



# WPI

## Promoting Awareness and Development of Green Roofs at WPI

An Interactive Qualifying Project

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## **Abstract**

The goal of our project was to gauge how much the students, faculty, and staff at WPI know about green roofs and investigate options for establishing a new green roof. First, we researched green roofs to understand their history and their functions. We interviewed a variety of specialists with knowledge regarding green roofs and their benefits in order to understand their views and how some of their views differed. We also created a survey which asked a handful of basic questions to members of the WPI community in order to get a sense of what people know about green roofs. Lastly, we investigated the status of WPI's only green roof on the East Hall building. From our research, we concluded that the majority of WPI's community members would appreciate an additional green roof on campus.

## **Executive Summary**

In urban environments, many issues arise from the large building density that is characteristic of cities. Such problems include chemical buildup from stormwater, urban heat, air pollution, and inefficient use of energy. Stormwater runoff and the heat island effect are major problems that perpetually plague cities. Stormwater runoff is known as “rain and snowmelt that flows over land, such as paved streets, parking lots, and building rooftops, and does not soak into the ground” (Environmental Protection Agency, 2023). Such excess water can relocate and deposit harmful chemicals and toxics creating areas with large deposits of harmful substances. Another phenomenon caused in cities is the urban heat effect. This is caused by highly concentrated urban areas which tend to absorb and retain heat rather than diffuse it such as in natural habitats like forests. Such large absorption of heat can lead to inefficient use of energy that is used to cool the buildings to compensate for the temperature increase from the heat effect. A final resounding problem dense urban areas face is heavy air pollution due to a mass amount of traffic, construction, and increased energy consumption for residential buildings.

Green roofs are starting to have an increasing presence globally, but especially in the United States (Environmental Protection Agency, 2022). Part of the large push for this increase in greenery is the solutions provided by green roofs that combat the negative effects of urbanization, while also providing significant benefit to their surroundings. With an increasing presence, green roofs are gaining recognition in providing benefits for remediating many urban problems.

The goal of this project is to provide increasing awareness to the WPI community about the economic, environmental, and psychological benefits of green roofs. In order to understand the status of green roof knowledge currently present on campus, our team conducted surveys of

the current WPI population. The goal was to determine the extent of knowledge generally known by the WPI campus and how that current knowledge could be expanded. By raising the awareness of green roof benefits, we worked to promote green roof recognition on campus to advocate and suggest potential areas for adding additional green roofs in addition to stimulating interest and collaboration of green roof research.

In order to understand the key aspects of green roofs, we interviewed multiple green roof specialists including: the senior manager at Recover Green Roofs, a green design architect at Nitsch Engineering, and an architectural and civil engineering professor from WPI. Through the expertise and knowledge provided by these green roof experts, we were able to determine the key aspects that could be shared to the WPI community when promoting general knowledge of green roofs. Additionally we also interviewed two psychologists. The knowledge gained from these interviews provided valuable insight into the psychological benefits provided as further incentive for promoting green roofs on campus. We also surveyed sections of the WPI population in order to gauge the current level of green roof knowledge and interest on campus. We were able to determine where certain areas of knowledge were lacking, and the extent of interest for further green roof related studies on campus. We also physically investigated two different green roofs: Professor Servatius's green roof and the green roof on East hall.

In summary, the information gained through our interviews and surveys provided us with a framework for the information needed to stimulate green roof knowledge at WPI in order to add additional green roofs to campus and incentivize research related to green roofs.

## **Authorship**

Each member of the project team (Jack Arabian, Sarah Chen, Bennet Kracz, Atharva Tiwari) contributed nearly equally in authoring each chapter of this report. In addition, each member of the team frequently revised and edited their own work as well as the work of other members.

## Table of Contents

Abstract	1
Executive Summary	2
Authorship	4
Table of Contents	5
Table of Figures	7
Introduction	8
2. Background	11
2.1 Green Roof Definition	12
2.2 Historical Background	13
2.3 Green Roof History at WPI	15
2.4 Types of Green Roofs	17
2.5 Environmental Benefits of Green Roofs	18
2.6 Economic Benefits of Green Roofs	19
2.7 Psychological Benefits of Green Roofs	21
2.8 Green Roof on East Hall at WPI	22
2.9 Summary	24
3. Methodology	25
3.1 Gathering Relevant Data on Green Roofs	27
3.1.1 Literature Review	28
3.1.2 Interviews	29
3.2 Green Roof Knowledge and Interest	31
3.3 WPI Green Roof History	32
3.4 Stimulating Green Roof Research	33
3.5 Summary	34
4. Results and Discussion	35
4.1 Environmental, Economic, and Psychological Impacts of Green Roofs	36
4.1.1 Environmental Impacts	37
4.1.2 Economic Impacts	39
4.1.3 Psychological Impacts	41
4.1.4 Summary	45
4.2 Assessment of Survey Results	46
4.3 East Hall Green Roof Visit	51
4.4 Potential Green Roof Sites at WPI	57
5. Conclusions and Recommendations	60
5.1 The Future of the East Hall Green Roof	61
5.2 New Green Roofs on Campus	62

