

**BRIDGING THE GAP BETWEEN THEORY AND PRACTICE OF GREEN BUILDING WATER SYSTEMS
AT THE UNIVERSITY OF BRITISH COLUMBIA, CANADA**

by

SAHAR BADIEI

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ADVANCED STUDIES IN LANDSCAPE ARCHITECTURE

in

THE FACULTY OF GRADUATE AND POSTDOCTORAL STUDIES

THE UNIVERSITY OF BRITISH COLUMBIA

(Vancouver)

December 2017

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Abstract

The sustainability of the built environment involves efficient performance of all related systems, including the water system. The way water is consumed in urban areas is proven to be inefficient and unsustainable. Although the green building industry has taken profound steps to reduce water footprints in the built environment, a significant gap is observed in predicted and actual performance of water systems in some green awarded projects. Therefore, this thesis aims to review, question and redefine water systems on paper and in practice of green building in the University of British Columbia (UBC) Vancouver campus. Water strategies within current green building practice are studied to find the performance gaps. The Center for Interactive Research of Sustainability (CIRS) building was researched as a case study through different lenses of academics, planners, designers, builders and operators, who were involved with this project.

This research finds a number of successes and areas for improvement in water strategies of the CIRS project. The performance gaps are due to a lack of a comprehensive water plan for UBC, policies and incentives for water pricing, and not engaging all stakeholders in early stages of the process. Finally, this research recommends improving campus-wide water policies and plans and enhancing collaboration and integration throughout all phases of building projects. These strategies can bridge the gap between theory and practice of water systems in future green building projects at UBC.

Lay Summary

Water is life, however, the way water is consumed in urban areas is proven to be inefficient and unsustainable. Although the green building industry has taken profound steps to reduce water footprints in the built environment, a significant gap is observed in predicted and actual performance of water systems in some green awarded projects. Therefore, this thesis aims to review, question and redefine water systems on paper and in practice of green building in the University of British Columbia (UBC) Vancouver campus.

Preface

This thesis is original, unpublished, intellectual product of the author, S.Badiei.

Case study analysis in Chapter 3 was also designed, carried out, and analyzed by the author solely using publicly available sources.

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List of Abbreviations

CAP, Climate Action Plan

CIRS, Center for Interactive Research of Activities

GBP, Green Building Plan

LBC, Living Building Challenge

LEED, Leadership in Energy and Environmental Design

SAS, Solar Aquatic System

UBC, University of British Columbia

USI, Urban Sustainability Initiatives

WAP, Water Action Plan

WES, Water and Energy Services unit

Acknowledgements

I would like to express my appreciation to my advisor Professor Cynthia Griling, for her enormous support to leading this thesis to its final results. Also, all my thesis committee, Kathy Wardle, Michel Labrie and Dr. Jordi Honey-Rosés. Without their great contribution, this research would not have been realized as it is today.

Remarkable thanks to all interviewees who enhanced my project with their knowledge and insights. Especially, Peter Busby, Martin Nelson, Kimron Rink, John Madden, Bud Fraser, Angelique Pillon, Troy Vassos and Jeff Giffin. Also, particular thanks to SEED program for collaborating with this research, especially David Gill.

I can not forget to thank all the friends I had the opportunity to meet and learn from during my UBC life and at the School of Architecture and Landscape Architecture.

Finally, deepest appreciation is owed to my parents, Mina and Hossein, and my brother and sister, Amin and Ladan, whose have supported me throughout my life, both morally and financially.

Dedication

To my parent

Chapter 1: INTRODUCTION

1.1 Problem Statement

*“Action on water is an absolute and ethical imperative...
Acting now is a matter of human dignity, justice, and survival.
Waiting to act is no longer an option.”*

This was one of the strong messages in the Budapest Water Summit 2016, which took place 28-30 November 2016 in Budapest, Hungary by Global Water Partnership (Global Water Partners, 2016). Many national and international organizations have announced similar alerts about the water crisis.

Water is life. We rely on water in both untreated and treated states in domestic, industrial, and ecological uses in daily life. Freshwater ecosystems—lakes, rivers, and the small ponds and streams—make up only two percent of Earth's water resources, and only one percent remains drinkable (UN Water Report 2016).

“The amount of freshwater on the planet has remained fairly constant over time—continually recycled through the atmosphere and back into our cups— while the population has exploded!” (fresh water crisis, nationalgeographic.com, accessed January 5th, 2017).

Fast population growth, climate change, urbanization, migration and industrialization, along with

highly unsustainable water use patterns; have generated ever-increasing demands for freshwater resources (UN Water Report 2015).

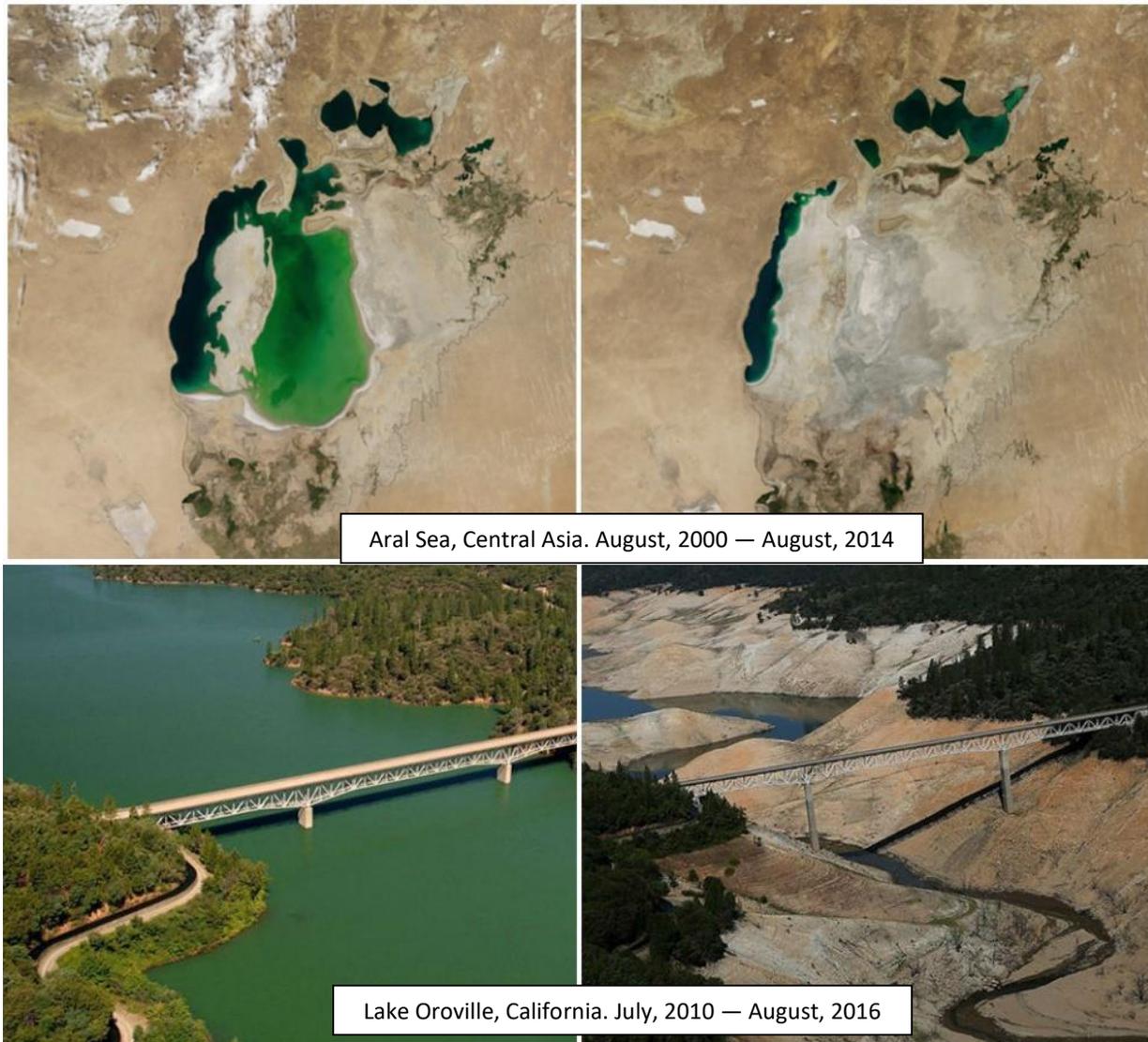


Figure 1. Earth then and now, dramatic changes in our planet as shown by NASA images

(Source: www.brightside.me, accessed March 2nd, 2017)

This water shortage has already changed the landscape of many cities around the world in a dramatic way (Figure1).

By 2050, the global urban population is estimated to double (New Urban Agenda, Habitat III, 2016). In urban areas, the way water is treated and consumed is proven to be excessive and inefficient. Therefore, turning challenges into opportunities, cities can provide significant opportunities for more sustainable water use and wastewater management.

The high water consumption problem in urban areas can be addressed in four scales: region, city, site, and building. Some cities like Vancouver are taking the lead on sustainable water use model as well as water quality, through city action plans and regulations. There are many water efficient design strategies to further explore and facilitate water efficiency in both building systems and building site. These strategies include low flow fixtures and appliances, rainwater harvesting, wastewater reuse, green roof, rain garden and bio swale. If designed and operated well, each water design strategy can improve building water use to meet water goals set by the project designers. These strategies are addressed in environmental rating systems, like Leadership in Energy and Environmental Design (LEED) or Living Building Challenge (LBC), as requirements to be certified and graded as a green building. UBC has a long history in the theory and practice of sustainable development and green building. There are 26 registered and certified LEED buildings on campus. However, in some of these buildings like Center for Interactive Research for Sustainability (CIRS) which is designed to target net-zero water, the water system is not performing as expected. Therefore, this thesis aims to review, question and redefine water

design strategies on paper and in practice of the green building at UBC Vancouver campus, in order to find the barriers and make recommendations to improve the efficiency of water strategies.

1.2 Goal and Objectives

The goal of this research is to develop a better understanding of the requirements for reducing green building water footprint on UBC campus. This is done by reviewing, questioning and redefining water system in design and implementation and learning from success and failures of each system to bridge the gap between theory and practice. The objectives of this thesis are:

- Identifying through the literature review and in-depth case study, what physical planning and design strategies contribute to the creation of net-zero water system
- Deeper explanation of the problem(s) caused water system performance gap in the case study
- Developing an understanding of influential factors in successful implementation of water system in UBC green building practice

The project-specific lessons learned in comparison to the more generalizable lessons are critically discussed including, the unique constraints on the net-zero water system in the case study and the potentials for future developments. Based on the objectives, the thesis is organized into four chapters:

Chapter 1, Introduction: A literature review on green site/buildings and water use, defining problem statement, research questions, methodology and research background

Chapter 2, The context, UBC water footprint, water regulations, common strategies applied in the context of green building practice, redefining water goals and principles

Chapter 3, The case study: lessons learned from the CIRS building water system from design to performance

Chapter 4, Conclusions and recommendations

1.3 Methodology

This thesis explores green building water strategies in design and practice to develop an understanding of requirements to meet net-zero water goal. Using case-study as the research method provides direction to the complexity of sustainability in practice, more specifically, reducing green buildings water footprint. Narrowing down to local examples which have targeted the rigorous set of requirements of sustainability, the case study to learn from is CIRS project. Based on the case-study, the proposed method defines and illustrates an integrated site plus building scale process to be applied by design teams at early stages of the projects.

The case study method for Landscape Architecture by Mark Francis, as well as guideline of The Case Studies in 'The Study and Practice of Architecture', by American Institute of Architects (AIA), form the theoretical basis of the methodology.

Defined by Francis a case study is: *"A well-documented and systematic examination of the process, decision-making and outcomes of a project, which is undertaken for the purpose of informing future practice, policy, theory, and/or education."* (Francis, 2001)

"Each case study presents an informative story which represents perspectives that articulate point(s) of view from which the project story may be told. Stories of practice inform the interrelated nature of events and people that cause buildings, places, and services to evolve."
(AIA, 2001)

In this research, a case study will help to answer main questions at the intersection of design and water strategies and also, is a useful tool to evaluate the success and failure of the projects. Critical dimensions for a case study in this research are framed as a guiding menu by combining the suggested question lists in *Francis* and *AIA* case study analysis guidelines. To understand the project process, interviewing key people involved in different phases of this project is applied to this study.¹ As explained in the *AIA* framework, interviewing addresses critical thinking involved in understanding the impact of varying perspectives.

The guideline question list begins with:

- Baseline information/context—List the location, size, client, designers, consultant(s), density, scale, land use type, timeline etc. (A detailed list of building facts)

The question list is seeking to understand the water-design strategies applied on this case, and also how these strategies have performed to meet water goal of this project. Therefore, the question list is divided into four phases: Schematic Design, Design Development, Construction, and Performance of the project.

¹ The interviewee list and interview contents are in Appendix A and B

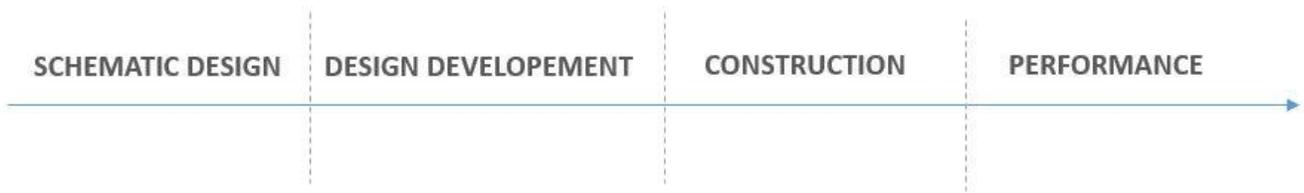


Figure 2. Project phases

1. Schematic Design

- Design team— How many professional teams were collaborating in the design phase of this project?
- Goals— what were the key goals of designing the water system (social, ecological, aesthetic)?
- Program—How did the net-zero water goal affect the program of the site or building?
- Design—What are the key design concepts? The inspiration for the form? The shape of massing? How has net-zero water goal affected the schematic phase?
- Environmental sensitivity and impact—How is the environment served by this project? What is its contribution to sustainability? Any impact on advancing water design strategies on campus?

2. Design Development

- How did the ideas about water efficiency influence design development?
- Did any early concepts for water systems get deleted in the Design Development process?
- Innovation--Are there any specific examples of innovation in service and technology applied to achieve net-zero water goal?
- Site— What are the underlying challenges of the site? Any opportunities on site to improve water strategies?

3. Construction

- Team--Which team were involved in the construction phase?
- Cost—How much was the construction cost per square meter?
- Infrastructure—What are the technological pros and cons in regards to water system?

4. Performance (onsite data)

- Use— water data: How much water is consumed? What is the water used for in this building? Where is the water supplied from?
- Based on the water data, is the water system functioning as designed? Has the water goals been met? To what extent? If not, what was the reason(s)?

- Which strategy or component is working successfully in this case? Which one is not functioning? Why? What was overlooked and in which phase?
- Time—How well do the technologies fare over time? Is the water system effective in all seasons? How persistent are the effects?
- Cost—Is the water system cost-effective? How do we assess the cost-effectiveness of each system? Which strategy or component is most cost-effective?
- Impact on context - How is the UBC campus served by this project?
- Maintenance - How is the maintenance of the water systems managed? Does UBC need to hire outside contractors for maintenance?
- Recommendations – What do you recommend for future green building water systems on UBC campus?

To make it more clear where to find the answers, the following table is created to navigate the main sources of the information for each phase.

RESOURCES QUESTIONS	REPORTS AND MANUALS	RESEARCH PAPERS	DRAWINGS	INTERVIEWS	SITE VISIT
BASELINE INFO.	✓	✓			✓
SCHEMATIC DESIGN	✓			✓	
DESIGN DEVELOPMENT	✓		✓	✓	
CONSTRUCTION	✓		✓	✓	
PERFORMANCE	✓	✓		✓	✓

Table 1. Sources of data for each phase questions list

1.4 Background Research

Water shortage is a global issue, demand for water is increasing every day while the supply is limited. According to the United Nations, water use has grown at more than twice the rate of population increase in the last century as a result of climate change, urbanization, fast pace development and irresponsible planning. By 2025, an estimated 1.8 billion people will live in areas plagued by water-stressed regions which mean two-thirds of the world's population. Thus,

“safe water interventions are the most urgent international dialogues as these strategies have the ability to transform the lives of millions”. (UN Water Report, 2016)

Water contributes to urban sustainability in many ways. It serves as a development guide, enhances the livability of the built environment, and helps the circulation of culture and economy as a key infrastructure. However, the unsustainable water use pattern has caused water issues in the built environment. The impact of built environment on water has two folds:

- The first problem is supplying all sort of water needs by drinking water while 80% of buildings’ water use can be supplied by non-potable water. (Lovell, 2013)
- Another one is relying entirely on centralized municipal water systems as the only source of water and direct rainwater to stormwater runoff system. This centralized water system is a one-way linear piping system that starts from a reservoir and ends in discharging in lakes, rivers or ocean, rather than recycling to use for human or ecosystems’ needs.

This dysfunctional water pattern causes both, water scarcity as well as water pollution in urban areas. Moreover, this system is vulnerable to climate change and major natural crises like earthquakes.

In Metro Vancouver, water supply depends on the Capilano, Seymour and Coquitlam water reservoirs. Each year the combined capture and storage is approximately 22% of the watersheds’ average 1.80 m of annual precipitation. During most of the year, precipitation exceeds the reservoirs’ storage capacities. However during the summer months, when precipitation is at its

lowest, water demand increases by nearly 50%. This causes consumption of the greatest amount of water when the least amount is available. Freshwater sources which provide drinking water to Vancouver and the region, are expected to provide adequate water until 2050 (Greenest City Action Plan 2020, City of Vancouver, 2012). However, climate change is coming and cities need a more resilient response than the current centralized watershed system.

In the discourse of sustainable urban water management, Wong and Brown in *Water Sensitive City* explains three key pillars to achieve water resiliency in cities: (Wong and Brown, 2009)

1. access to a diversity of water sources underpinned by a diversity of centralized and decentralized infrastructure;
2. provision of ecosystem services for the built and natural environment
3. socio-political capital for sustainability and water sensitive behaviors

This thesis looks at the first pillar's application for UBC campus. There are a number of strategies in the water efficiency practice such as conservation, water reuse and using alternative sources of water (groundwater, rainwater or stormwater) and seawater desalination (Margolis, & Chaouni, 2015). Since Vancouver is located in a water-rich area, conservation, rainwater harvesting and water reuse are effective ways to live within and avoid the need for source expansion because expanding the existing water supply or finding a new one is financially and ecologically expensive (Greenest City Action Plan 2020, City of Vancouver, 2012).

Rainwater harvesting is a simple system that collects water from the rooftop to a cistern, mostly for non-potable use like flush toilets, general washing, and irrigation. Traditional water management has much to contribute to future solutions, but we need to move towards a new paradigm that considers rainwater as a main water resource within the entire water cycle in a city. Besides water balance, this decentralized system has additional benefits to the centralized watershed-scale approach in case of major natural disasters like earthquake. When the conventional piping system may not be available anymore and many citizens may be cut off from the city network, rainwater harvesting can potentially supply fresh water for post-disaster time. These water strategies are being practiced in the green building industry and they form water imperative as a core component in green building rating systems.

1.4.1 City and Water

Vancouver is a water-rich city with annual precipitation of more than 1200 mm. (vancouver.weatherstats.ca, accessed November 2017). This city is already leading the way on becoming the greenest city in the world by 2020 and has a strong interest in green building development. The City's regulations for new buildings are some of the greenest of any jurisdiction in North America. The City's Green Buildings Strategy set out rigorous goals in terms of water such as 50% reduction in water use for irrigation in new developments over 2008 levels, on a site-by-site basis. (City of Vancouver, 2012)

However, comparing Vancouver to similar cities in similar climate zone, 2013 Total Water Consumption in Metro Vancouver was nearly three times more than Metro Portland or Metro Seattle (Water Planning Lab, 2016).

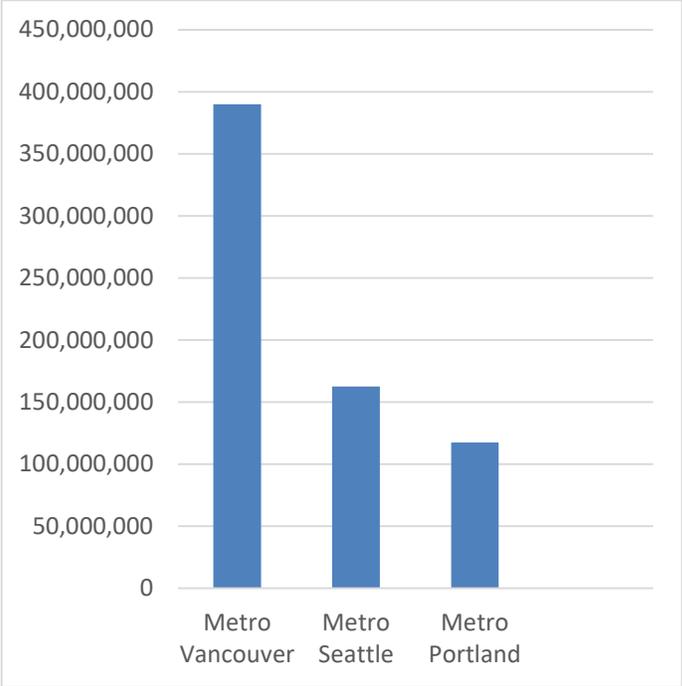


Figure 3 Water Consumption in similar cities m3/year
(Source: www.wpl.scarp.ubc.ca)

About 60% of water consumed in the region is for residential uses, while 30% is consumed by industrial, commercial and institutional uses. Targeting 33% reduction in water use in Greenest City Action Plan 2020, Vancouver has begun to develop a Water Conservation and Stewardship Strategy, which incorporates the following key elements:

- Universal water metering and volume-based pricing;
- Strengthening water efficiency requirements in the Vancouver Building Code including purple pipes (the second set of plumbing that uses rainwater and recycles water from dishes, washing, and showers) in all new buildings;
- Rebates for the purchase of water-efficient fixtures;
- Increased social marketing and public education;
- Greater use of rainwater;
- Water efficiency audits, including a proactive leak detection program; and
- Increased enforcement of water conservation bylaws,

These actions have brought down per capita water consumption by 20% in the past 10 years (City of Vancouver, 2017).

However, City action plan does not apply to UBC campus area. The campus is regulated by *British Columbia University Act* which gives the board of governors the power to manage and control development on the UBC campus.

1.4.2 Green Building and Water

“The planet demands better performance from buildings”

John Ochsendorf, The Search for Form, MIT, Notes from SALA lecture series, March 2017.

