	N/A
13				N/A	N/A