5.3 Final Thoughts	65
References	69
Appendix A: Interviews	71
A.1: Professor Brigitte Servatius	71
A.2: Coleman Horsley	75
A.3: Professor Jim Doyle	79
A.4: Charles Morse	82
A.5: Professor Suzanne LePage	85
A.6: Professor Pamela Weathers	88
A.7: Professor Soroush Farzin	90
A.8: Theresa Rosato	93
A.9: Pete Ellis	95
Appendix B: Survey Questions	98

## **Table of Figures**

Figure 1. East Hall green roof, August 2008

Figure 2. Responses to the survey question “Which of the following best describes your level of interest in green roof research?”

Figure 3. Responses to the survey question “Would you be interested in participating in a green roof focused project?”

Figure 4. Responses to the survey question “WPI has a green roof on top of East Hall. Were you already aware of this?”

Figure 5. Responses to the survey question “Would constructing additional green roofs at WPI provide any substantial benefits to the school?”

Figure 6. A word cloud created from the responses of survey question 6: “If you answered ‘Yes’ for the previous question, what do you think the substantial benefits would be?”

Figure 7. East Hall water sampling station in the lobby, April 2023

Figure 8. East Hall water sampling station in the maintenance room, April 2023

Figure 9. Plants on the East Hall green roof, April 2023

Figure 10. Green sedums on the East Hall green roof, April 2023

Figure 11. Red sedums on the East Hall green roof, April 2023

Figure 12. Orange sedums on the East Hall green roof, April 2023

Figure 13. Chives on the East Hall green roof, April 2023

Figure 14. Ice plants on the East Hall green roof, April 2023

Figure 15. Potential green roof sites at Worcester Polytechnic Institute as of May 2023

Figure 16. Potential green roof site between Fuller Laboratories and Kaven Hall as of May 2023



## **Introduction**

Building development, especially in urban environments is on the rise. By 2030 it is anticipated that urbanization will grow to 83% (Tafazzoli, 2023). With the increasing urban area, there also comes the effects that are brought about by city space. For instance, much of the natural absorbing ground is replaced by an impenetrable urban surface which decreases the potential stormwater absorbing area. This leads to less water that is able to be absorbed into the ground and instead this runoff flows along the ground collecting contaminants and pollutants before collecting into stagnant areas of high concentration waste. Once this runoff water is eventually relocated to a water source, the high concentration of toxins can cause detrimental effects to the wildlife and ecosystem. Additionally, this runoff water can also lead to erosion to the water stream bank. In order to combat these negative effects, an increase of natural surfaces in urban environments is needed to absorb this runoff water.

Other detrimental environmental issues caused by increasing urbanization are the heat island effect and air pollution. Defined as the increase in temperature in urban areas compared to rural natural areas, the heat island effect causes what is referred to as a heat bubble around cities. This causes the temperature to be higher in the cities and causes inefficient energy expenditure especially in the summer (Takebayashi, 2020). In a study done in Athens, it was found that the heat island effect was causing “thermal degradation in the environmental efficiency of buildings” (Ferrante, 2016). Among other studies done to observe these effects, they found that one potential solution in combating this effect is an increase in urban vegetation (Hulley, 2012). As rooftops comprise between 20-25% of city area, this space could provide surface area for growth medium (F Abass et al., 2020). Such a solution would incorporate green roofs into urban environments.

Since a lack of vegetation and absorption area are the part of the root causes of these urban problems, green roofs are a suggested solution to remediate these issues. A building roof that is either partially or completely covered in vegetation or plant growth, a green roof is a rooftop that serves to house vegetation in addition to also functioning as a building roof (F Abass et al., 2020). Providing both a means of absorbing stormwater runoff and reducing the heat island effect, green roofs would add functions to counteract these urban problems while providing additional benefits (Desario, 2012).

The incorporation of green roofs in many of the denser areas of Massachusetts, such as Worcester would improve pollution. This could be accomplished through decreasing the need for temperature regulation devices such as air conditioning units as well as adding plants to rooftops to remove harmful pollutants from the air. Green roofs provide urban and suburban areas with an effective stormwater management system to avoid runoff water being absorbed into the pavement and for pollutants being washed into local bodies of water. Another reason for the growing prominence of green roofs can be associated with the energy savings that occur. These green roofs can also provide a habitat for local wildlife which can help increase biodiversity.