There are many different definitions for green building, US Green Building Council (USGBC) defines it as: *“An integrative process of planning, design, construction, and operations of buildings with the key considerations of energy use, water use, indoor environmental quality, material selection and the building's effects on its site.”* Green Building focuses on reducing the impact of built environment on the natural environment throughout the entire lifecycle of a building (USGBC, 2016). Green building contributes to water efficiency by requiring both building site and building systems to incorporate strategies that preserve water quality as well as quantity. These requirements form water imperative in green building rating systems.

1.4.3 Green Building Rating Systems and Water

The USGBC introduced Leadership in Energy and Environmental Design (LEED) in the late 1990s which became the most prevalent green building rating system globally in the industry (Yudelson, 2016). Water efficiency has always been a key imperative for all green building rating systems. In the timeline of *Green towards Regenerative design*², the green building's rating systems have also been evolved gradually as shown in the graph below:

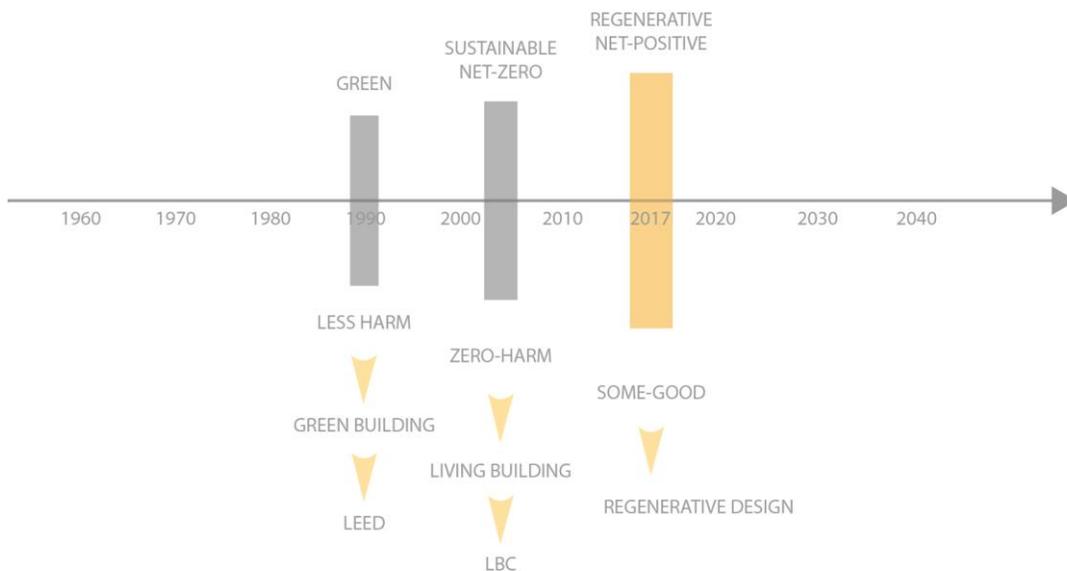


Figure 4. Green building evolution timeline

² Regenerative design: A design process that engages and focuses on the evolution of the whole of the system of which we are part. (Reed, 2007)

This shift from “less harm” towards “no harm” or net-zero, to “some good” or net-positive has developed a regenerative sustainability paradigm which challenges a number of measures set by today’s prevalent green building rating system like LEED. (Cole, 2011)

The concept of “net-zero water” means *“a building that is designed, constructed, or renovated and operated to greatly reduce total water consumption, use non-potable sources as much as possible, and recycle and reuse water in order to return the equivalent amount of water as was withdrawn from all sources, including municipal supply, without compromising groundwater and surface water quantity or quality.”* (US Department of Energy, 2017).

One example of net-zero water projects is called *A wetlands Strategy*, built by University of Maryland students and faculty in the 2011 Solar Decathlon project. The concept of this design is preserving water’s role in the ecosystem. They created a “micro-scale ecosystem” with pitched green roof and water axis to function as parts of a mini wetland. To filter rain and greywater for reuse they used a mix of native vegetation, soil, sand, and excess water can eventually release into nature (www.greenbuildingadvisor.com, accessed March 12th, 2016)

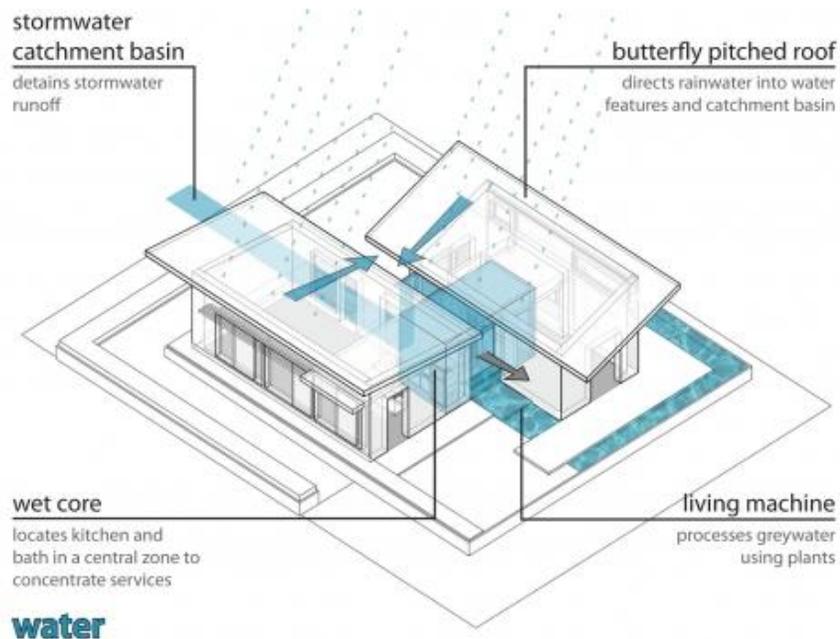


Figure 5. Source: www.greenbuildingadvisor.com, accessed March 12th, 2016.

The water strategies incorporated to green building design include but are not limited to: rainwater harvesting, onsite wastewater treatment, improved efficiency and improved water consumption behavior, in building scale. Also, integrated with the scale of the site, the water-related strategies include Low Impact Design (LID) strategies as green roof, green wall, bioswale and rain gardens.

1.4.3.1 LEED Contribution to Water

LEED is the most common green building rating system in building industry. In this system, water efficiency sits fourth within its main categories in this system. In LEED, water goals are set to minimize water consumption as well as reuse water strategies like onsite water treatment and collecting and using rainwater for irrigation and for flushing toilets.

In British Columbia, as of 2008, all publicly-owned new construction and major renovation projects over 600 m², must achieve LEED Gold certification. At UBC, green building policies made it mandatory to obtain LEED Gold certification for all new construction and major renovations for institutional buildings. Also, the LEED standard is taken one step beyond in *UBC's Technical Guidelines*, by adding further mandatory green building requirements. (LEED-UBC, 2017)

But, how does LEED contribute to water efficiency? Can buildings get their LEED certificate without doing much in the way of water efficiency?

LEED buildings can contribute to 40% water use reduction. LEED's water efficiency credits category focuses on the reduction of potable water use through:

- Conservation with water-efficient fixtures and usage monitoring through sub-metering
- Water efficient landscaping techniques and technologies



Figure 6. LEED main imperatives

- Collection, reuse and/or treatment of non-potable water

Of the 69 possible points in LEED, five are directly associated with water efficiency. These five points are apportioned among three LEED 2009 Water Efficiency credits:

- Credit 1 – Water Use Reduction, two points
- Credit 2 – Water Efficient Landscaping, two points
- Credit 3 – Innovative Wastewater Technologies, one point
- Credit 4 – Process Water Use Reduction

Some water efficiency technologies and strategies can easily be incorporated at any point in the design process, or even late in the construction process, while others require early planning and integration of multiple disciplines. Understanding the requirements for each Water Efficiency Credit, as well as the design strategies for meeting those requirements and the planning process, are necessary to successfully develop and incorporate those strategies, is critical to optimizing water efficiency in LEED projects (LEED Green Associate Guide, www.cagbc.org/CAGBC/LEED, accessed February 2nd, 2017).

1.4.3.2 LEED Version 4 vs LEED 2009 Water Category

Water Efficiency category has improved in many ways in LEED V4 (LEED Version 4, www.usgbc.org, accessed February 2nd, 2017). Four new credits are added, one is removed based on previous LEED buildings performance studies by United States Green Building Council (USGBC). The LEED V4 water credits are shown in the table below:

LEED 2009

LEED V4

Water Efficiency Credit	Point	Water Efficiency Credit	Point
Prerequisite 1: Water Use Reduction	0	Prerequisites: Indoor Water Use Reduction	Required
Credit 1: Water Efficient Landscaping	2-4	Outdoor Water Use Reduction	Required
Credit 2: Innovative Wastewater Technologies	2	Credit 1 Building Level Water Metering	<i>NEW</i> Required
Credit 3: Water Use Reduction	2-4	Credit 2 Outdoor Water Use Reduction	2
		Credit 3 Indoor Water Use Reduction	6
		Credit 4 Cooling Tower water Use	<i>NEW</i> 2
		Credit 5 Water Metering	<i>NEW</i> 1

Possible: 10 points

Possible: 11 points

Figure 10. LEED 2009 in comparison to LEED Version 4 Imperatives

- **Building level water metering**, New, worth 1point

It means the entire building is needed to be metered. It is a required credit now.

- **Cooling Tower Water Use**, New, worth 2points

This credit aims to capture the entire water picture of the building. In a building water budget, a significant amount of water is used in cooling towers. This credit requires one-time potable water use analysis in order to optimize cooling tower cycles. It also requires to perform a test on the

water to look at the various level of chemicals and based on that analysis you have to design the cooling tower to maximize the number of cycles available, which means:

- One point awarded for up to 10 cycles
- 2 points awarded for above 10 cycles

- **Innovative wastewater technologies, deleted**

This credit is eliminated from credit categories because most of the projects did not pursue this credit, so CIRS is not the only LEED-certified building that was not successful in the performance phase of reuse systems (see page 79).

- **Outdoor water reduction, worth 2point**

Which was known as water-efficient landscaping in LEED 2009 is now a prerequisite credit.

This credit requires 30% irrigation reduction as calculated using EPA's Water Sense Water Budget Tool. This is a free tool available online to determine the water intensity of irrigation in the design.

- **Indoor water use:**

This credit is referring to plumbing fixtures and appliances used inside the buildings. There are 6 points available for this credit, comparing to LEED 2009 that was 4 points. It incorporates a wider

scope of water fixtures including clothes washers, dishwashers, pre-rinse spray valves, ice machines.

In addition, in LEED 2009 you could earn the maximum of points with a 40% reduction, in order to achieve 6 points under LEED V4 you have to achieve 50% reduction. The baseline water consumption for calculation is International Plumbing code which is not changed since LEED 2009. (LEED Version 4, www.usgbc.org, accessed May 2017)

1.4.3.3 Living Building Challenge (LBC) Contribution to Water

The Living Building Challenge promotes the most advanced measurement of sustainability in the built environment possible today. This performance-based rating system is structured in 7 Petals or areas and 20 imperatives in associated with petals.

LIVING BUILDING CHALLENGE PETALS



Figure 7. Living Building Challenge 7 petals, (Source: www.living-future.org, accessed November 2nd, 2016)

These 7 petals are:

1- Site: Limits to Growth, Urban Agriculture, Habitat Exchange, Car-Free Living

2- Water: Net zero water, Ecological Water Flow

3- Energy: Net zero energy

4- Health: Civilized environment, Healthy air, Basophilic

5- Materials: Red List, Embodied carbon footprint, Responsible industry, Appropriate sourcing
Conservation and reuse

6- Equity: Democracy and social justice, Rights to nature

7- Beauty: Beauty and spirit, Inspiration and Education

Water is one of the main seven petals in LBC rating system. Net-zero water imperative in LBC means:

“One hundred percent of the project’s water needs must be supplied by captured precipitation or other natural closed-loop water systems, and/or by recycling used project water, and must be purified as needed without the use of chemicals. All stormwater and water discharge, including grey and black water, must be treated onsite and managed either through reuse, a closed loop system, or infiltration. Excess stormwater can be released onto adjacent sites under certain conditions.” (water petal, www.living-future.org, accessed November 15th, 2016)

LBC seems to be a more comprehensive rating system because it is a performance-based system which all of its 20 'imperatives' must be met before the designation of 'Living Building' is granted. In contrast to the checklist-based system of LEED where, particularly for the Certified, Silver and Gold levels, it is possible to select from a basket of potential credits in order to gain the necessary overall score level. (International Living Future Institute, www.living-future.org, accessed April 12th, 2017).

One successful project that has recently achieved LBC water petal is the UniverCity Childcare in the Simon Fraser University (SFU), in Burnaby, BC. To learn more from best practice, focusing on water, this building is explained in more details.

1.4.3.3.1 The UniverCity Childcare (SFU Daycare)



Figure 28. SFU Daycare, Source www.Archdaily.com, accessed August 5th, 2016

Project Description:

UniverCity Childcare Centre located on the center of the SFU campus was designed to be Canada's first Living Building (LBC) and named as the greenest childcare center on the planet.

Targeting to meet the criteria of the LBC requirements, the water goals of this project are:

- One hundred percent of the water used in the building to be provided on-site.
- One hundred percent of the project Stormwater and Wastewater must be treated on-site. (HCMA, www.archdaily.com, accessed August 2016)

Building facts:

Project Name: UniverCity Childcare Center

Location: Burnaby, British Columbia, Canada

Project Year: 2012

Cost: CA 3.2 million

Size: 530.0 sqm

Architect: HCMA

Landscape Architect: Space2place

Client: Simon Fraser University Community Trust, in partnership with SFU
Childcare Society and SFU Faculty of Early Childcare Development

Civil Engineer: AECOM

Structural Engineer: Fast + Epp

Mechanical Engineer: Integral Group

Wastewater Treatment: ECOfluid System

This building has successfully implemented a balance of water efficiency strategies integrated with the site. These strategies include rainwater harvesting, low-flow fixtures, onsite stormwater management and water efficient planting. Rainwater is collected in a 10,000-gallon cistern for use within the building (only non-potable use). Therefore, the stormwater run-off will be

significantly reduced and the rest of run-off will be infiltrated on-site or diverted to the community's sustainable stormwater treatment system.

By onsite wastewater treatment, the non-potable water demand of the building is entirely supplied (HCMA, www.archdaily.com, accessed August 14th, 2016). Only drinking water is supplied by municipal water backup in this project.

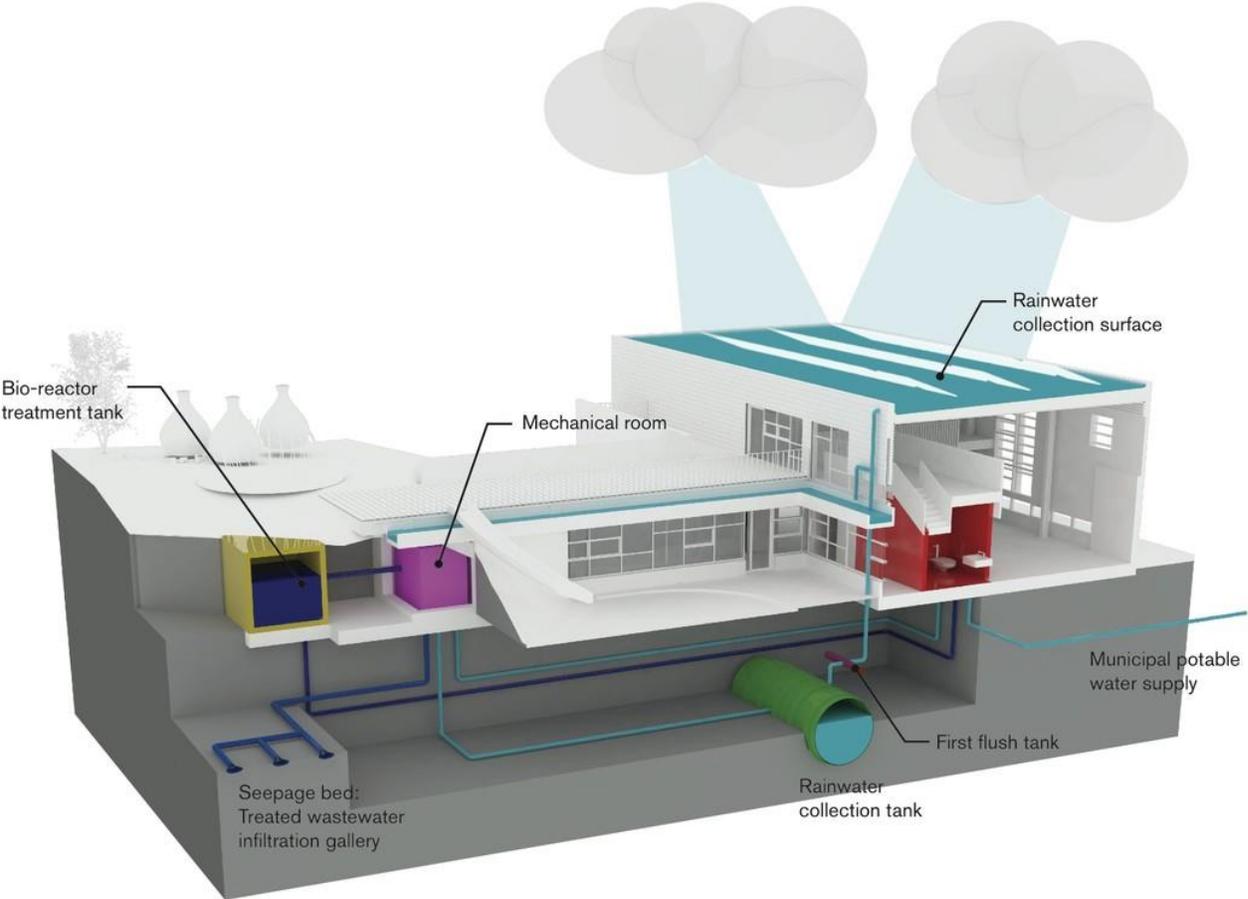


Figure 31. SFU Daycare water system
source: www.Archdaily.com, accessed August 14th, 2016.

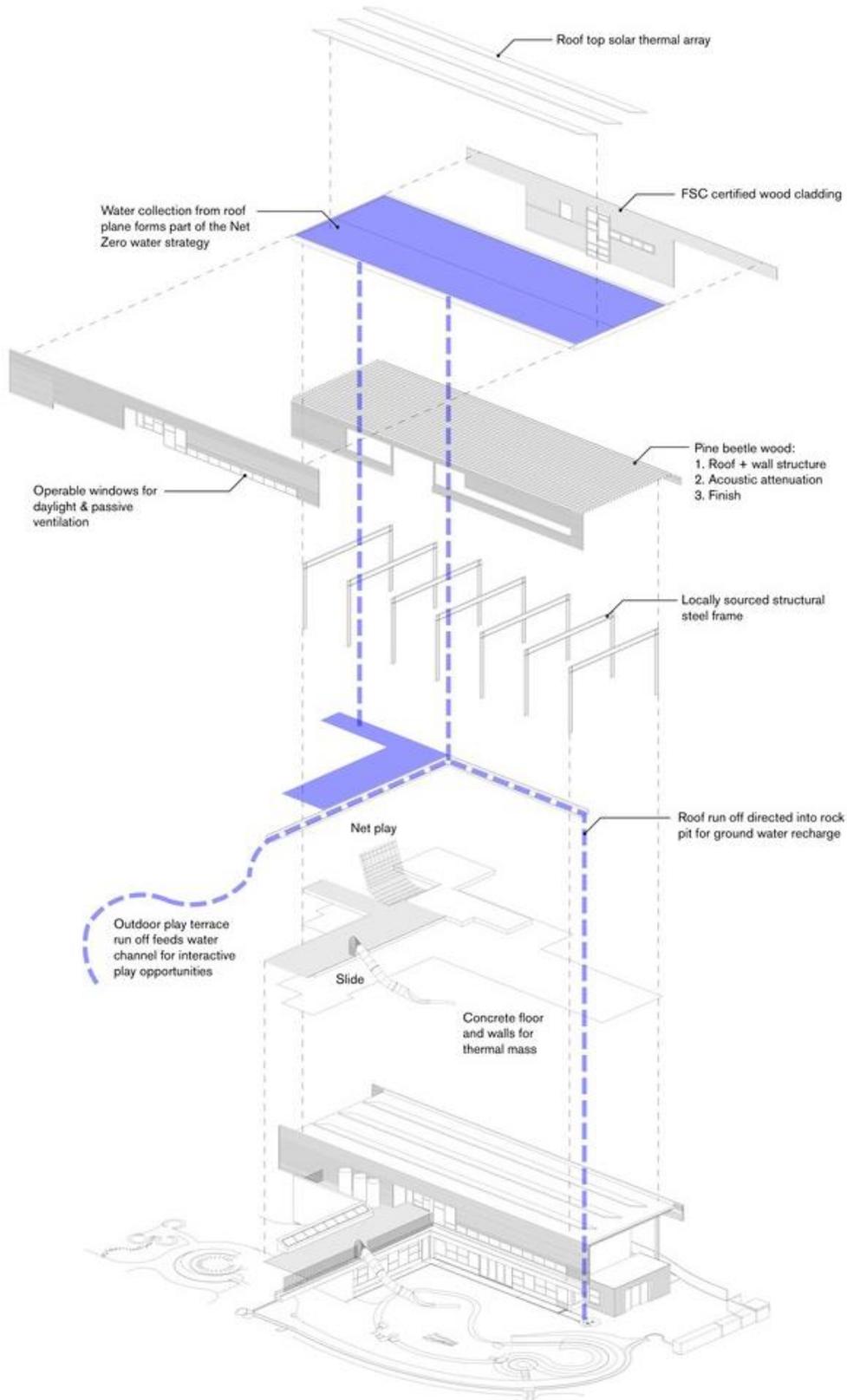


Figure 32. SFU Daycare water system, integrated site and building water design exploded diagram, Source: www.Archdaily.com, accessed August 14th, 2016.

In the landscape, by using native and adaptive plants, no irrigation after the initial planting is required.



Site Plan

- A- Pole Forest
- B- Seating Stumps
- C- Lookout Platfrom
- D- Rainwater Channel
- E- Woven Willow Huts

- F-Stepping Stones
- G- Giant Rope Nest
- H- Log Climber
- I-Woven Willow Huts
- J-Stepping Stones

- K- Rooftop Deck
- L- Rainwater Fall
- M- Storage
- N- Skylight
- O- Stormwater Swale

Figure 30. SFU Daycare landscape
 source: www.spacetoplace.com, accessed August 2016.

The regulators of this project are the City of Burnaby, SFU Community Trust, SFU Campus Planning and Fraser Health. Through Integrated design workshops, all users and stakeholders were involved in the project process from the beginning to the end.

According to architects' description, LBC system was the main force of this project success: *"The Living Building Challenge criteria influenced the sustainable design strategies for this project. The LBC was a catalyst for the project's contribution to social, economic and environmental sustainability."* (HCMA architects, www.archdaily.com, accessed August 14th, 2016). LBC is a performance-based system, with specific goals defined clearly by all required components and details. Also, specific to the water system, the technology choice was simple and practical.

However, do all green buildings perform as they predicted? If not, what are the barriers and how can we remove them to improve the environmental aspect of future projects?

1.4.4 Do Green Buildings Perform 'Green'?

Jerry Yudelson in his book *"The World's Greenest Buildings, Promise Versus Performance"* compares the performance of fifty non-residential buildings among the highest-rated green buildings globally, using actual energy- and water-use data for the first time. All studied projects are LEED Platinum including CIRS building. Initially, researchers were greatly surprised that only a few owners were willing or even be able to share operating data, each for different reasons.

But how can practitioners and designers improve their work without feedback from actual operating data?

A few key lessons to learn obtained from this study are:

- High-performance green design uses the same energy everywhere in the world, no matter if they are located in Northern Europe or in the tropics
- Regardless of geographical location, buildings are able to achieve LEED Platinum energy and water goals through a specific (and early) intent by the entire building teams to meet clear numerical targets for energy and water use.
- The commitment of owners and their building teams to achieving "best-in-class" results is essential
- An integrated design process (IDP) is a must for achieving project goals
- Aesthetically, green buildings are as beautiful, if not more so, as buildings with typical water and energy consumption. There is no inherent conflict between buildings with architectural merit and those with high-performance green characteristic
- Disclosure of operating data in publicly accessible databases is necessary for future improvements in this industry

This research shows that there is a gap between predicted and actual performance in some cases that studies. Also, there is a gap in the standard definition of building energy or water use, which

means we need to develop common definitions so that comparison among projects in different zones can become meaningful and straightforward (Yudelson & Meyer, 2013).

Focusing on local examples, another study “Assessment of Alternative Water Systems” by UBC grad students in Social, Ecological, and Economic Development Studies (SEED) program is done to find water system performance gap among four green buildings (LEED Certified) in Vancouver, BC. These case studies include; Vancouver Convention Centre (Vancouver, BC), Buchanan Building Courtyard (UBC Vancouver Campus, BC), University of Victoria (Victoria, Vancouver Island, BC), CIRS Building (UBC Vancouver Campus, BC). According to this research, there are some failures in the performance of traditional as well as alternative water systems. The alternative system issues include lack of flow to the system, unforeseen design and regulation issues, and in some cases, the system was not built as designed (Ebrahimi & Cheung, 2014).

The unforeseen water reuse systems regulations include the 2012 Municipal Wastewater regulation, which requires the completion of an environmental impact assessment to make sure about health issues. And also, reuse water regulation requires a certified operator by the Environmental Operators Certification Programs (EOCP) with at least level 3 or level 4 plus at least 5-10 years of experience working in a wastewater treatment facility. This study made some recommendations to UBC including, effective collaboration among all the stakeholders at all stages of project life, design an integrated network water system, not just one operational piece, *“accurate operational understanding of the system”* is required. Moreover, more emphasis on

community engagement, cost-benefit analysis before decision making step, are recommended in this research for future projects (Ebrahimi & Cheung, 2014).

In another similar study initiated by iiSBE Canada, the performance of nine green buildings in Canada is evaluated based on a post-occupancy evaluation standard framework. Based on this research water performance gap is estimated **4%-138%**. These gaps arise from a variety of reasons such as *“modeling inaccuracies, envelope and systems integration problems, construction quality issues, occupancy changes, commissioning and handover processes, operational issues and motivation of occupants”*. (Bartlett et al., 2014; Gorgolewski et al., 2016)

These gaps between the predicted and actual performance of green buildings systems result in rethinking about green building rating systems. Yudelson in his last book *“Reinventing Green Building”*, argues that as the most prevalent rating tool, LEED delivery model is still wrong and LEED scores do not necessarily reflect high sustainability. He suggests adding stronger emphasis on the performance measurement, by establishing a protocol to require all LEED-certified new buildings systems undergo a conducted functional testing and monitoring process at least for a reasonable amount of time (Yudelson, 2016).

In green building practice, focused on net-zero water goal, several strategies have been explored and practiced so far. These planning and design principles to achieve net-zero water, are studied in details through a case study, CIRS building on UBC campus. Learning from best practices

successes, failures and challenges demonstrate the requirements to meet water goal in green building practice. Studying CIRS project will structure the following chapters of this thesis.

Chapter 2: UNIVERSITY OF BRITISH COLUMBIA WATER PICTURE

In this chapter, first UBC water footprint, goals, gridlines and regulations are studied and then, the UBC green buildings' contribution to water efficiency is reviewed to find the barriers and gaps, following with a more detailed case study on CIRS building in the next chapter.

2.1 UBC Campus Water Footprint

The University of British Columbia (UBC) is located at west of the city of Vancouver and is separated from the rest of the city by Pacific Spirit Regional Park.

UBC campus has four watersheds that drain rainwater from campus and sits on a natural aquifer, a porous, layered bed of sand and gravel that holds water (www.planning.ubc.ca, accessed July 10th, 2017). Each watershed requires site-specific drainage plan. For this, the *UBC Integrated Stormwater Management Plan* focuses on the retention of rainwater, distribution of clean water to the natural environment, mitigation of erosion and handling peak stormwater events (CIRS Technical Manual).

In UBC, the majority of water comes from the Seymour and Capilano Reservoirs. Water is piped over 20km from these watersheds before being stored in the Sasamat Reservoir and reaches to campus by two water mains from University Boulevard and West 16th Avenue.

Water Distribution in Vancouver / UBC

UBC buys almost **4** billion liters of water from Metro every year

UBC receives **5** billion liters of rain falls on campus each year

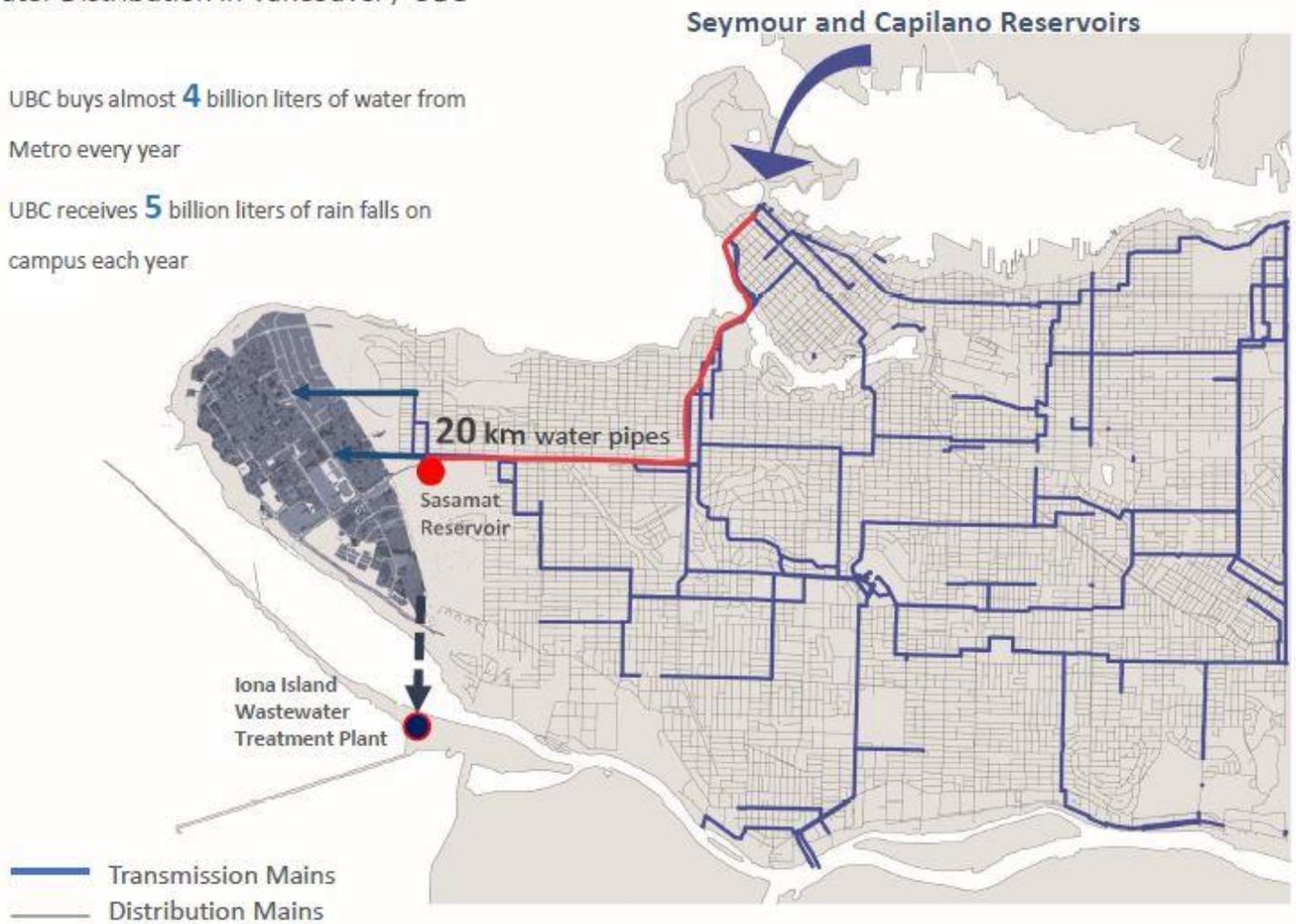


Figure 8. Water distribution map in Vancouver and UBC

At UBC, potable water is used for all sort of water demands including drinking, cleaning, toilet-flushing, irrigation, steam production, equipment cooling and research applications.

After water is used on campus, wastewater is collected in pipes and conveyed to the Iona Wastewater Treatment Plant in Richmond, BC before discharging to the Strait of Georgia. The following chart illustrates the composition of water use at UBC’s Vancouver campus.

Total water consumption and sewage generation are metered at UBC. Water rates are continually increasing.

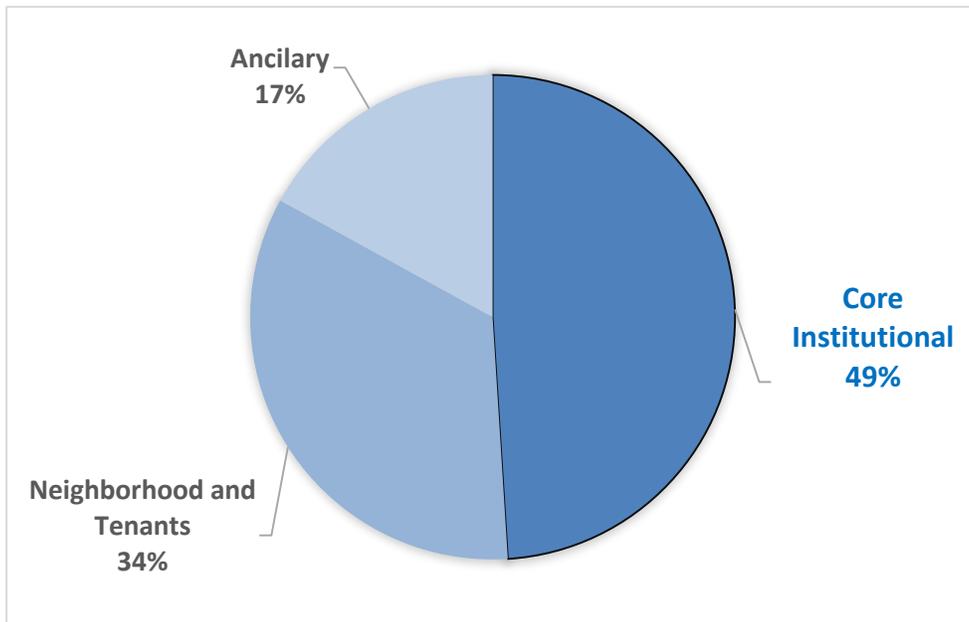


Figure 9. Water use in UBC

(Source: Urban Sustainability Initiatives (USI), UBC)

BUILDING CATEGORY	M3
Core Institutional	1,832,025
Ancillary	641,768
Tenant	1,273,720
Total = Core + Ancillary + Tenant	3,747,512

Table 2. UBC Vancouver Water Consumption, 2016-2017 fiscal year

(Source: Urban Sustainability Initiatives (USI), UBC)

Among all type of buildings, institutional buildings are the largest water consumer building type with 49% of UBC water use. This type includes all office buildings of different departments, laboratories, learning spaces like classrooms and libraries. Laboratories account for the largest consumers in this category.

The UBC campus Water Facts can be listed as follows:

- UBC consumes **3.75** billion liters of water annually (2016 reading), enough to fill **1,600** Olympic-sized swimming pools. (www.sustain.ubc.ca, accessed on October 5th, 2017)
- UBC buys water from Metro which costs **\$3.5** million each year and it is increasing due to population growth and water price. (www.sustain.ubc.ca, accessed on October 5th, 2017)

- UBC campus receives five billion liters of rainfall each year.(Water Action Plan)
- All human consumption water demand is supplied by drinking water while drinking water purposes only represent approximately **1%** of UBC's overall consumption.
- Rainwater mostly channels and discharges from the catchments to the natural environment. (Energy and water services Unit). Among buildings, institutional water consumption accounts for the majority of water use on campus, and the lowest water consumers are office buildings.

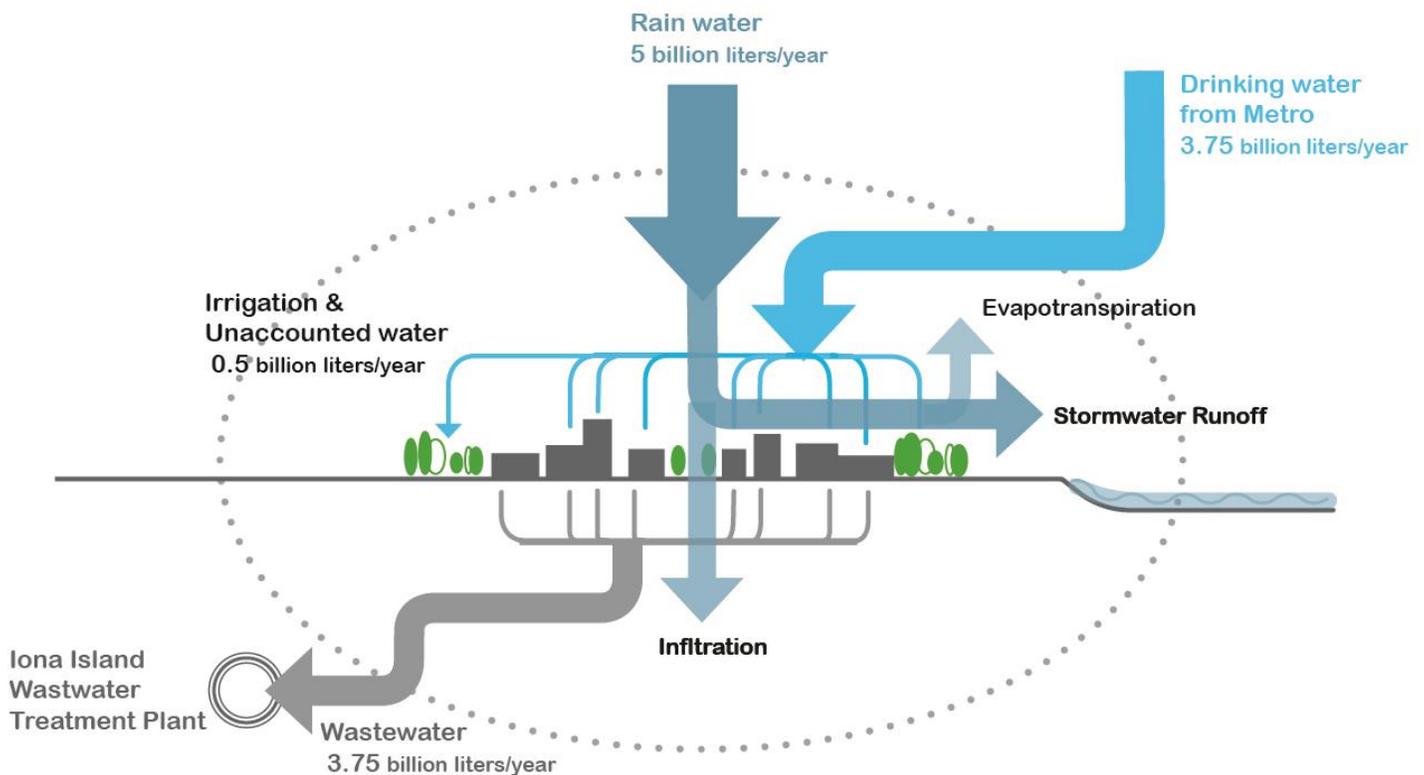


Figure 10. UBC Water Picture

This diagram summarizes water and wastewater systems on campus. UBC is entirely dependent on municipal water and wastewater systems which are both located at a far distance from the campus.

In a wider look, campus habitat map also shows another important water fact which is very small water bodies on this site despite receiving a high annual volume of rainwater. The following map of the biodiversity potential, as well as graph of detailing the amount of each habitat on campus, shows that fresh water reservoir accounts for the smallest portion of this site. Fresh water reservoir is modified ponds or wetlands that are not naturally occurring. (Dyck, 2016)

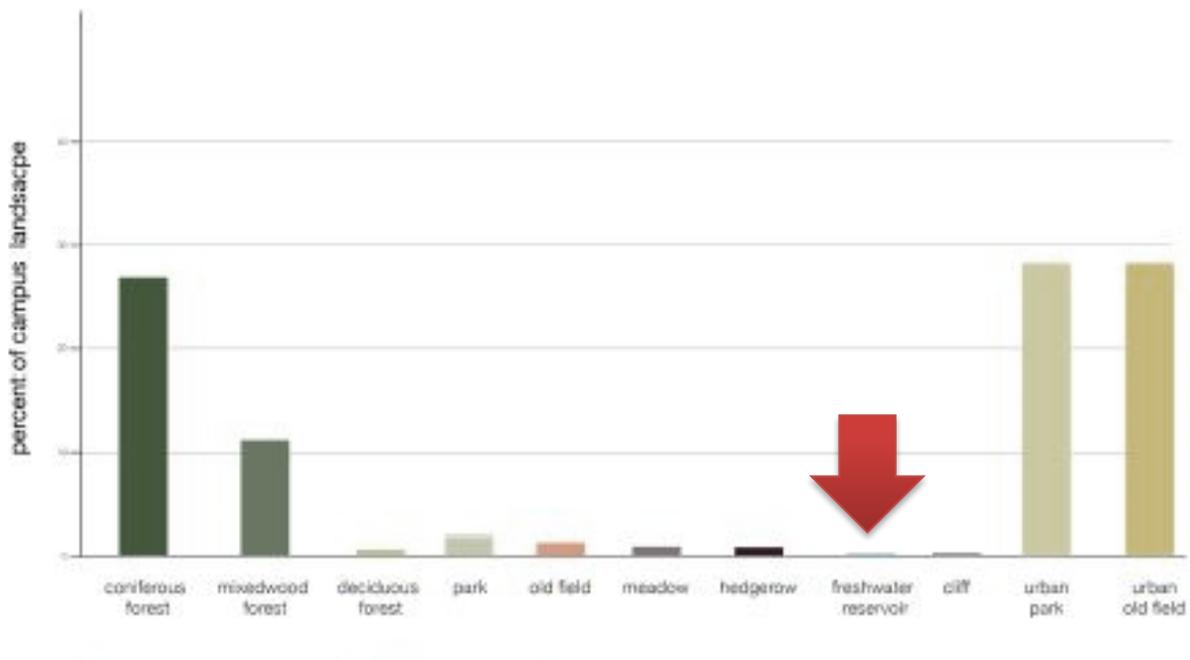


Figure 11. A quantity analysis of the current habitats present on campus
[Source: 'Mapping the biodiversity potential on the University of British Columbia Campus', by Caylee Dyck, 2016]



Figure 12. Small water body areas on Habitat Mapping of UBC campus

[Source: 'Mapping the biodiversity potential on the University of British Columbia Campus', by Caylee Dyck, 2016]

A few key water-related facts obtained from the UBC Institutional Green Building Plan (GBP,2017) are as follow (UBC Sustainability and Engineering, 2017):

- **The largest end uses of water** are a pool, process cooling and research (including animal care), washroom facilities and irrigation. Therefore, the guidelines prohibit once-through cooling of equipment, which is one of the largest types of water use on campus.
- **Runoff mitigation** in Institutional building projects is required through the LEED Implementation Guide's mandatory rainwater management credit to control the rate, quantity, and quality of site runoff by replicating natural hydrology. (GBP, 2017)
- **Water Reuse:** Rainwater reuse at the building level is challenging, due to the expense and the public health-related requirements that a rainwater harvesting system requires, but has been achieved in some buildings on campus. The reuse of stormwater at a larger scale is extremely expensive compared to the local value of water is not currently financially feasible. (GBP, 2017)
- **Using an alternative source of water:** while a few alternative water source projects have been implemented at UBC including at CIRS, these projects have not proven successful as of yet. Part of the challenge is the more complex requirements these systems have for commissioning and ongoing operations, which includes a higher degree of monitoring than conventional systems, and specialized operator roles or skills. (GBP, 2017)

- **Irrigation:** it represents a relatively small portion of institutional water use. Additionally, during summer months, water use for irrigation is often restricted due to low regional reservoir levels. While “smart” irrigation systems can improve efficiency, the planting choices and maintenance regimes for landscaping could have a significant impact on irrigation water demand. (GBP, 2017)

UBC is seeking to reduce the overall impact of the water footprint. The water goal in institutional building plan is reducing water consumption in a cost-effective way in order to be net-positive by **2035** (UBC Institutional Green Building Plan, 2017). The UBC Campus Plan is developing the Water Action Plan (WAP) to reduce the environmental impact of the University’s potable water use through basic strategies:

1. Reducing water consumption,
2. Maximizing reuse,
3. Using alternative sources.

To achieve UBC water goals five priorities are indicated in *Water Action Plan (2011)* for water management on campus including:

4. rainwater harvesting
5. efficient landscape irrigation
6. reduced water use and wastewater generation

- 7. water use management in building operations
- 8. Education and engagement

As a result of this approach and the retrofit plans (ECOTrek project launched in 2001) on upgrading water fixtures and piping systems, the overall water consumption per Square Meter has decreased since 2000 despite population and building floor area growth on campus.

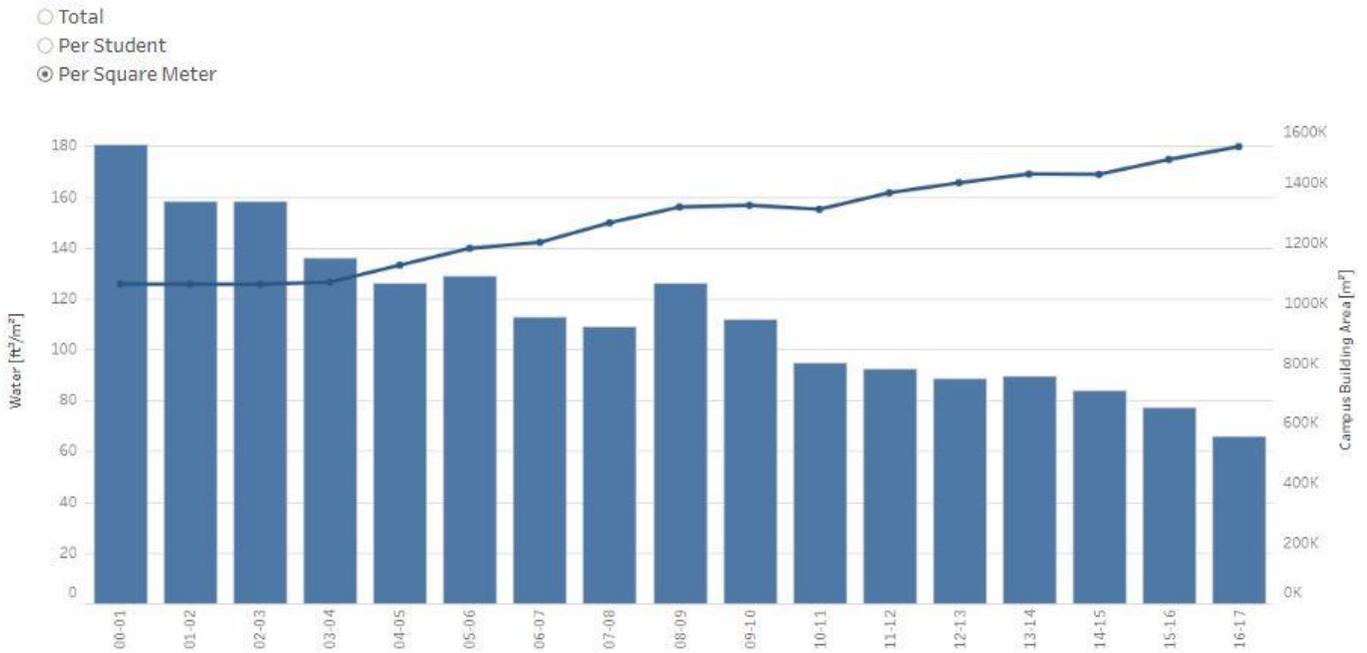


Figure 13. UBC Water Consumption per sq. meter, from 2000 to 2017,

Source: www.public.tableau.com, accessed October 5th, 2017.

2.2 UBC Campus Water Regulations

UBC has different planning and building regulations than the City of Vancouver. UBC is the owner, policy-maker, regulator and the developer (UBC PT) of institutional projects. After construction, buildings are commissioned by City³ and handed over to **UBC Building Operations** to operate and maintain. UBC policy towards water consumption in buildings is influenced by the **UBC Technical Guidelines** and **LEED Implementation Guide**. Both guides require high-efficiency water fixtures including toilets and faucets, and some types of appliances and other equipment. Currently, WAP is developing as the future campus water roadmap.

UBC is both the owner and the operator of the water distribution system. Energy and Water Services (EWS) unit is responsible for the distribution of potable and firefighting water on the University campus area. (www.energy.ubc.ca/ubcs-utility-infrastructure/water, accessed September 12th, 2017)

In terms of quality, water quality should comply with **Canadian Drinking Water Guidelines**.

Sustainability and Engineering Director at the UBC Campus and Community Planner, describe regulatory systems for water as:

“Water regulations within new buildings are defined under part 7 of the BC Building and referenced, under the **BC Plumbing Code**. Both these codes are administered/enforced by UBCs

³ City of Vancouver

chief building official (verified via submitted of Certified Professional) through the building permit process. UBCs institutional buildings are also required to follow the **UBC LEED Implementation Guide** and **Technical Guidelines** which identify specific water efficiency requirements to achieve better performance levels beyond base code. The **Green Building Plan** will identify further improvements (informed through the draft Water Action Plan which is currently being completed).

Water use outside the building (primarily irrigation, water features, car washing) is regulated by the **Greater Vancouver Water District** under the Provincial Water Act. It regulates water use throughout the metro region including irrigation, car washing, and water features, etc.

Vancouver Coastal Health sets regulations for non-potable water resources. They require a number of criteria like signs on flush toilets and spray irrigations to give people awareness of non-drinking water.

Metro Vancouver has just released a new **Drinking Water Conservation Plan** (November 1, 2017) which sets out water conservation initiatives/restrictions. Each member municipality and authorities having jurisdiction (AUJ) are responsible for administering water use under those regulations.

In terms of consultations, we typically engage all our university stakeholders including UBC properties trust, students, faculty, residents, and staff as well as government representatives that

are responsible for the development of policies.” (UBC Campus and Community Planner, November 2017)

For wastewater treatment & reuse system cases like CIRS, the **Ministry of Environment** permits these systems under the **Municipal Sewage Regulation**. (Bud Fraser, UBC Sustainability Initiative (USI), November 2017)

UBC is developing the WAP to build on water conservation achievements and to help guide water management activities in the future. UBC has achieved significant reductions in water consumption well beyond the 40% reduction target relative to 2000 (adjusted for growth) identified in the Inspirations & Aspirations Sustainability Strategy. However there are other opportunities to further conserve water and develop new targets, and also to look beyond water conservation and consider issues such as community resiliency. With the Climate Action Plan 2020 Update in 2016, development of the WAP has resumed and is anticipated to be completed in 2017.⁴

Other themes to be addressed within the WAP are:

- New and existing green buildings: these themes are being discussed as part of the Green Building Plan consultations

⁴ Alternative Water Sources & Resilience section discussion which was a part of the development of the Water Action Plan discussion meetings, Sustainability & Engineering, UBC, September 2017

- Landscape and irrigation
- Infrastructure, metering, and monitoring (including water system losses, water costs, and water governance)
- Drinking water provision and food services
- Campus engagement

2.3 UBC Green Buildings and Water

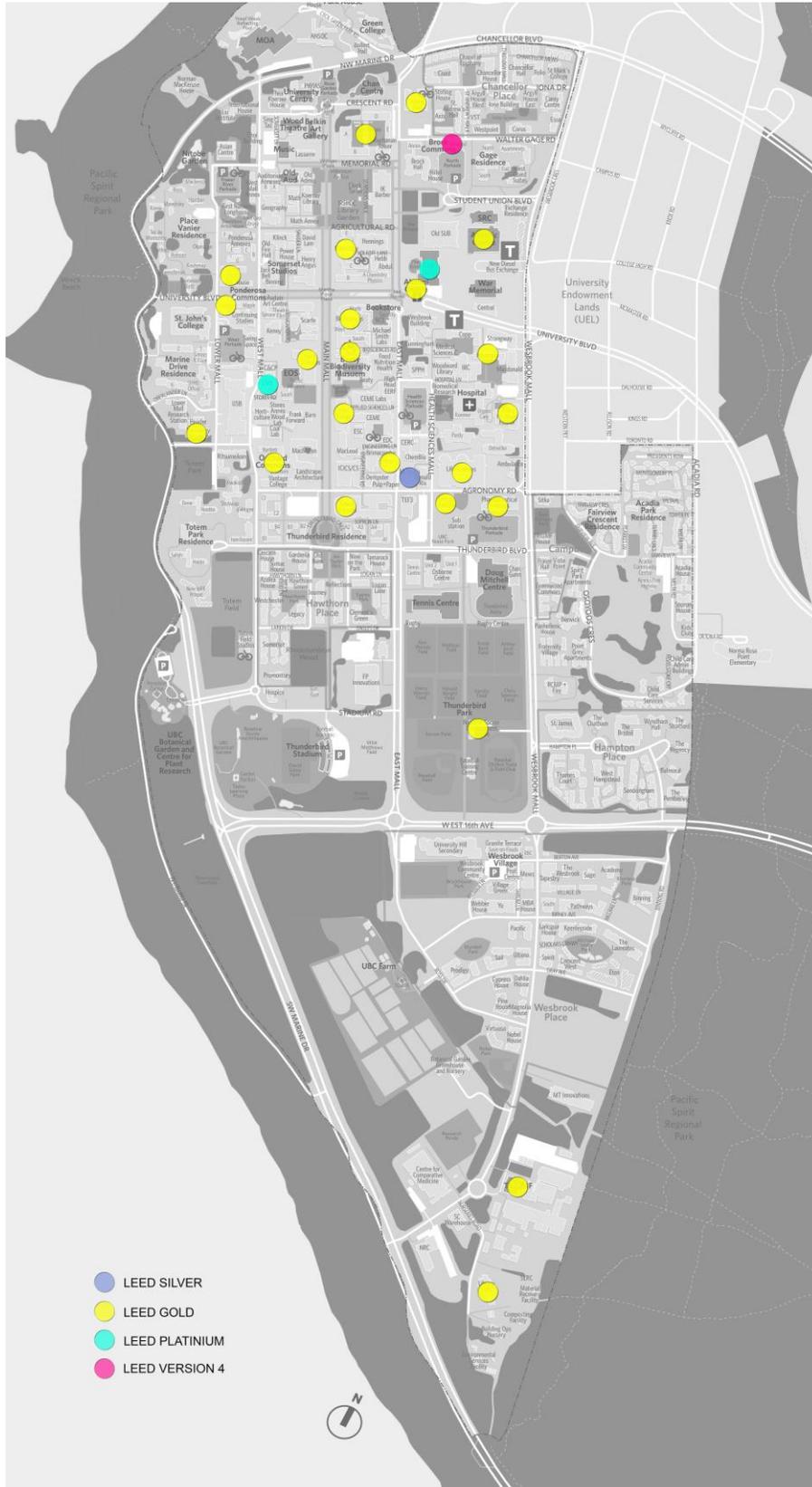
“Building operations is the largest component of UBC’s environmental footprint”
(www.sustain.ubc.ca, accessed July 11th, 2017).

UBC has a long legacy in green building development starting early in 1996 with The C.K. Choi Building. In BC province, it is mandatory for all publicly owned new construction and major renovation projects over 600 m² to achieve LEED Gold certification which includes UBC buildings. There is room for LBC or Passive House certificate application under certain conditions but, targeting LEED based on *LEED Implementation Guide* is a must in UBC institutional building operations. (UBC Green Building Plan, Institutional formation Package, 2017).

On UBC campus, there are twenty-six (26) LEED buildings including both twelve (12) LEED certified and fourteen (14) LEED registered projects. Of these twenty-six buildings, Brock Commons (Tall wood) building is registered as LEED Version 4, CIRS and NEST (New SUB) buildings are awarded LEED Platinum, Technology Enterprise Facility 3 is certified as LEED Silver and the rest are LEED Gold projects. Figure 14 illustrates the location of these buildings on the UBC campus map.

Only five of LEED projects on campus have incorporated alternative water systems. These buildings include CIRS, the new Student Union (Nest), Aquatic Center, Buchanan Building Courtyard and the Bioenergy Research Demonstration Facility (BRDF).

Figure 14. UBC IEED certified and registered buildings Location, sourced at Green Building Directory, Dec 2016



However, none of these buildings are using alternative water systems at the moment, each for different reasons. The Aquatic Center, targeting LEED Gold, has the largest rainwater facility on campus to capture approximately 2.7 million liters of water annually through rainwater harvesting, and almost 7,000 liters of water saving daily through water-efficient showerheads (www.recreation.ubc.ca, accessed on September 2nd, 2017). The water system is still in commissioning phase, therefore, this facility is using municipal water at the moment. The Nest is a certified LEED platinum building which is designed to incorporate rainwater harvesting for flush toilets as well as irrigating the roof garden. Visiting the system, meters indicate that this building is also using city water. The Buchanan courtyard site water harvesting and recycling system process the collection, conveyance, storage and reuse of site stormwater for the purpose of irrigation and water feature recharge, is also not functioning.⁵

Therefore, the questions are: why none of these systems are functioning as designed? What are the gaps or barriers? And what we can learn for future green building development on campus? Seeking to find the answers in the next chapter, CIRS building water system is studied in details, relying on information from UBC documents and conversations with designers, decision makers, staff involved in planning, building, managing, and operating this project.

⁵ Site visit and meter reading with Jeff Giffin, Energy and Water Service office, UBC, September 2017

Chapter 3: CASE STUDY

In this chapter water-related strategies that are applied in the context of green buildings are discussed critically through a case study. The case study is Center for Interactive Research on Sustainability (CIRS) building located on UBC Vancouver campus. This mid-academic building is designed based on the most ambitious sustainability goals and is the first building to achieve LEED Canada New Construction Platinum certification, on UBC campus.

Among all green buildings, CIRS has also facilitated an onsite water treatment system to reuse wastewater in order to create a closed loop water system. This system is designed to harvest rainwater for potable water needs and recycle wastewater, collected from building fixtures, onsite for non-potable water demands like flush toilets and irrigation. This building is studied further in this chapter to understand the water goal, strategies, design and performance successes, and failures on paper and in practice.

3.1 Center for Interactive Research on Sustainability (CIRS)



Figure 15. CIRS building

(Source: www.archdaily.com, accessed October 2nd 2016)

CIRS as the living laboratory is a significant demonstration of the sustainable approach to building design at UBC campus. This building was designed with the vision to test technologies, learn from them and accelerate sustainability in the built environment. The design process of CIRS is unique since a network of almost 20 professionals in high-performance building design was involved in the process from the beginning. They set ambitious goals for CIRS to be zero carbon and zero emissions and also self-sufficient in terms of water and energy. (Peter Busby, Managing Director at Perkins+Will, October 12th , 2017)

There is a long list of sustainable attributes for this building; the building systems, strategies as well as the process of planning, designing and operation including energy and water systems and its inhabitants are grounded in the principles of regenerative design. It is a dynamic project monitored by a complex network of controls and sensors to ensure that all systems are properly functioning, in addition to the continuing research and education leadership.

CIRS is located in South West zone of the campus, surrounded by Earth and Ocean Sciences, Campus and Community Planning and Horticulture buildings (www.Cirs.ubc.ca, www.archdaily.com, accessed October 5th,2016).

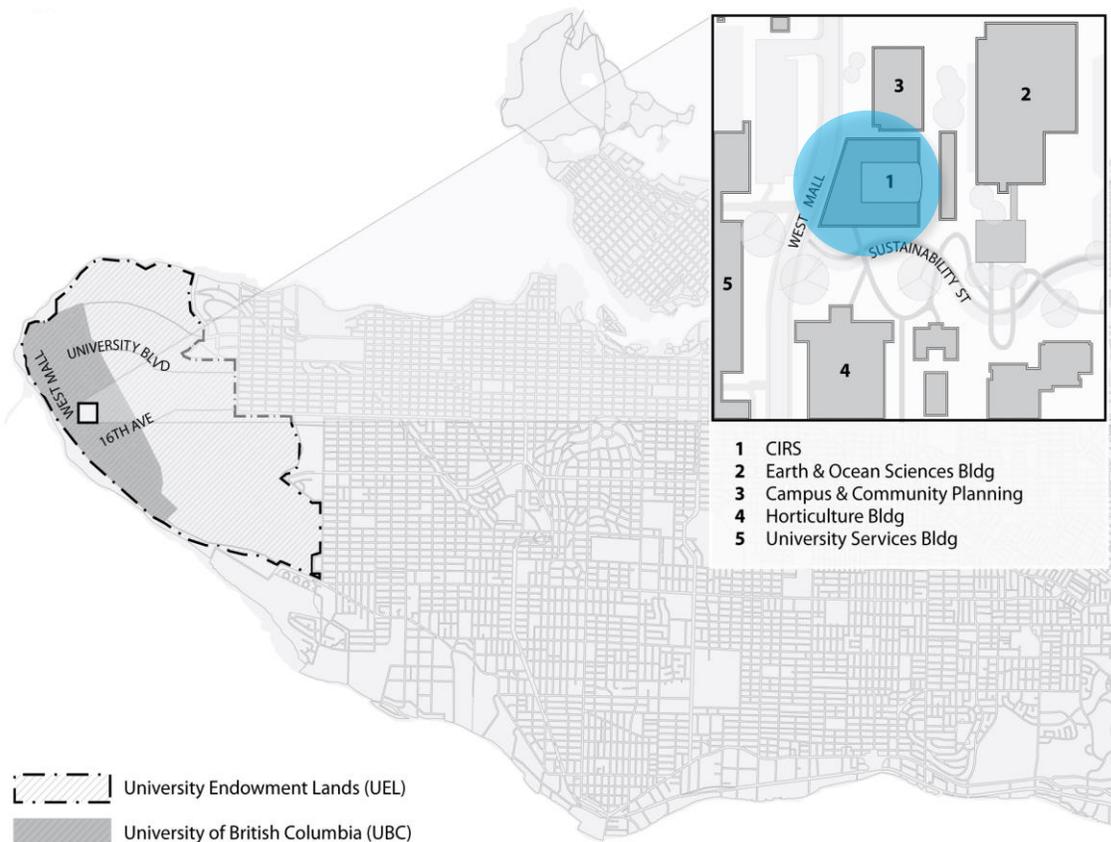


Figure 16. CIRS Location

(Source: Velasco, MASA thesis, 2016)

Although the building performs 50% better than a typical academic building (Bartlett et al., 2014), there are performance gaps observed in the building systems such as energy and water which prevents the building to live up its potentials. To address these gaps, there are ongoing efforts to understand the building performance deficiencies and to enhance both energy and water systems. In this study, the focus is on the water system, design, performance and future plan.

The significance of the project to my thesis:

The thesis objective is to develop an understanding of influential factors in achieving water goals for future green building developments on UBC campus.

Therefore, learning from success and failures of CIRS project, as a building that has achieved the highest green building awards, and currently seeking to improve water systems to perform as designed, can significantly help finding answers to the research questions. This project engaged more than thirty stakeholders in a unique process to learn from.

Building Facts:

Location: Vancouver, British Columbia, Canada

Client: University of British Columbia

ASHRAE Climate Zone 5A - Moderate oceanic climate with dry summer months and rainy, humid, and cool winters (2,817 HDD, 56 CDD)

Building Type: Medium Academic

Date Designed/Planned: 2008

Construction Completed: 2011

Cost: CA 35\$ million

Timeline: 12 years

Net floor area: 5.675 sqm

Architect: Busby Perkins+Will

Landscape Architect: PWL Partnership

Structural Engineer: Fast + Epp

Mechanical Engineer: Stantec

Electrical Engineer: Stantec

Code Consultant: LMDG Building

Construction Management: Heatherbrae Builders

Building Envelope: Morrison Hershfield

3.2 Water Efficiency in CIRS

This building is designed to be entirely water self-sufficient which means 100% of potable and non-potable water demands to be supplied by building's rainwater capturing and water reuse, while 100% of surface water is to manage onsite as well. However, this goal has not been achieved yet because the water systems are not functioning as expected (Site visit, January-November 2017). Therefore, this unique project is selected to study the design intent, the performance gap and what we can learn to apply in future buildings.

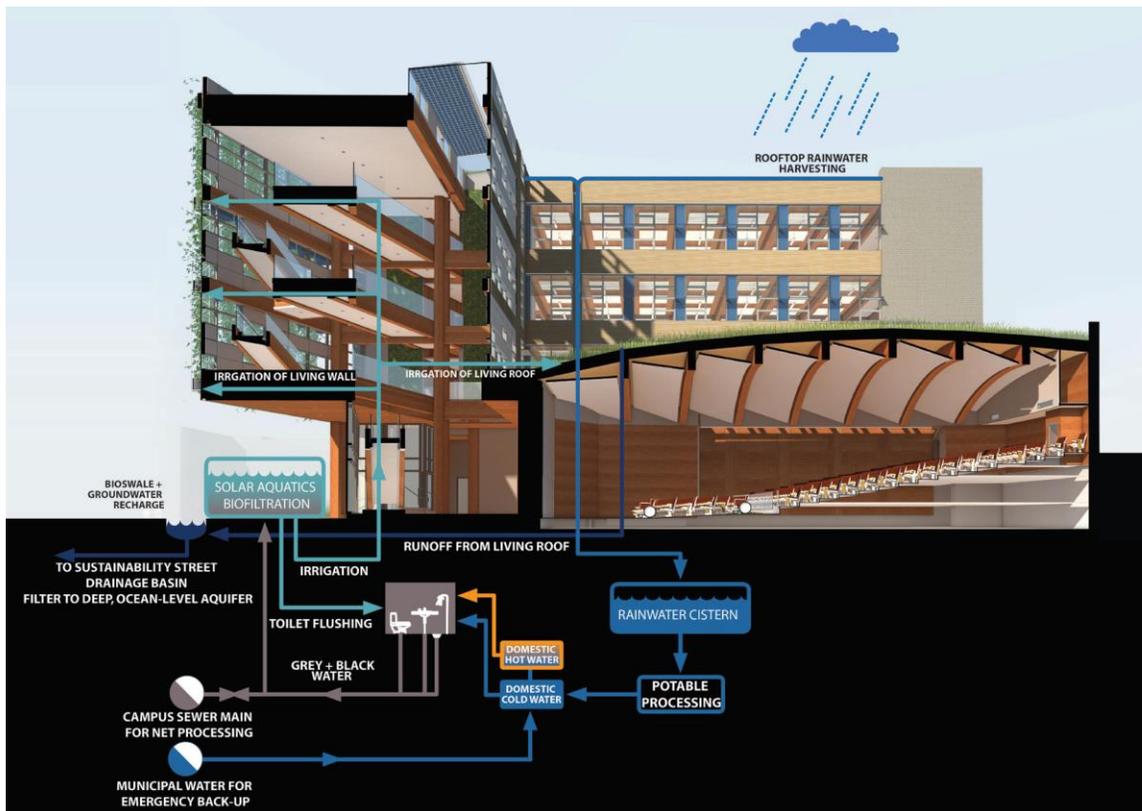


Figure 17. CIRS Water diagram, source: CIRS Technical Manual

There are four integrated water efficient strategies applied in the design process of CIRS building (CIRS Technical Manual):

- 1- Storm-water runoff system
- 2- Rainwater harvesting system
- 3- On-site water treatment system (Solar Aquatic)
- 4- Low flow fixtures

Each system is described individually following with further exploration to find the gaps and reasons in case of failure. The baseline to assess success or failure is each system's design targets.

3.2.1 Storm-Water Runoff System:

At the site scale, there were a number of criteria involved with the location of the site, like the campus land use considerations, synergy with other buildings as well as infrastructure, and also featuring the project as a symbol of sustainable approach in UBC campus (CIRS Technical Manual).

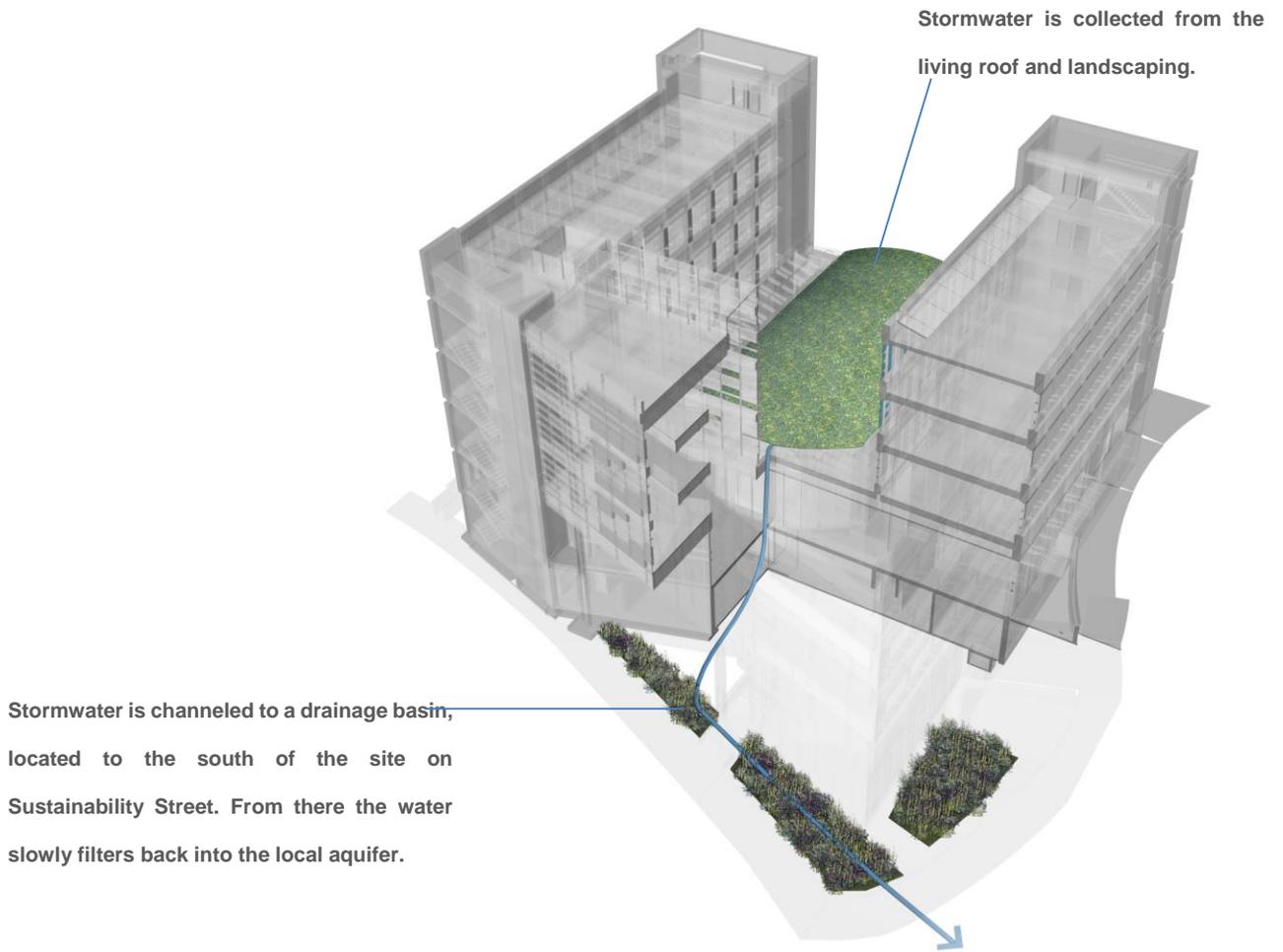


Figure 18. CIRS Landscape water strategies, source: CIRS Technical Manual

Water movement on site was a priority, however, the large footprint of the building limited the area of building's landscape to about 310 square meters total, which makes onsite stormwater management challenging. Therefore, stormwater is channeled through the small rain garden and

the bioswales designed in the south of the site on the Sustainability Street, a cross-boundary solution for leading stormwater to campus landscape infiltration basin. The landscape also benefits from living roof and all planting with native, low-maintenance plants that require no additional watering (CIRS Technical Manual). The rainwater capture for the landscape works relatively well. It mitigates the impacts of regularly occurring storms and slows the rate of water that would go to the storm system in outlying events. If additional space were allocated to landscape design to infiltrate the site runoff, the landscape could probably handle more stormwater than is currently designed. (Associate Director, Municipal Engineering, UBC Staff, October 10th, 2017)

3.2.2 Rainwater Harvesting System:

In the building design, low flow fixtures, on-site water treatment, and rainwater harvesting are the main water efficient strategies that were applied. The rainwater harvesting system was designed to supply all potable water demands of the building. Potable water is used for sinks, showers, the Loop Cafe (drinks, cooking, cleaning), janitorial services and building maintenance (CIRS Technical Manual).

The rainwater harvesting system consists of 7 steps process as:

- 1- Collection
- 2- Storage
- 3- Filtration
- 4- Disinfection

- 5- PH adjustment
- 6- Treated water tank
- 7- Monitoring and back-up

Figure 19 shows the system components in the building diagram. This system takes only a few of hours to process rainwater to drinking water (CIRS Technical Manual).

This system was designed to collect rainwater from the rooftops into the cistern in the basement, then processed to produce drinking water to distribute for pot-able use water fixtures and appliances inside the building. A backup connection to municipal water is also added to use if required.

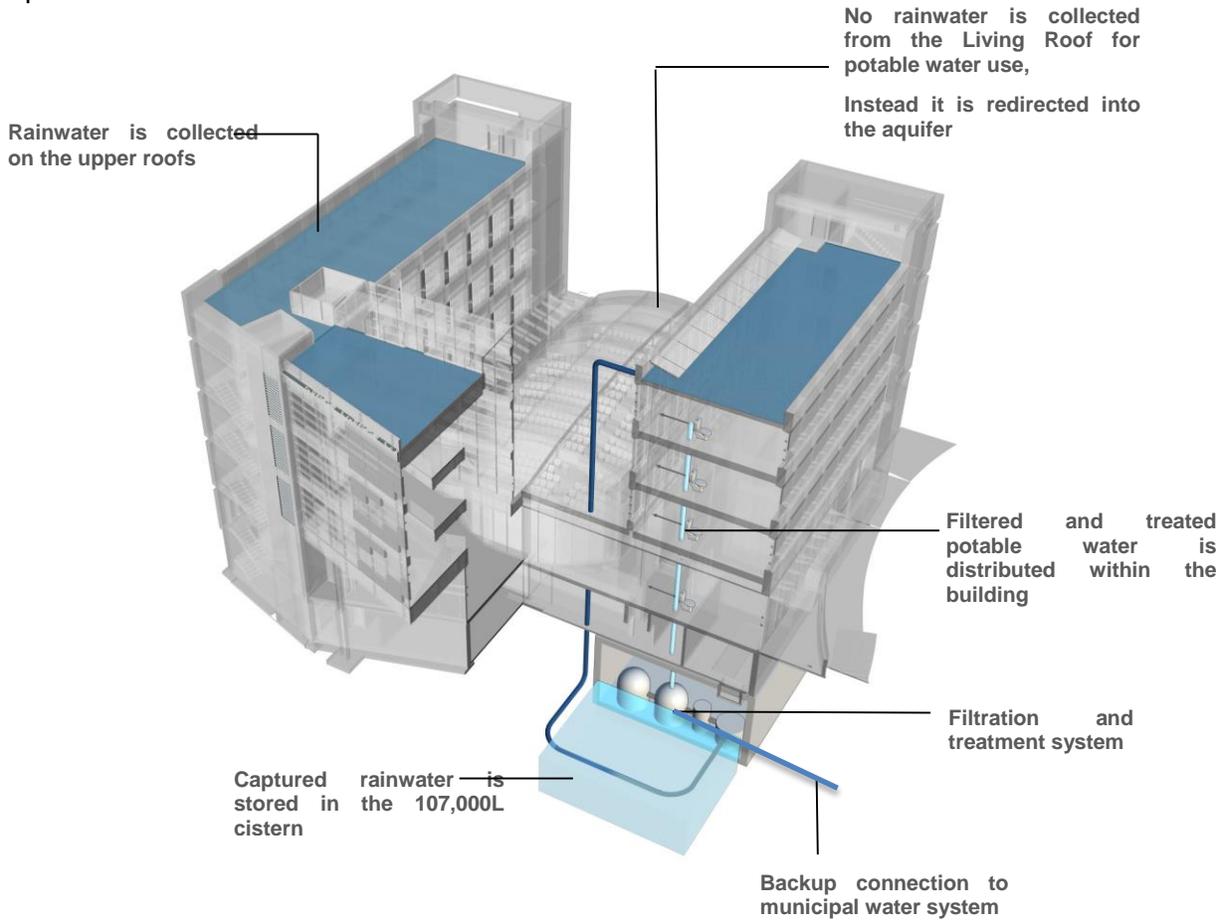


Figure 19. The Rainwater Harvesting System diagram, source: CIRS Technical Manual

Vancouver approximate annual rainfall amount = 1226 millimeters per square meter

CIRS rooftop collecting area = 1000 sqm

Potential rainwater to capture (water budget) = 1226,000 L

Actual rainwater cistern capacity = 107,000 L

Surprisingly, the rainwater harvesting system is ready to work but it has not been operated yet due to high maintenance costs and unclear health regulations. The future plan for this system is using the harvested water only for irrigation and to flush toilets and not for potable water use (Director at UBC Sustainability Initiative, September 19th, 2017).

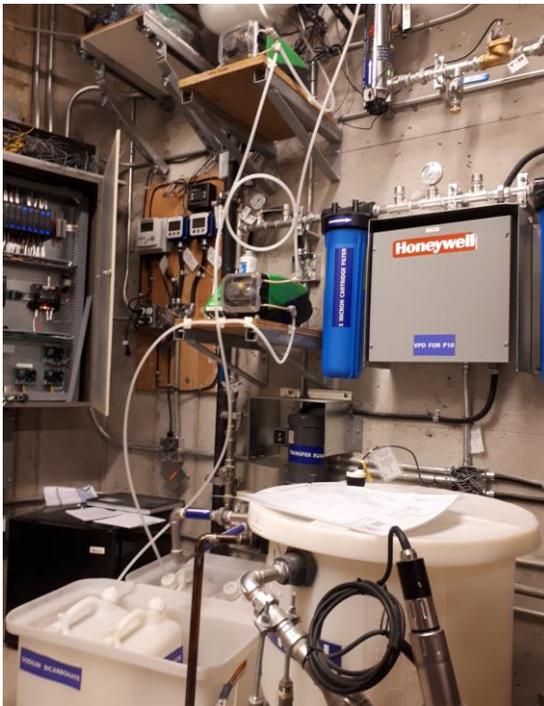


Figure 20. CIRS Rainwater mechanical room, Date of photos and meter reading: September 2017

As the figure 20 shows, the meter indicates that so far, only 2.6 liters (almost zero) of water has been processed in this system since 2012.

3.2.3 On-site water treatment system (Solar Aquatics)

Another distinctive feature of the CIRS building is the Solar Aquatic System (SAS) that was designed following the concept of mimicking nature by bio-filtering black and grey water to produce treated water without the use of chemicals. The goal of this system design was to reclaim water from CIRS and campus sewer system to treat in the Solar Aquatics and reuse for flushing toilets and irrigation. This ecologically engineered system is located in the southwest of the building and is separated by a pedestrian path from the building.

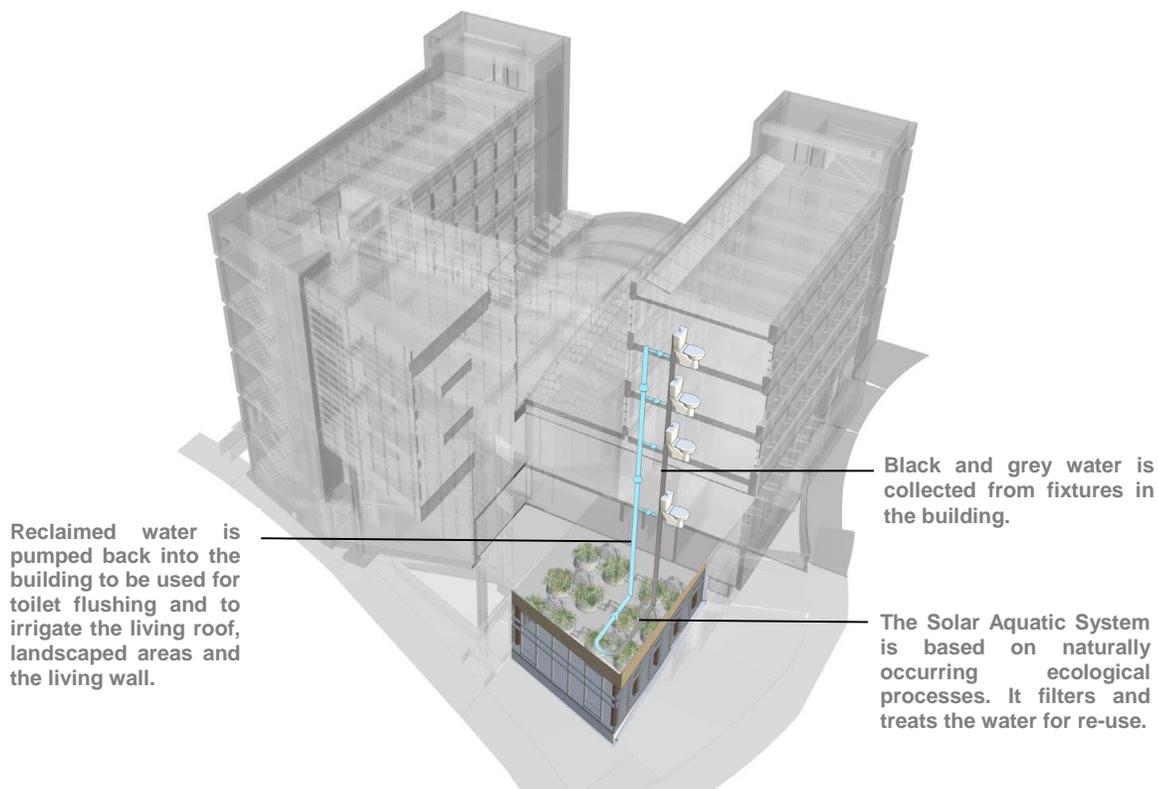


Figure 21. The Solar Aquatics water treatment diagram, source: CIRS Technical Manual

This system is designed based on a 10 step process which is mostly a few open and closed tanks to collect wastewater from the building fixtures and campus sewer system and produce treated water without using chemicals. However, the *Health Canada Reuse Guidelines*⁶ later required adding chlorine residual for purification purposes. (Vassos, 2014)

This system includes:

- 1- Collection/Buffer Tank
- 2- Blending Tank
- 3- Aeration Tanks
- 4- Gravity Clarifier
- 5- Sand Filter
- 6- Constructed Wetland
- 7- Ultra-Filter
- 8- Disinfection
- 9- Storage and Re-use
- 10- Compost (as a future development)

The building design team, Busby Perkins+Will, Stantec, and Eco-Tek were collaborating for building and commissioning of the Solar Aquatics treatment system. In January 2009 ECO-TEK was hired for the SAS installation at CIRS. (Eco-Tek CEO, October 2017)

⁶ *Health Canada Reuse Guidelines* recommend that chlorination be used at least as a secondary means of disinfection to maintain a chlorine residual within the distribution system. (Vassos, 2014)



Figure 22. The Solar Aquatics Water Treatment
Interior, September 2017

The purpose was to develop an ongoing experiment on an innovative water treatment system and a demonstration test for future developments on campus (CIRS Technical Manual). However, after visiting the system and reading the meters show that the system is not functioning as expected.

In fact, the system has been using more water to work than to produce treated water. There are a number of technical, regulatory, operational and financial barriers that led to this system failure. These barriers will be discussed further in this chapter.

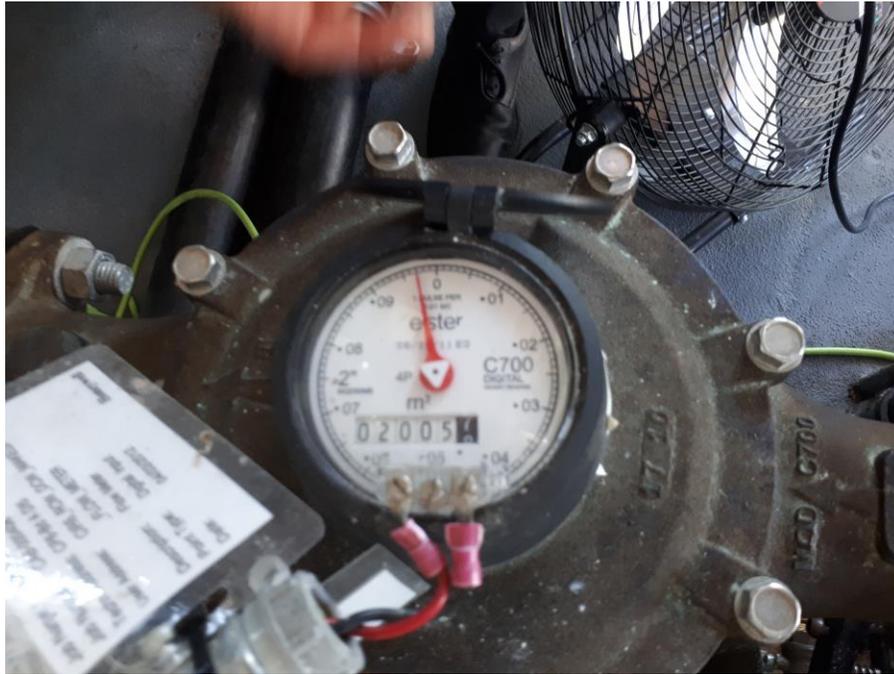


Figure 23. Solar Aquatics municipal water back up meter

The future plan for Solar Aquatics is to run it as a research lab on water treatment project of this type, with no actual operation as it was designed for.

Even though the Solar Aquatics has not been performing, it helped the project in achieving LEED

Water Efficiency required credits of:

- 1.1 & 1.2 – Water Efficient Landscaping
- 2 – Innovative Wastewater Technologies
- 3.1 & 3.2 - Water Use Reduction

CIRS integrated water system design is illustrated in this diagram:

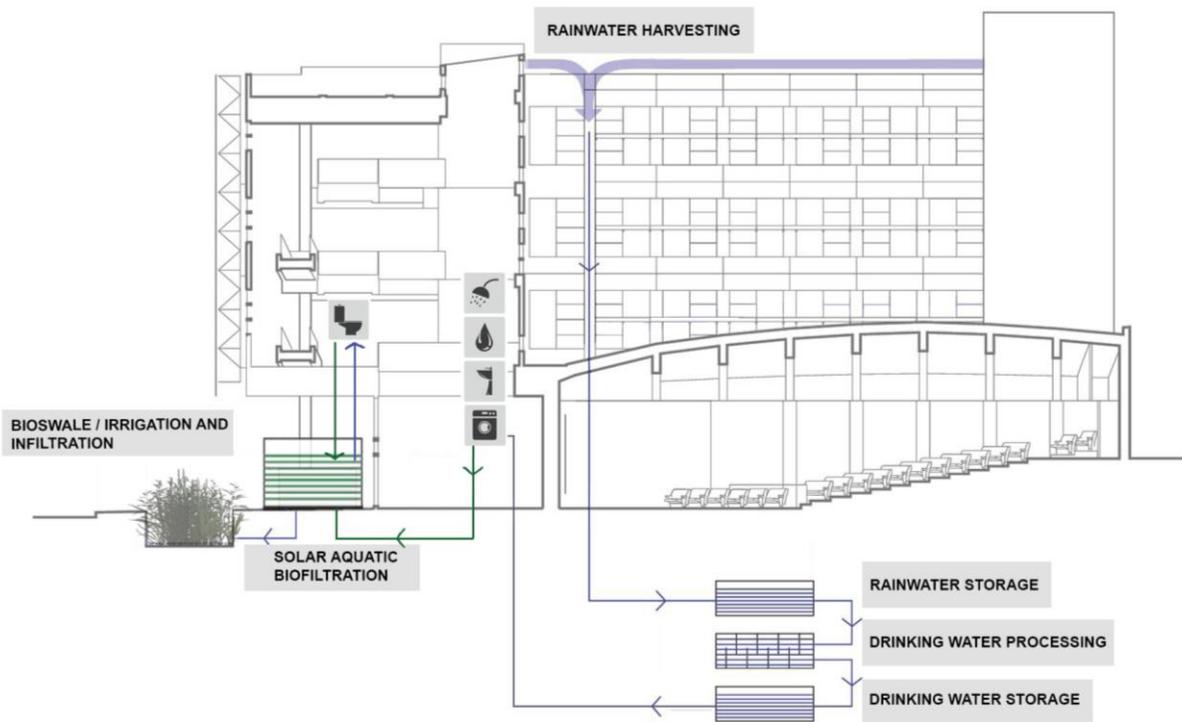


Figure 26. CIRS water system design diagram

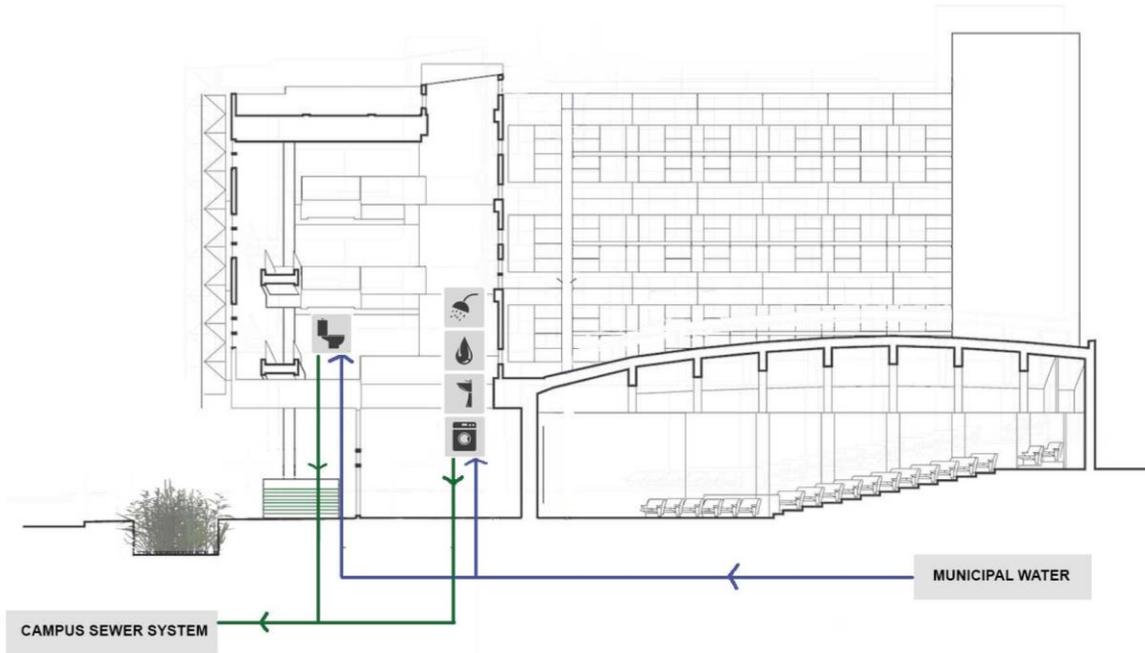


Figure 27. CIRS actual water system diagram

CIRS was also aiming to obtain Living Building Challenge (LBC) water petal, however, the LBC program requires the entire building to be water self-sufficient which is not achievable due to operational gaps. (Director, UBC Sustainability Initiative, September 2017).

3.3 CIRS Water Efficiency Analyses

CIRS water quantitative data are summarized in the table below:

CIRS Water Fact Sheet

<i>Predicted water consumption</i>	730,000 L per year
<i>Actual water consumption (meter reading September 2017)</i>	600,000 L per year
<i>Water Budget (rainwater from the collecting rooftop)</i>	1,226,000 L per year
<i>Cistern capacity</i>	50,000 L
<i>Fire safety required water</i>	57,000 L
<i>Makeup flow water meter at Solar Aquatics (meter reading September 2017)**</i>	2005 m ³
<i>Total reclaimed water at Solar Aquatics</i>	

	0 L per year
<i>Total rainwater captured</i>	57,000 L for fire safety cistern

Table 3. CIRS Water Quantities

*The makeup flow water is the amount of water injected into the Solar Aquatics to back flush the sand filter, in order to help the filters work. (Water meter readings compiled from UBC Energy and Water Service, September 2017)

The table shows that the building consumes less water than predicted and has not met the project goal of water self-sufficiency. Although the building was successful to reduce water consumption through low-flow fixtures, it has been using municipal water shortly after opening. The water meter shows the total water consumption since 2012 is 3,667,000 liter. Considering the price of city water, even if the entire water system has been functioning as designed, UBC would have saved less than \$3,000 (which means less than \$600 per year):

$$3667 \text{ QL} \times 80 \text{ cent} = \underline{\$2,934}$$

This simple but important calculation shows that the low price of water offers no financial incentive to invest in water conservation measures like rainwater harvesting or onsite water

treatment in this scale. However, the low price of water should not underrate the environmental impact of such systems. Therefore, knowing that UBC campus pays about \$3 million for water compared to \$22 million electricity bill, (Campus Energy and Water Office) the question is: In what scenario does it make financial and environmental sense to integrate these water strategies/systems to building other than pursuing a green building rating system? In other words, what is needed in the next green building to meet the water goal?

Comparing predicted and actual performance of CIRS water system

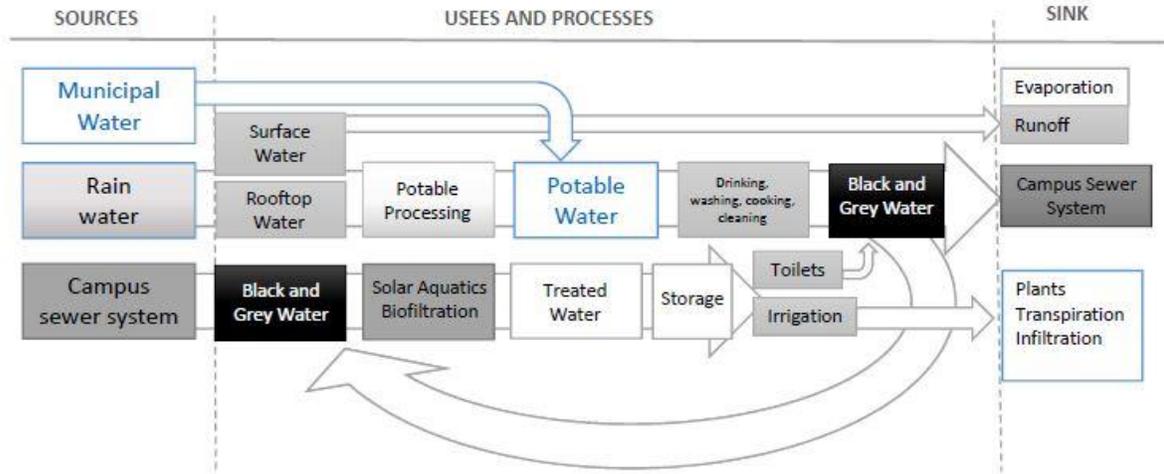


Figure 24. CIRS water system design diagram

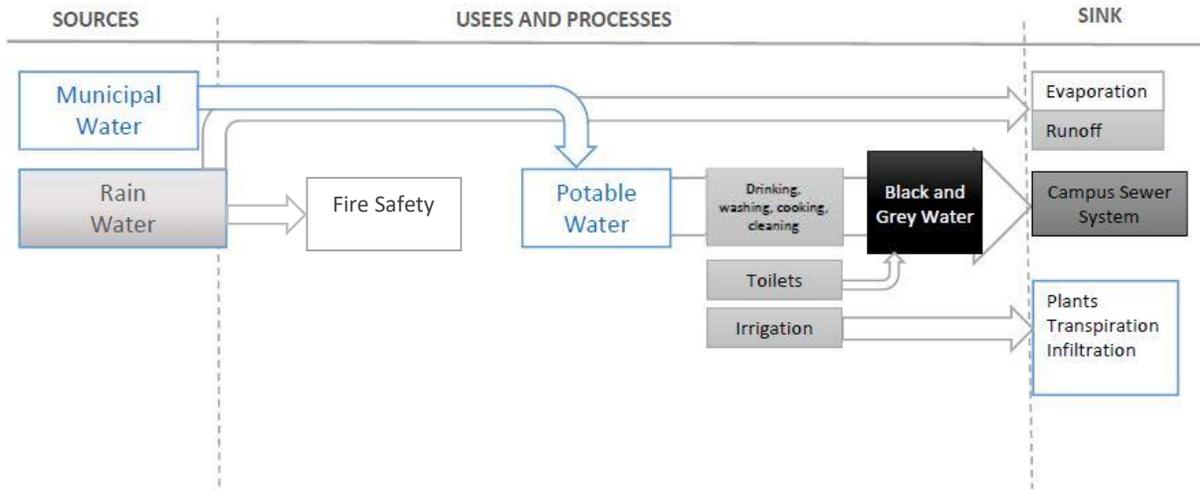
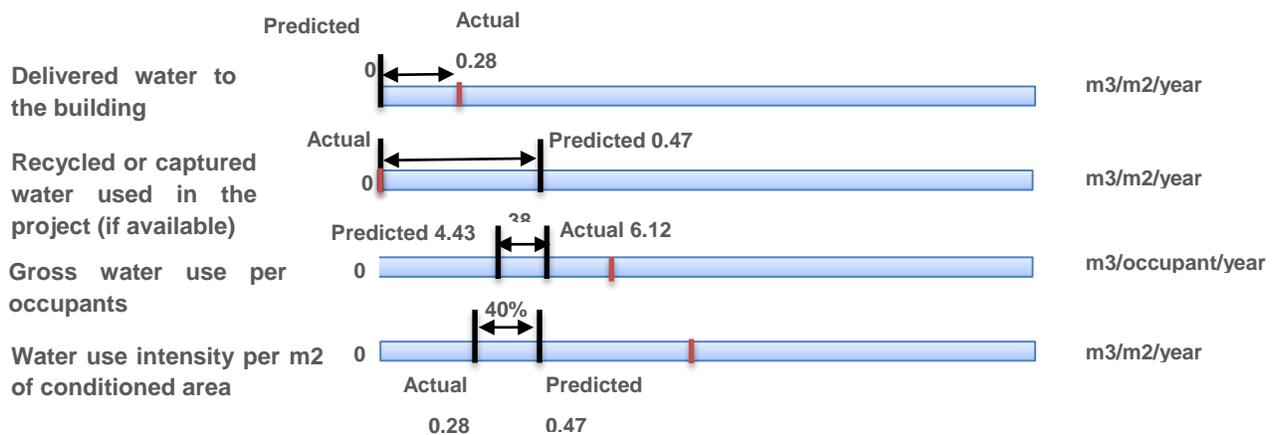


Figure 25. CIRS water system performance diagram

Water Quality

To understand the design expectations and performance gap, a quantitative post-occupancy evaluation of this building is completed for 3/2012 to 2/2014 time period. In this assessment, the Key Performance Indicators (KPI) is applied which include; the amount of water delivered to the building, the amount of water recycled or captured in the project, gross water use per occupants, and water use intensity per square meter. The KPI assessment is illustrated as below:



Red bar indicates typical industry performance for the region

Figure 26. CIRS Key Performance Indicators (KPI) for water system - predicted vs. actual

Source: An assessment conducted by researchers from the University of British Columbia, University of Manitoba and Ryerson University, <http://iisbecanada.ca>,

This research shows that the occupancy rate was lower than the design prediction, therefore, the water use intensity per square meter was 40% lower than predicted, while the gross water use per occupant was 38% higher than predicted. This post-occupancy study concludes that performance gaps arise from a variety of reasons such as engineering design and system

integration problems, commissioning and handover processes, operational issues, financial motivations, and the cost of water. (Bartlett et al., 2014)

Therefore, main reasons that led to performance gaps can be listed as:

- **Lack of involvement with all stakeholders such as UBC Operations**
- **Communication gap between teams**
- **Lack of a clear vision and plan for UBC in terms of water efficiency**
- **Low cost of municipal water**
- **Lack of operational and maintenance financial support and capabilities**
- **Lack of clarity in regulations**
- **LEED as the rating system is not an efficient driver**

Based on the research background, site visit, interview with key people involved in the design, construction, operation of the CIRS water system, and the proposed methodology to study the case, each phase of this project is explored and organized in an individual table sheet. The table summarizes the questions as a qualitative assessment factor in the left column and the descriptive answers to the right.

SCHEMATIC DESIGN

Decision making

CIRS project architect describes the decision making process: The project initiated by the Dr. John Robinson (former UBC professor in IRES program) by inviting a network of almost 20 people working in high-end performance building profession in workshops and charrettes to collaborate on defining building goals.

The very ambitious building goals were zero-carbon, water and energy self-sufficient.

The water goal was set to be:

- Self-sufficient
- Environmental (supply all water needs from rainwater and wastewater to reduce runoff, and decrease surface water pollution and prevent cliff erosion)
- Educational, as a demonstration of sustainable design as well as an ongoing opportunity to learn and research “

(Managing Director at Perkins+Will, October 2017)

The site decision was made by UBC through internal processes during the initial stages of the project and it was changed three times before confirming the current site of the building. The building, as well as landscape, was created through the integrated design process and teamwork charrettes. (CIRS Technical Manual)

Design teams

Architects: Busby Perkins + Will

Landscape Architects: PWL Partnership

Civil Engineer: Stantec

Environmental Engineers: NovaTec Consultants

	<p>Solar Aquatics designer/builder: EcoTek</p> <p>Mechanical Engineers: Stantec</p> <p>Operators: UBC Campus Operations (CIRS Technical Manual)</p>
Water Goals	<p>100% water self-sufficient</p> <p>100% rainwater input</p> <p>Zero stormwater output from site</p> <p>100% stormwater will be treated, used or infiltrated onsite.</p> <p>(CIRS Technical Manual)</p>
Impact of net-zero water goal on the site and building on Program	<p>Solar Aquatic, living roof, living wall, bio swale, rain garden are added to the project program</p>
Impact on the Environmental sensitivity	<p>Low-flow fixtures reduces total water use inside the building and at the building site, the rain garden, bio swale and living roof bio-filter the surface water while reducing runoff.</p>
Impact on advancing water design strategies on campus	<p>Lessons learned from this project can improve future water efficient buildings project and provide them with actual performance experience</p>
Contribution to sustainability	<p>Contributes to campus goal of creating a fully integrated water system (UBC Green Building Plan, 2017)</p>

Table 4. Schematic Design Phase

DESIGN DEVELOPMENT

<p>Core Concept— How did the ideas about water efficiency influence design development?</p>	<p>Design of the water system was developed through early concept development and charrettes by collaborators.</p> <p>Approach remained significantly focused on self-sufficiency. Water self-sufficiency was a core concept and none of the water-related ideas has been folded throughout the process. (CIRS project lead architect, former principle at Perkins+Will, September 2017)</p>
<p>Impact on Form, massing</p>	<p>Features like Solar Aquatics glass box, green wall in the South elevation, visible green roof, rain garden and visible water leads from atrium, have created a distinctive ‘green’ look in this building</p>
<p>Are there any specific examples of innovation in service and technology applied to achieve net-zero water goal?</p>	<p>The Solar Aquatics system was the first reclaiming water project at UBC, and of onsite water treatment project type. It was developed through a design-build approach to mimic natural process of plant water treatment. Generally, implementing a balance combination of systems; Solar Aquatic, living roof, living wall, bio swale, rain garden, was also an effective approach to achieve a closed loop water cycle. (CIRS Technical Manual)</p>
<p>Site— What were the underlying challenges/ opportunities of the site to improve water strategies?</p>	<p>Small footprint of building landscape was challenging to mitigate runoff onsite, so it is channeled to Sustainability street in the South of the site instead. It also limited the size of the rain garden and bio swale as well. (CIRS Technical Manual)</p>

Table 5. Design Development Phase

CONSTRUCTION

Construction teams	Heather Brae Busby Perkins+Will Architects EchoTek NovaTec Stantec
Construction process	<p>The construction was challenging because the contractor, <i>Heather Brae</i>, had never built a building like CIRS before. (CIRS project lead architect, former principal at Perkins+Will, September 2017)</p> <p>Rainwater harvesting system was constructed as a standard part of the building systems.</p> <p>The Solar Aquatics was designed and constructed by <i>EchoTek</i> engineers with the collaboration of mechanical and architectural team, towards the end of the building construction as a design/build package.</p> <p><i>Stantec</i> was the mechanical engineers for the project, responsible for estimating potable water consumption requirements, determining cistern storage capacity, cistern design, roof water collection system and rainwater conveyancing system design, first flush bypass and stormwater diversion, and overall mechanical design of the pump system to transfer water to the building (i.e. rainwater collection and storage and treated water distribution) (NovaTec Senior Process Engineer, UBC faculty, October 2017)</p> <p><i>Eco-Tek</i> were responsible for the turn-key supply and commissioning of the Solar Aquatics treatment system and chlorination dosing system (NovaTec Senior Process Engineer, UBC faculty)</p>

	Green roof, green wall, and landscape work completion was the final stage of the building construction by <i>PWL</i> partners.
Construction cost	6,150 (\$/m ²)
Infrastructure— What are the technological pros and cons in regards to water system?	<p>Pros: The green infrastructure, rain garden, bio swell and living roof biofilter the surface water while reducing runoff</p> <p>Cons: No significant disadvantages were observed</p>

Table 6. Construction Phase

PERFORMANCE

<p>Decision making</p>	<p>The building performance decision is made by UBC campus Operators. The operating permit for the rainwater system was granted in fall of 2012, although it was never activated. The work on the Solar Aquatics Box continued, with engineering reviews etc. through 2016 (Director, UBC Sustainability Initiative, September 2017)</p>
<p>Time—How well do the technologies fare over time? Is the water system effective in all seasons? How persistent are the effects?</p>	<p>None of the rainwater reuse or reclaimed water technologies have functioned since the opening of the building. The green wall plants took more time than expected to establish and grow. (Site Visit, September 2017)</p>
<p>Cost—Is the water system cost-effective? How do we assess the cost-effectiveness of each system?</p>	<p>Due to the low price of water and failure of the building water systems, they are not cost-effective in this project. However, low flow fixtures, as well as landscape water strategies, are performing in a cost-effective way.</p>
<p>Impact on context - How is the UBC campus served by this project?</p>	<p>Lessons learned from this project can provide future water efficient buildings project with actual performance experience. Solar Aquatic will serve as a research lab.</p>

Maintenance - How the water systems maintenance are managed? Does UBC hire outside contractors to perform maintenance?

Lack of an ongoing maintenance support is one of the main barriers in running these systems, UBC needs to hire a full-time professional wastewater engineer with staff support to run, monitor, test and maintain the systems which increases maintenance fees unaffordable for CIRS to afford due the low price of water. (Director, UBC Sustainability Initiative., UBC Energy and Water Service unit (EWS), September 2017)

Recommendations – What do you recommend for future green building water systems on UBC campus?

See Chapter 4

Table 7. Performance Phase

Building failures that were observed in the performance phase were arguably related to the gaps in the planning and designing phase. In addition, operational capabilities and capacities are required in sustaining or improving the performance of each system which can potentially be predicted in the pre-design phase for similar projects.

	LEVEL OF SUCCESS	FULLY SUCCESSFUL	PARTLY SUCCESSFUL	NOT SUCCESSFUL	BARRIERS
STRATEGY					
STORM-WATER RUNOFF SYSTEM		✓			
RAINWATER HARVESTING SYSTEM				✓	Operational Financial
ON-SITE WATER TREATMENT SYSTEM				✓	Operational Financial Technical
LOW-FLOW FIXTURES		✓			

Table 8. Evaluation of Each Water Strategy in CIRS project

3.4 Summary

The majority of interviewees suggest that inviting all stockholders early in the process, better communication and collaboration between different teams, having a clear plan for UBC water vision are the most important requirements to run a net-zero system sustainably.

Key findings of this case study in summary are:

- 1- Lack of involvement with all stakeholders:** UBC Operations, a key stakeholder in building construction on campus, was not consulted during the decision making of the project.

Furthermore, regulators like Vancouver Coastal Health were missing in the decision making phase. A key to success in construction projects is to identify and engage all related main parties in the early phases of design through an integrated design process.

- 2- The communication gap between teams:** Another reason for the failure of this system is inadequate communication between teams, particularly when the project is a design-build type and is not following typical project procedures.

- 3- Lack of a clear vision, plan, and guidelines for UBC in terms of water efficiency:** UBC is currently developing water goals and targets in WAP. However, such planning supports were not available at the time when the CIRS project was being designed and developed.

- 4- Insufficient financial and technical support for operation and maintenance:** The rainwater harvesting and the Solar Aquatics systems require a higher degree of professional and financial support than a typical water system for operating and maintenance. However, UBC Operations do not yet have the technical and financial support to fund the system and to hire certified professionals in wastewater reuse to monitor and maintain the water system.

5- Lack of clarity in regulation: Another reason for performance gaps is not consulting with all regulators in early stages of the project. Therefore, decision-makers were insufficiently informed about water and wastewater systems regulations when implementing it in the design process. Regulations require water reuse systems in a university to be monitored by an experienced (level 3 or 4) operator certified at the Environmental Operators Certification Programs (EOCP). Another requirement for water reuse systems in the 2012 Municipal Wastewater regulation is to undergo an environmental impact assessment test to assess the health risks of treated water to building users as well as to the public. (Ebrahimi & Cheung, 2014)

6- Lack of technical experience: The Solar Aquatics System (SAS) for water reclamation and reuse was an innovative design-build project and the first one of this type on UBC campus. Many architectural, mechanical, electrical systems have failed in the SAS as a result of unforeseen design issues. Also, the adjacency of SAS to the offices above is problematic. Despite isolation and using an air pump to ventilate the system, moisture and bad odor from this facility disturb the upper-level offices which have resulted in shutting down the system regularly (Eco-Tek CEO, October 2017). The scale of the system, as also recognized in the CIRS Technical Manual, was not the right scale for wastewater treatment. The amount of grey and black water produced by CIRS building is less than predicted, particularly during summer months. This type of system could work more efficiently on a

wider scale like a cluster of buildings to capture more grey water and provide nutrients for other facilities like the adjacent horticultural building.

7- LEED as an inefficient driver: LEED does not require any performance measures in its rating system which means a project can achieve the highest green building award even when a building's systems are not actually functioning. Some interviewees believe that a performance-based rating system like LBC should be considered, as it can potentially help future projects to perform up to their potential.

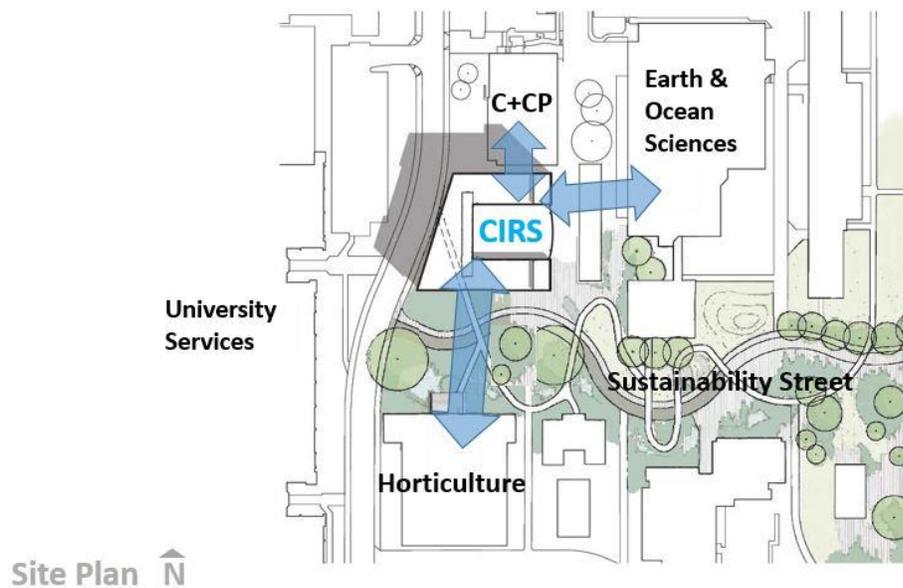


Figure 27. Onsite wastewater treatment working with a network of building.

Looking at CIRS timeline as well as UBC sustainability millstones, we learn another fact about this project:

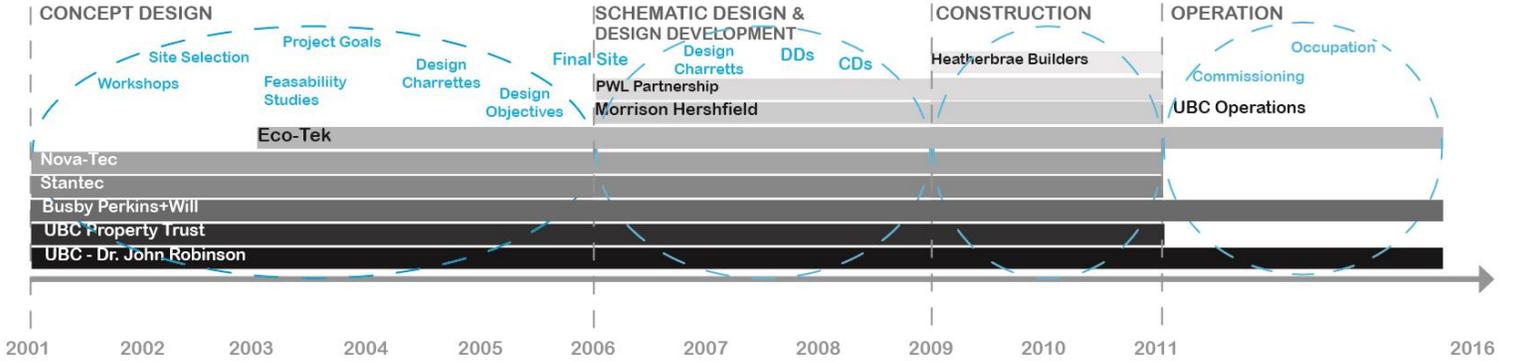


Figure 28. CIRS Project Timeline

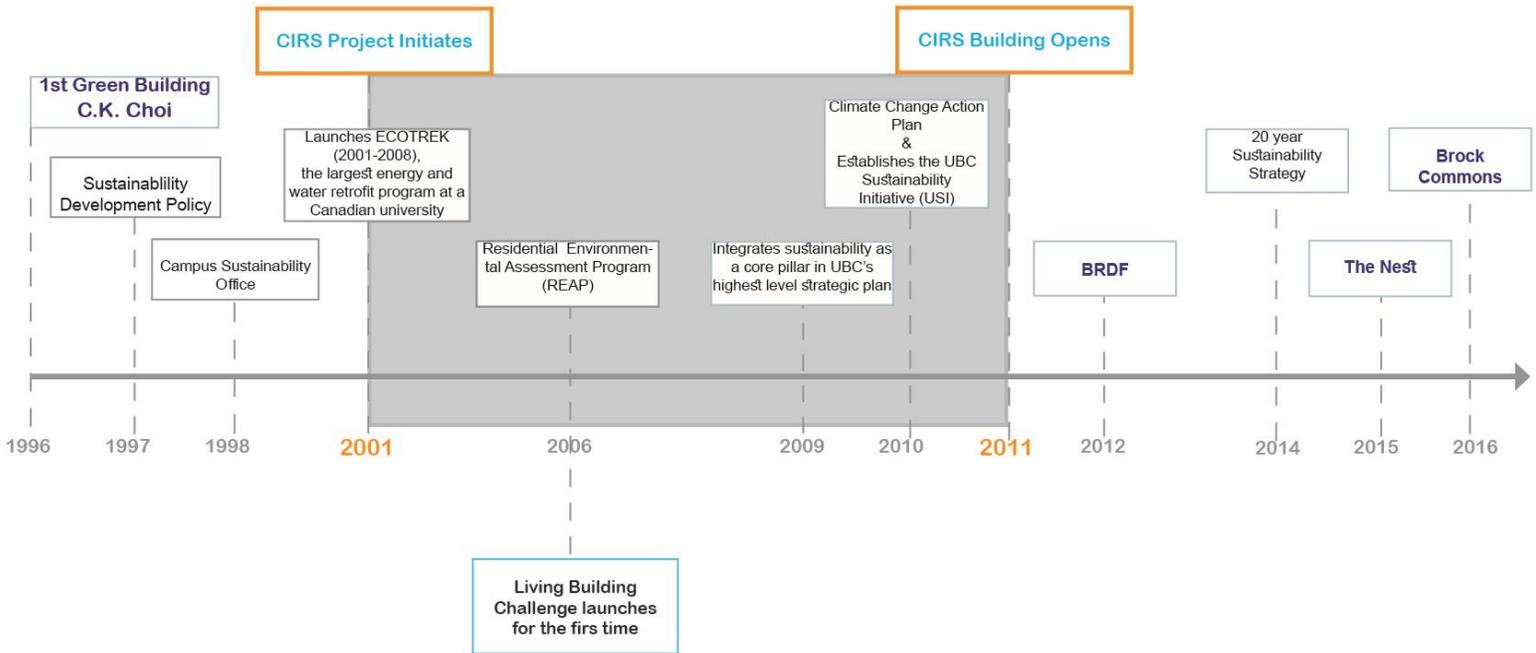


Figure 29. Sustainability and Green Building History at UBC Vancouver Campus,

Source: UBC GBP Institutional package 2017

Comparing CIRS timeline to Sustainability and Green Building timeline at UBC, we learn that this project initiated years before UBC had solidified its sustainability milestones. There was no clear water policy context to guide the project when CIRS project was developing. This gap caused the CIRS building to fall short of some of its designers' goals. For example, the designers of CIRS set ambitious sustainability goals for this project eight years before UBC adopted the integration of UBC's sustainability strategic plan or the Climate Change Action Plan. Moreover, the comparison illustrates that CIRS project incorporated the idea of net-zero water in its schematic design phase in 2001, five years before the introduction of LBC to the industry.

Without question, CIRS is a pioneer project that has provided water efficiency practice in green building context on campus with a number of opportunities. It also sheds new light on many challenges and limitations of water efficiency practices. These challenges and opportunities are summarized in Table 8.

Table 9. Opportunities and Challenges CIRS project has gone through

OPPORTUNITIES	CHALLENGES
PRACTICING WATER SELF-SUFFICIENT SYSTEM	Changing the perception towards water, Cost of Water
LOOKING AT RAINWATER AND WASTEWATER AS A RESOURCE	Unclear Regulations
ENGAGING REGULATORS, DESIGNERS, ENGINEERS, OPERATIONAL & MAINTENANCE STAFF, RESEARCHERS, AND OCCUPANTS	Gaps between multiple phases of design and between consultants
MIMICKING NATURAL PROCESS IN WATER CYCLE	Finding Sustainable alternatives
MAKING WATER EFFICIENCY VISIBLE	Gaps between predicted and actual consumption
UTILIZING A DESIGN-BUILD TEST MODEL	Lack of actual functional experience
CREATING A DISCUSSION TO EXPLORE AND RESEARCH IN PRACTICE (LIVING LAB CONCEPT)	Operational and maintenance capacities, capabilities and costs

OPPORTUNITIES	CHALLENGES
SCALABILITY OF THE STRATEGIES	High costs for water reuse vs. low Water price
DEMONSTRATION AND EDUCATIONAL POTENTIAL	Budget challenges and prolonged project schedule

Although CIRS building did not meet the water self-sufficiency goal, the “added value” (Cole, 2015) of CIRS project to the UBC campus green building history should not be overlooked by performance metrics. CIRS is a demonstration of sustainable practice on UBC campus with a “living lab” concept-goal which has been truly achieved. Therefore, this project does not represent a typical building process because it tried to push the boundaries to create a self-sufficient building and tackled many first time challenges at the UBC campus. Now, this project is an iconic building, internationally recognized in the green building industry with an interesting story with learning opportunities. Lessons learned from this study as well as recommendations and future directions are discussed in chapter 4.

Chapter 4: CONCLUSIONS AND RECOMMENDATIONS

4.1 Contribution

This thesis is seeking to bridge the gap between theory and practice of green buildings' water systems on UBC Vancouver campus based on the findings of background research and the case study.

Due to the rising global water crisis, developing an understanding of influential factors to achieve water efficiency in new developments is significantly important. The context of this research is UBC green building water systems that were identified as one of the problematic systems in the performance phase.

New technologies and mechanical components are constantly added to green buildings in the name of sustainable architecture with no proper efficiency check. Although green building rating systems have been reducing buildings environmental footprints considerably, some of them failed to meet performance goals (Bartlett et al., 2014; Yudelson, 2012; Yudelson, 2016). Even though the professional sector realizes and explains the problem of the performance gap in green building practice, very little literature exists on the solutions. Most of the solutions are focused on the mechanical systems in the form of component or device additions which are highly energy and carbon-intensive, and costly with little payback on saving water. On UBC campus, the unchecked use of alternative water systems in green buildings also resulted in adding costly and

high energy intensive mechanical components which only helped to achieve high enough scores to receive “green” awards rather than achieving water efficiency goals.

This study took four steps. Firstly, identifying the problem; secondly, understanding the context; thirdly, finding the gaps by looking through different lenses to the case study; and finally, making recommendations in order to bridge the gap in future projects to design, construct and perform sustainably.

4.2 Recommendations

Some of the recommendations in the case study are specific to the CIRS project but some are transferable to future green building projects. For future practices of green buildings this research makes a few recommendations prioritized in the following fashion:

1. Developing UBC Water Vision, Plan and Guidelines

Having a supportive policy environment, with institutional goals, would have helped meet the ambitious water targets. The case study shows that CIRS building did not meet its water goals due to the absence of campus-wide water policy during the design phase of this project. It is important to have a clear vision for UBC campus and a clear plan showing how to achieve water goals at each scale of campus, precinct, and building. Currently, UBC is developing the Water Action Plan (WAP) based on the goals set by Climate Action Plan (CAP) and Green Building Plan (GBP). However, these plans were not available at the time of designing CIRS and other green

buildings like BRDF, Nest, and Aquatics Centre that have ambitious water goals. Alternative water systems such as rainwater harvesting and wastewater treatment and reuse can have significant implications for operations and could potentially contribute to campus water resiliency. However, there is currently no clear strategy or guideline for implementing these systems on campus (Water Action Plan group discussion, a session on Alternative Water Sources & Resilience, September 2017). Therefore, it is recommended to develop the specific design, implementation and operation guidelines for alternative water sources in new developments, based on CAP and GBP. These guides can assist architects, landscape architects, developers, and operators to design and run water systems sustainably.

Moreover, the low price of water, 80 cents per cubic meter, leaves little financial incentives for UBC to spend on alternative water systems. Designing, constructing, operating, and maintaining these systems requires a constant funding support. Changes in pricing policy or adding water efficiency incentives can provide financial motivation to support such systems in facilities such as labs, sports centers, and other large water users. These pricing policies also can be addressed in the new water action plan.

2. Adding Performance Criteria to UBC LEED Implementation Guide

Some stakeholders are not seeking performance criteria in green building practice because LEED is not a performance-based green building rating system. UBC has taken one step beyond LEED

metrics and created LEED Implementation Guide to apply this rating system more effectively on campus. This study recommends UBC to add a protocol to LEED Implementation Guide requiring future building systems to meet performance goals for at least one year. Further research is required to learn how and to what extent this protocol should address water systems performance.

3. Exploring Opportunities To Improve Integration In the Process of Future Projects

Fragmentation between design phases, teams, and systems within the project process is known as the basic reason that causes gaps in green buildings performance (Bartlett et al., 2014; Reed, 2007; Yudelson, 2016). Therefore, it is essential for this industry to explore ways to enhance integration and collaboration among teams and stakeholders throughout the project timeline. For example, looking at CIRS project timeline shows that although many key stakeholders and professional teams were collaborating from the beginning, there were few teams missing or been

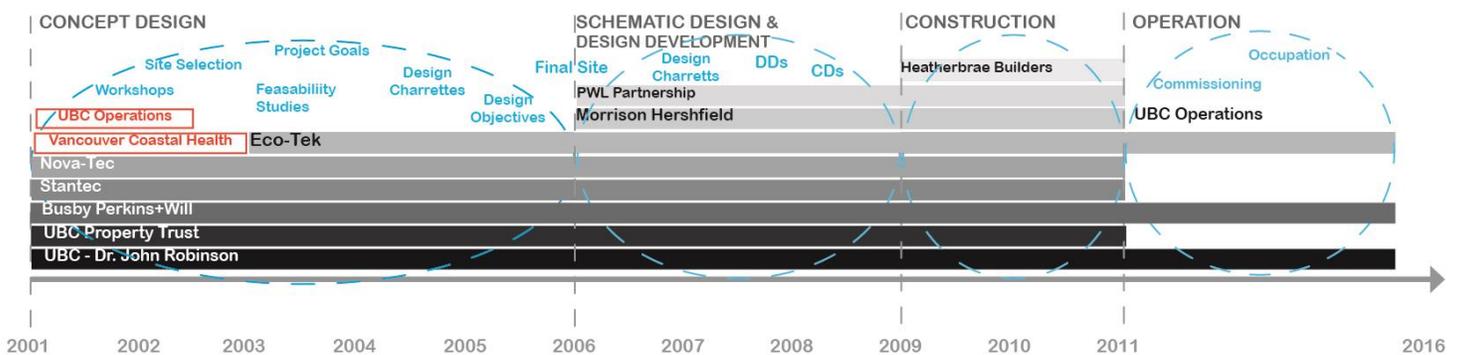


Figure 30. CIRS project timeline- involving all stockholders early in the project

involved late in the process. UBC Operations were not involved in the process earlier than operation phase and PWL Partners (landscape architects) were not at the table in the schematic design phase. Which resulted in not reflecting these teams' viewpoints, concerns, capabilities or limitations.

Therefore, it is recommended to recognize all related teams and integrate them effectively early in the project life. For pioneer projects like CIRS dealing with many different stakeholders, aspirations, and expectations, it is important to create a clear alignment between all players and to simplify project targets as much as possible. Soft technologies like IDP (Integrated Design Process) and IPD (Integrated Project Delivery) are effective tools in this industry to help bridging the gap between promise and performance.

4. Increasing Campus Water Resiliency

UBC, as a public university, should be able to attract and serve students, scholars, and staffs who are living in its community even in case of natural changes or crisis. One would argue that planning and investing in water efficiency is not financially feasible due to the cost of water. However, it is promising for UBC's long-term environmental, resiliency, and safety goals.

In this regard, UBC has adopted the *20 Year Sustainability Strategy* in 2014 which set clear goals and targets for the campus in 2035. One of the five strategic goals to describe the success for UBC in 2035 is *"The integration of campus-scale energy, water, waste, and food systems is linked*

to improved quality of life for students, staff, faculty and campus community and to enhanced ecological integrity.” Water is extremely important in the livability of the campus, however, the current water and wastewater system are not sustainable nor environmental. Because it is a centralized, one-way piped system, completely depended on municipal water, which is high carbon and energy intensive. It is also vulnerable to climate change and natural crises like earthquakes.

The climate is changing and the campus needs to respond to it. UBC has adopted *Climate Change Action Plan* (CAP) in 2010 with specific greenhouse gas (GHG) mitigation targets, 100% till 2050. The challenge and response will need to differ depending on scale. In the *Design for Climate Change* book, Bill Gething talks about buildings and issues such as water efficiency, based on the largest research focusing on the climate change adaptation of buildings in the UK. The goal of this program is to improve the climate resilience of building projects. He argues that *“not all of the impacts of climate change must be resolved at the level of a single building.”* This study also shows that small-scale water treatment plants or rainwater harvesting systems are not economically and environmentally efficient (Gething & Puckett, 2013).

A similar issue has been observed in UBC campus green buildings’ water systems. None of the single buildings’ alternative water systems function sustainably in a cost-effective way. In another word, that efficiency of the water system is not limited to building scale. *“Water is a shared*

responsibility” (UN Water Report 2015). The integration of infrastructure, landscape, and buildings’ water systems is essential to meet water goals in future green buildings. It is fundamental to understand that we are bound to systems in order to be able to sort, define and work with them, but it can sometimes become problematic when we stick within boundaries that

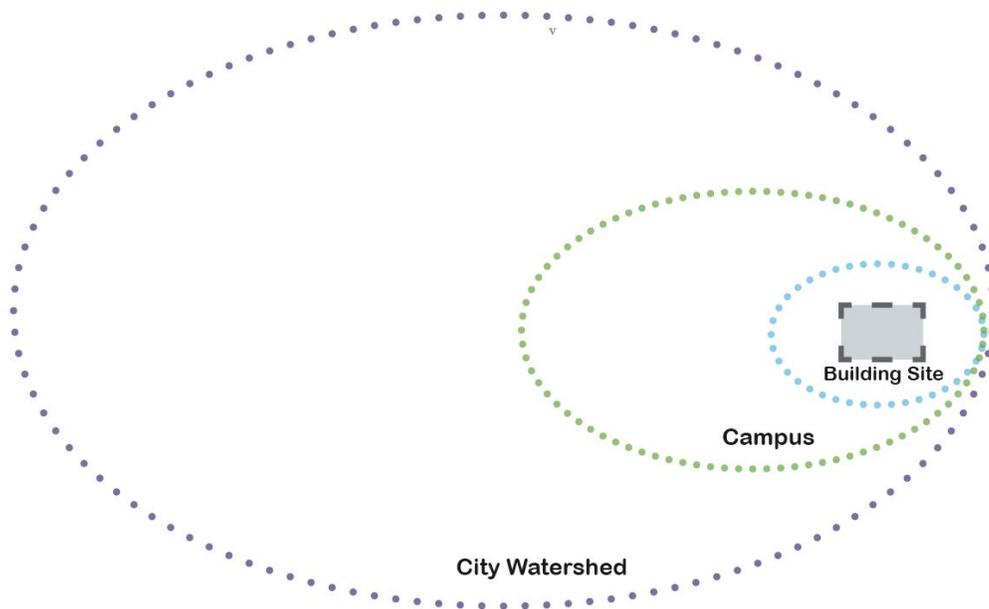


Figure 31. Water Boundaries

do not really exist (McLennan, Jason F. Reed, Bill, 2013). We need some boundaries to understand water systems; however, we need to remove them and design holistically.

To increase the resiliency of UBC campus in case of natural changes, it is recommended to look at water design strategies through a wider lens than a single building. A campus-wide scale could have added benefit based on interview discussions.

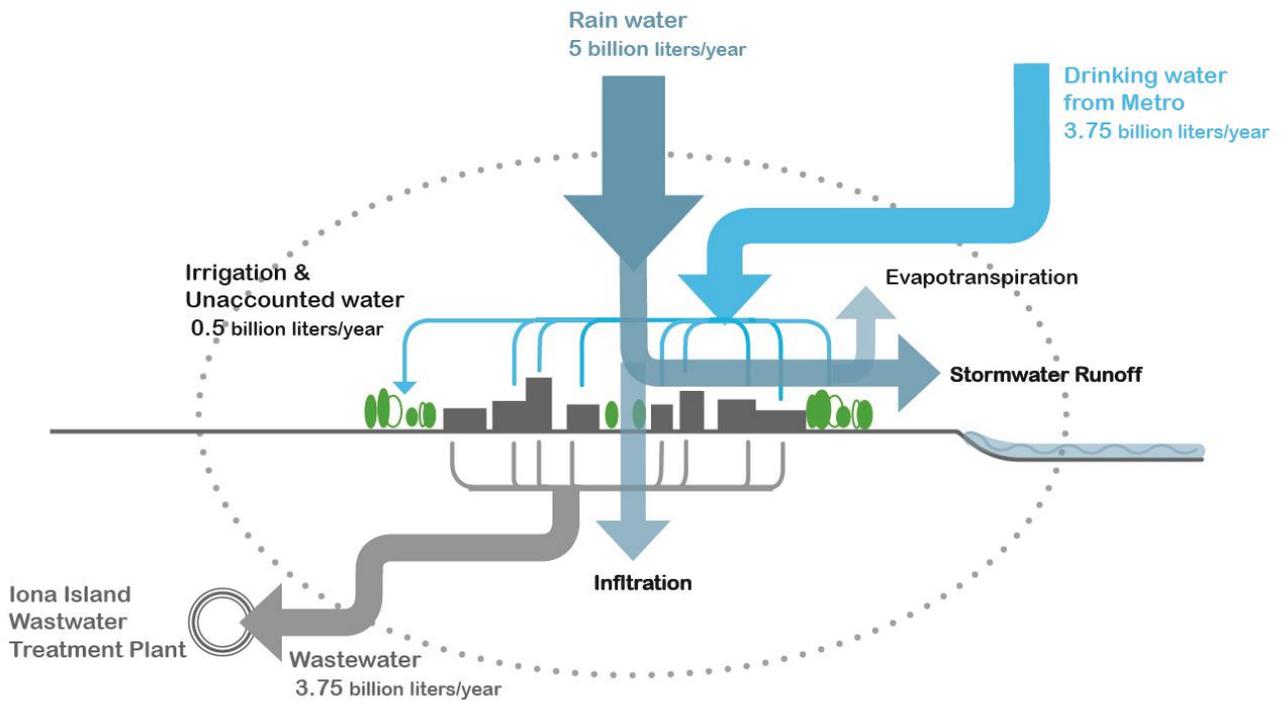


Figure 32. UBC Campus Water Model - Current

To take water strategies on campus to a more efficient level, it is necessary to understand the water system of UBC campus, what role different areas of campus play, and what opportunity each can provide. Currently, water supply and wastewater treatment are facilitated outside of

the campus boundary, while an efficient water plan would make it possible to manage both within the boundary of the site.

A few strategies are recommended in order to achieve a more resilient water model:

- Limiting potable water consumption, which comes from outside of the campus boundary, only for drinking uses.
- Rainwater harvesting systems can be more efficiently allocated to large water consumers like pools or process labs. Different building types offer different potential sources of non-potable water specific to their use, such as cooling towers in research buildings or flush toilets in academic facilities that can be supplied by alternative sources of water rather than municipal water.
- Stronger emphasis on water strategies outside of buildings is recommended. Incorporating Green and Blue infrastructure in the landscape of the campus can reduce runoff and consequently mitigate soil erosion. While increasing natural infiltration, recharging groundwater, and enhancing visual aesthetics by having more freshwater ponds, rain gardens or waterways on campus. Increasing water and wastewater treatment efficiency in a more visible way within the campus boundary, to enhance public awareness about these systems.

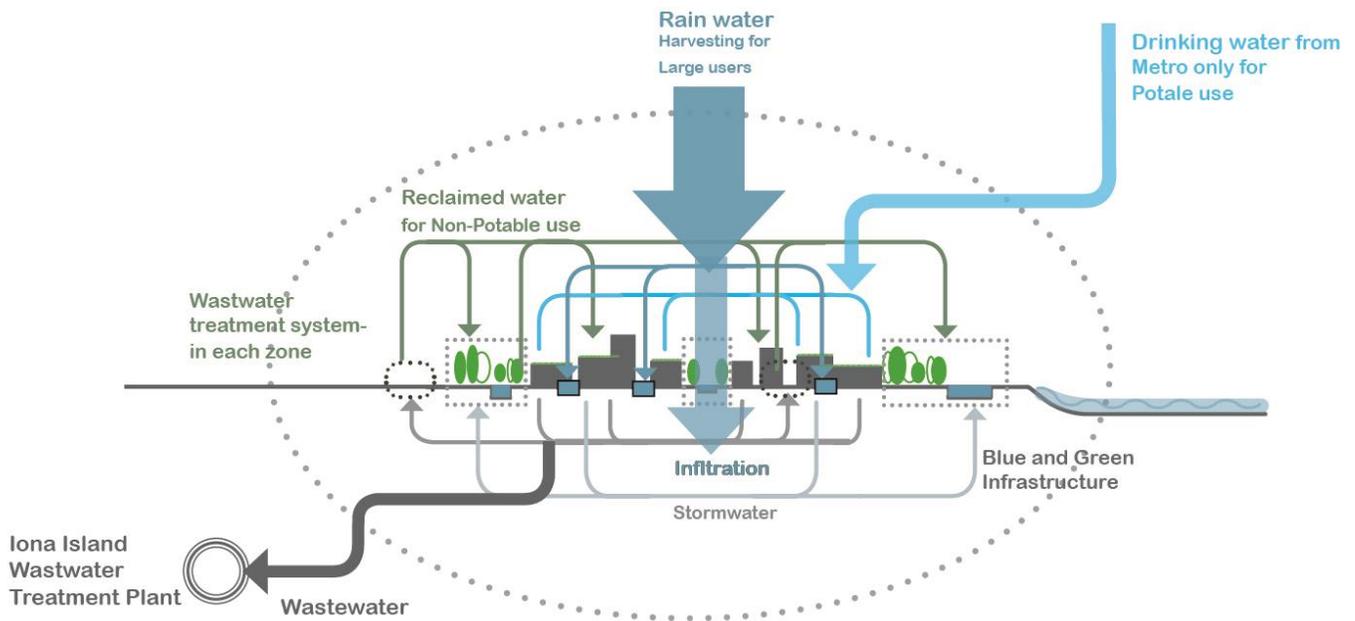


Figure 33. UBC Campus Water Model - Proposed

These strategies can help UBC to achieve its water suitability goals, bring long-term values to the livability of the campus while increasing resiliency to future natural changes.

4.3 Future

This thesis is seeking to bridge the gap between theory and practice of green buildings' water systems on UBC campus. Based on the findings of research background and the case study, it proposes several ideas for future green building projects to achieve water goals. However, these recommendations require future research on the following aspects:

- Exploring opportunities at large water consumers like laboratories to reduce water use or increase reclaimed water use in a network of building or campus scale
- Research on cost-effective ways of implementing alternative water systems
- Exploring programs that can encourage water sensitive behaviors in the UBC community

This thesis provides a preliminary understanding of influential factors in the performance of water systems in green building projects at UBC campus. Indeed, more research is needed to elevate water efficiency and performance. Pioneer projects like CIRS offer invaluable insights to further bridge the gap between water sustainability goals in theory and practice. In the face of climate change and other rising issues, this work helps to pave the way to the greater resiliency of the built environment.

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Appendices

Interviewee List

The list of key people interviewed in regards to the CIRS project organized based on date:

Title	Contribution to CIRS project	Date of Interview
UBC Campus and Community Planner, UBC	NA	9.Nov.2017
Managing Director at Perkins+Will	Project Architect	23.Oct.2017
Eco-Tec CEO	Solar Aquatics design-build project	23.Oct.2017
Principle at DIALOG	Lead Architect, Principle at Perkins+Will at the time of project	18.Oct.2017
Nova Tek CEO, UBC faculty	Consultant for the Rainwater harvesting and Solar Aquatics	17.Oct.2017
Associate Director, Municipal Engineering, UBC	NA	16.Oct.2017

Director, Urban Sustainability Initiatives (USI), UBC	CIRS water system performance	26.Sep.2017
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Interview Contents

Sustainability and Engineering Director

UBC Campus and Community Planning

9. Nov.2017

In person meeting

Water regulations within new buildings are defined under part 7 of the BC Building and referenced, under the BC Plumbing Code. Both these codes are administered/enforced through UBCs chief building official (verified via submitted of Certified Professional) through the building permit process. UBCs institutional buildings are also required to follow the UBC LEED Implementation Guide and Technical Guidelines which identify specific water efficiency requirements to achieve better performance levels beyond base code. The draft Green Building Plan will identify further improvements (informed through the draft Water Action Plan which is currently being led by Bud Fraser).

Water use outside the building (primarily irrigation, water features, car washing) is regulated by the Greater Vancouver Water District under the Provincial Water Act. It regulates water use throughout the metro region including irrigation, car washing, and water features, etc.

Vancouver Coastal Health sets regulations for non-potable water resources. They require a number of criteria like signs on flush toilets and spray irrigations to give people awareness of non-drinking water.

Metro Vancouver has just released a new Drinking Water Conservation Plan (November 1, 2017) which sets out water conservation initiatives/restrictions. Each member municipality and authorities having jurisdiction (AUJ) are responsible for administering water use under those regulations.

In terms of consultations, we typically engage all our university stakeholders including UBC properties trust, students, faculty, residents, and staff as well as government representatives that are responsible for the development of policies.

Busby + Perkins & Will Manager, CIRS Project Architect

23. Oct.2017

Phone meeting

Dr. John Robinson was the leader of this project. He invited a network of almost 20 people working in high-end performance building profession in workshops and charrettes to share, talk, taking notes of how they wanted the building.

They set very ambitious goals for the project as zero-carbon, water self-sufficient, energy efficient and so on.

They added all academic perspective to the decision making process.

The water goal was set to be:

- self-sufficient
- environmental (supply all water needs from rainwater and wastewater to reduce runoff, and decrease surface water pollution and prevent cliff erosion)
- Educational, as a demonstration of sustainable design, looking at this project as an ongoing opportunity to learn and research

There are similar buildings designed with the goal of water efficiency: Vandusen Botanical Garden and Dockside green project.

For Solar Aquatics, Biology department was collaborating to run it

About performance gap, he was not updated with the operation of water system but he thinks it might be a regulation issue.

What would you recommend for the next green building similar to CIRS? Moisture is a problem as we use considerable amount of wood in such buildings, so I recommend using more prefabrication to protect wood structure from moisture

For Eco-Tek's Timeline, I can add:

November 2003 initial consult with Busby Architects; site at UBC

March 2005 second consult with Busby, Perkins, Will: site in Great Northern Way.

February 2006 Schedule from Stantec

December 2008 Meeting with BPW, Z Smith brings us up to date with drawings and flow calculations

January 2009 ECO-TEK is hired for the SAS installation at CIRS.

June 2011 ECO-TEK gets access to begin installation of the SAS

November 2011 Official Opening of the CIRS.

> And also, can you help me defining what caused CIRS water system not functioning as expected

For the most part, we have discovered that many of the systems have failed in the Solar Aquatics Room.

ARCHITECTURAL:

Glazing: the glazing was a major mistake in not specifying a clear glass to promote the growth of plants, whereas the remainder of the building uses a low-E glazing to reduce both heat gain and heat loss.

Ceiling: As the SAS Room is subject to a higher humidity and the possibility of odor we specified an airtight seal on the ceiling of the room to prevent transfers of moist air through to the

offices above. The job was not carried out with enough precision to penetrate into the cracks of the ceiling structure, so when the HRV would fail and produce a positive pressure in the room, it would push moist air through into the offices above and sometimes at the same time as the aeration pumps would fail due to the faulty control system.

ELECTRICAL:

Control System: The Honeywell control system for the SAS Process and the rest of the building was improperly installed and as a consequence is being removed and replaced with a Delta control system. Early on the Honeywell system was shorting out and over time destroyed all our aeration pumps, often act the worst of times.

Control Access: Another aspect of operating the system was the lack of an “access point” for the operators to fine-tune the system on daily basis. UBC seems to be reluctant to give us access to control the system, for some unknown policy reason.

Lighting: Once we realized that the glazing could not support our “living system” we installed an interim lighting system to solve the problem. It was not ideal, but relatively inexpensive, but needed bulbs to be replaced yearly and we were anticipating a donation of LED lights that only partially happened.

MECHANICAL:

Heat Recovery Ventilator: The HRV was also faulty in that it was unable to maintain a negative pressure in the Room. When it failed it created a positive pressure in the Room and pushed moist air (sometimes with an odor) into the office spaces above the SAS room. As it turned out, the main failure was of an actuator cog made of plastic that broke some of its teeth during operation. No-one wanted to take responsibility and so it took several tries by the UBC Maintenance Staff before it was solved.

> And what do you recommend for the next green building on campus to perform efficiently in terms of water?

- **Integrated Design Process:** Companies being considered should be invited to the meetings because it's so easy for engineers to dismiss ideas when they really don't know the system well enough or they sometimes are in a conflict of interest as in the case of NovaTec wanting to create their own version of a SAS. Lucky for us the architect could see the conflict and the misinformation being used.

- **Provide Clear Specifications for the Building Envelop Design:** If we had written out all the requirements to house a SAS process then we might have avoided some of the problems but poor workmanship may still have crept into the project.

- **Use the Control System to Reduce Labor Costs:** We are considering that the control system with remote access and alarms should not need so much operator time doing senseless monitoring and that with the addition of a couple of sensors we can have the microbe demand for aeration run the system on its own.

- **Water Reclamation to Toilets and Subsurface Irrigation:** There are fewer issues for everyone when reclaimed water is used for flushing or is used to irrigate subsurface (therefore not in contact with humans). Also, aquifer injection is another possibility if reuse is not considered “safe”.

- **Larger System but Decentralized:** The UBC Campus is like a small city and compact, so it would make more sense to install one system for the entire Campus from a capital and operating cost point of view. But the small system at CIRS can be a very beneficial teaching lab for interdisciplinary studies and should be pushed to evolve and demonstrate the ideas of biomimicry and water reclamation.

Lead architect of CIRS project

18. Oct.2017

Phone meeting

Martin was the lead architect of CIRS project, working at Perkins+Will.

The project took 12 years to complete and changed the site three times.

I believe the UBC president at the time as well as Dr. John Robinson led the project to happen.

The initial idea was to use CIRS as a lab to test the ideas and to attract people from all over the world to accelerate sustainability of buildings. The initial vision created in the workshops stuck unchanged throughout the 12-year timeline while the budget was limited.

About water strategies, they did not affect the program and we did not eliminate any ideas in design developments or construction. The most ambitious water-related idea was to treat water onsite.

One issue was the contractor has never built such a building and another one was getting approval for health and safety permits.

For future, I would say first we need a champion like Dr. John Robinson to lead such pioneer project. Secondly, UBC needs to have a clear vision about water. And finally, funding and minimizing the complexity of financing these projects in UBC system.

NovaTec Senior Engineer, UBC Faculty

17. Oct.2017

In person meeting+ Email

Troy is NovaTec Senior Process Engineer, responsible for the following:

Water Reclamation and Reuse

- Conceptual treatment technology review and assessment

- Qualified Professional responsible for registering the treatment and reuse systems under the BC Environmental Management Act – Municipal Wastewater Regulation, including preparation of an Operations Plan and Environmental Impact Assessment and for obtaining authorization for reuse applications from Vancouver Coastal Health
- Hazards and operability (HazOp) assessment
- Preparation of initial operator training materials

Rainwater Harvesting – Potable Water Treatment System

- Water treatment system process and instrumentation/control design
- Professional responsible for negotiating and obtaining treatment and small potable water distribution system Permits from Vancouver Coastal Health
- Hazards and operability (HazOp) assessment
- Laboratory and chemical preparation design
- Commissioning
- Preparation of initial operator training materials

Stantec was the mechanical engineers for the project, responsible for estimating potable water consumption requirements, determining cistern storage capacity, cistern design, roof water collection system and rainwater conveyancing system design, first flush bypass and stormwater diversion, and overall mechanical design of the pump system to transfer water to the building (i.e. rainwater collection and storage and treated water distribution).

Eco-Tek were responsible for the turn-key supply and commissioning of the Solar Aquatics treatment system and chlorination dosing system (prior to building distribution_.

The starting point is to question “why?” were rainwater harvesting and wastewater reclamation considered at these case study locations? The answer (to maximize LEED Points) is a key

problem. LEED points, quite frankly, do not necessarily reflect high sustainability. To understand this better, if water conservation and management were important to UBC, the campus would have a water management strategy and philosophy in place that is reflected by LEED scores rather than visa versa. I have attached an article I wrote several years ago for Municipal World that describes the benefits of decentralized and onsite (parcel-level) wastewater reclamation and reuse for municipal infrastructure. The economic value is not reflected by the value (cost) of the volume of water saved, it reaches back to the development of a watershed and reservoir infrastructure, water treatment, water distribution, through to wastewater collection, treatment, and effluent disposal – and that is really just the start of the value assessment. Once you consider the environmental importance of the water that has not been extracted, and the refractory contaminants that are not treated through wastewater treatment – and are released to have a huge and yet hidden environmental impact – you can begin to appreciate the much greater global impacts of costs – and then there are the societal values and benefits that, again, dwarf the environmental benefits. The only effective means of preventing toxic and bioaccumulative contaminants from being released to the environment is source control, and not end-of-pipe treatment – that involves public education and behavioral change through education and understanding about the importance of source control. However, to reach that goal we need to start somewhere – and that is a key contribution the university can make. If UBC truly followed it's living laboratory philosophy, like all laboratory experiments there are promising outcomes, failures, and dead-ends – yet there hasn't even been an attempt to operate the treatment systems at CIRS to learn from them and modify them if necessary.

I can provide you with the detailed background on the history of the development of every aspect of the CIRS rainwater harvesting and wastewater reuse systems, beginning from the initial charrettes. In my opinion, the number one reason for their failure to be operational is a lack of involvement with UBC Operations at the very start – a key stakeholder who was not consulted. UBC Operations do not have the necessary experience or expertise to operate and

maintain water and wastewater treatment facilities; hence they are extremely reluctant to take on any support role. Following the failure to engage UBC Operations from the start, the second problem was the reluctance of UBC Properties Trust to commit to the water and wastewater systems until all government paperwork was completed – resulting in building tendering and construction starting without consideration for the water and wastewater components. As a result, the rainwater system drawing provided to the contractor was based on a preliminary design and did not have any construction details, and issues like incorrect glazing for the solar aquatics space were overlooked. Eko-Tek had never built or designed a Solar Aquatics treatment system for water reclamation and reuse – and almost everything they incorporated into the design had never been used by them before including the water tanks, the aeration system, the UV and chlorination disinfection system, and the ultrafiltration membrane. In.

Reviewing their design, I recognized and commented on this, but also noted that any problems that occurred could be incrementally accommodated and corrected – which was the premise of the living laboratory concept. No wastewater treatment process involves starting the treatment process and meeting the water quality requirements from day one – but the Solar Aquatics system could have begun operation and discharged the treated effluent to sewer until the “bugs” were worked out.

The tendering delay decision by UBC Properties Trust and lack of a detailed design stage and drawings significantly impacted the rainwater system. NovaTec had completed and submitted the Process and Instrumentation Diagram (P&ID) to Stantec, who were the mechanical engineers for the building. Because UBC Properties Trust did not want to commit to the rainwater system until Vancouver Coastal Health had provided a permit for construction, Stantec pasted the P&ID diagram into a single drawing sheet and issued it during the tender process, noting a decision on awarding that work would be made after the tender had been awarded. Once the permit was received, rather than authorizing the process design to be completed, the portion of the tender

for the rainwater system was simply approved and the poor contractor had to figure out what to do based on assumptions they made during tendering in the absence of detailed design information. As a consequence, the following occurred:

1. The green roof drainage was incorrectly directed to the cistern, contaminating it
2. The cistern was grossly underbuilt
3. No room was provided for the rainwater treatment system – except for a section of concrete wall tucked behind some tanks
4. The mechanical engineers installed pumps that could not transfer the water from the treated rainwater tanks to the building – so a booster pump had to be added
5. The wrong slow sand filter was purchased along with other pieces of equipment – to avoid the cost of returning this equipment, the treatment process was modified and adapted to make it work.
6. The original concept was “plug-and-play” with flexible piping used to facilitate research and testing of different treatment components – instead, the mechanical contractor installed everything in rigid stainless steel – snarling the piping up the wall to fit everything in
7. No electrical source or controls were provided for the equipment because no design information or drawings pertaining to electrical or controls were included in the tender drawings.
8. To meet the Cascadia Challenge requirements, the only pump that could be sourced with “no” PVC components cost ten times more than an equivalent pump that used only a small amount in a couple of seals.

NovaTec worked with the mechanical contractor to get the system operational. UBC contracted to Honeywell to provide power and controls, and the system was tested and commissioned – ready for use, including the provision of all materials, chemicals and field instruments for operations and maintenance. NovaTec also provided a junior engineer who was certified in small water systems to train UBC Operations staff who needed to complete two short courses and exams to become certified themselves. However, UBC Operations has a rotating schedule for staff that would require up to five people to be trained and certified – requiring a greater commitment to maintaining training that would have been the case with a daily routine schedule structure. This led to UBC Operations directing CIRS to consider contract operations for both the rainwater and reuse systems.

UBC operations were also concerned with certain aspects of the water reclamation system that could have health and safety impacts for operations staff. For example, the intake to the plant went through an elevated splitter box located about 10 feet above the glass exterior wall, requiring a ladder to access and clean it. While that problem was remedied by Eco-Tek by eliminating the mechanical screen in the splitter box, other problems became readily apparent. The first was aspirating aeration pumps all failed due to motor burn-out. Thinking this was due to the wrong voltage pumps being installed, they were all replaced and all failed again. Eco-Tek had never used these aeration pumps before, and it is my belief the problem is the debris from the plants floating on the surface of the tanks being sucked into the pump intake and either blocking the impellers or blocking the venture nozzle. A second problem was keeping the plants alive as a result of solar radiation being absorbed by the glazing surrounding the room – requiring grow-lights to be installed above the plants. The ventilation to the space was also quickly found to be inadequate as the air exchange requirements for a treatment system had not been allowed for by the mechanical engineers, and, in an effort to conserve energy, the air

exchange was tied to humidity and other control set points that quickly compromised the plenum space above the room and transferring odors to the building.

Making the decision to implement a rainwater harvesting system for potable or non-potable use, or a water reclamation system is only a small part of what is required to make such a system function. Further work is required to learn about the system, develop operating procedures and integrate it into the culture of the building and institution. The educational values can be immense. Integrated water management is not simply water conservation, nor is it only justifiable when there are no options left but to conserve.

As an environmental engineer, I am only too well aware that spending billions of dollars on municipal wastewater treatment plants does very little to protect the environment or public health. The treatment technologies are primarily based on growing bacteria on waste biodegradable contaminants, leaving the toxic complex organic and inorganic contaminants to either become “stuck” to the bacteria that is grown, or to pass through the treatment plant into the environment – in many cases to become someone’s drinking or irrigation water downstream.

My concern with the current architectural focus on LEED scoring is that it is “environmental” focused, and not balanced with respect to economic and social aspects – or applicability of the technology. I would like to see buildings receive scores that reflect sustainability, including holding true to the principles affecting design decisions. With respect to water there needs to be a consideration as to the role the building will play in advancing technology, practice, culture, etc. – and then being consistent with use and occupancy. Incorporating features for the sake of obtaining a higher LEED score and then not even trying to use or learn from them is such a waste of resources.

Associate Director, Municipal Engineering, UBC

16. Oct.2017

Email

I believe that the rainwater capture for the landscape works pretty well. It blunts the impacts of regularly occurring storms and slows the rate of water that would go to the storm system in outlying events. We could probably handle more stormwater than is currently designed, but we need to design additional landscape in the area of a building to accept this kind of runoff.

In the future, I am hoping to promote a green roof for a building, but there are a lot of preconceptions to overcome from past problems with this kind of design (outside of the university).

Director, Urban Sustainability Initiatives (USI), UBC

26. Sep.2017

In person meeting and Email

A key thing to note is that there were 3 versions of the CIRS project. The first one was planned at UBC campus, the second was a larger collaborative effort between UBC, SFU, BCIT and Emily Carr at the Great Northern Way campus, and the third is the one that was built here. The project didn't come back to UBC until 2007.

While there had been feasibility studies and workshops done throughout the years on the different versions of the project, and many of the project team were involved, I think it's worth primarily focusing on the one that landed here. By that, I mean, acknowledge the work before but keep in vague and worry about timelines for the final version of the project. It went through the standard processes for a project – site selection, RFP, design development, CDs, construction, commissioning etc. and is probably a cleaner story.

Also, the water systems in the building lagged behind the overall building project. The SAB was a design-build package, so a separate scope. The operating permit for the rainwater system was granted in fall of 2012, although it was never activated. The work on the SAB continued, with engineering reviews etc. through 2016. I'd recommend taking a stab at mapping out the activities through last year, and then we can check them with various stakeholders.

In terms of stakeholder, I know Busby and Stantec were involved really early (like 2001-2002) and stayed involved throughout the different versions, but I'm less sure about the rest of the project team. There was a new RFP process when the project came back to UBC that engaged the final team, but I don't remember who out of that group had been involved earlier. If you focus on this version, it may not matter so much.

In terms of regulators, the Board of Governors approves policy and finances for the university but I don't think they'd set regulations. UBC Properties Trust manages the capital project for the university, they have their own criteria but they aren't a regulatory agency. In terms of UBC departments that serve in that capacity – the ones issuing the development and building permit, like the Building Inspector, Ed Lin, and the Risk Management people would probably be more involved.