Worcester Polytechnic Institute has one green roof on campus, which is situated on the top of the residential building East Hall. Although the roof is inaccessible to students, two sections on the roof have been configured for research related to the green roof. The sections include monitoring ports that can be used to observe the storm water quality and rate of the stormwater runoff (Barnes, 2008). To promote further research and increase the benefits of having more green roofs, WPI needs to understand the best approaches for making use of its current green roof for development of new green roof areas on campus.

The ultimate goal of this project is to inform students at WPI of the environmental, economic, and psychological impact of green roofs, as well as to motivate further research on the topic. To first determine how knowledgeable WPI students are about green roofs, a survey was distributed to the student body. This survey asked the students questions about green roofs to gather valuable qualitative data. This data indicated not only how much the students know about green roofs, but what specifically they know about them. In addition, the multifaceted impact of green roofs was researched extensively to develop a deep understanding of the topic. Lastly, a variety of ways that the students and faculty could collaborate to popularize green roofs at WPI were explored. These options included participating in the existing sustainability efforts at WPI and investigating potential sites for new green roofs on campus.

This report presents the background literature, the methodology, the results and findings from our research, and a discussion of our findings. The literature review will discuss information relevant to green roofs based off of our research, and the methodology will cover our means of attaining this information, including literature review, interviews and surveys. The results discuss our findings and recommendations and suggestions are developed based on the research findings.

## **2. Background**

This chapter discusses the historical background of green roofs, the different types of green roofs, and the current green roofs status at WPI and in the surrounding local area. Through research of the historical origins of green roofs and the definition of what constitutes a green roof we gained insight into how green roofs came into existence and how this knowledge could promote their usage at WPI and in the Worcester community. Additionally, research into different variations of green roofs and structural requirements needed to support green roofs provided us with guidelines and potential limitations that could hinder green roof implementation on certain buildings. Finally, investigation of the green roof at WPI and those in the surrounding area provided examples of functioning green roofs and what sorts of green roofs are successful, which are not, and sort of potential options WPI could investigate to add to campus.

## **2.1 Green Roof Definition**

A green roof is defined as “a roof of a building that is partially or completely covered in vegetation” (Optima, 2023). The plants comprising the green roof are often sustained through a growing medium along with a waterproof membrane support that can consist of multiple layers. The more complex components can include a root barrier, drainage, and irrigation systems. Such green roof designs are shown to have many benefits including economic, societal, and environmental perks. The increasing popularity in the green roof trend has started rising dramatically in the United States in the past ten years with more than 900 green roofs reported.

## 2.2 Historical Background

Green roofs trace back thousands of years to times as early as the Babylonian empire in 600 BC. The mesopotamian ziggurats were layered pyramid towers, with vegetation at the different levels of the tower. This vegetation served as both a means of cooling the towers in addition to providing plants and greenery at the different layers (Magill et al., 2011). One of the oldest and most famous examples of ancient green roofs are the Hanging Gardens of Babylon. These gardens were recorded to have resembled nature and were constructed by Nebuchadnezzar II as a gift for his wife. By the great extent of the gardens and trees in these gardens, it can be inferred that these were an intensive type of green roof. Further examples of green roofs have also been noted to appear throughout history. For instance during Charlemagne's rule, he advocated planting vegetation on the building roofs to protect against fires and lightning strikes. Additionally the Renaissance was another period when green roofs had a large prevalence in monasteries.

The first modern green roof model appeared in the World Exposition in Paris in 1867 as an extensive roof possessing a waterproofing and drainage system (F Abass et al., 2020). Germany was the first country to begin implementing green roofs into their architecture after H. Koch discovered the creation of gravel, sand, and tar combined to create a non-flammable layer used in the green roofing. Switzerland and Germany were the first countries to significantly invest and dive into research of green roofs causing these countries to be at the front of modern green roof use (Magill et al., 2011). With the aid of policy creation supporting green roof implementation, Germany went from 1 million square meters of green roofs to an exponential increase of more than 9 million square meters by 1996 in less than a 10 year period. Germany's integration of vegetation on roofs started the green roof trend that eventually propagated into

Europe then to North America and now is becoming more prominent in Asia. In the US, the first green roof was established on the roof of the Rockefeller Center in New York City in 1931.

From the initial green roof research originated in Germany there came about the German Landscape research, development, and construction society (FLL) abbreviated from Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau which developed a set of guidelines for green roof design. Green roofs in North America are based on these German standards (Magill et al., 2011). These standards consist of guidelines for planning, upkeep and maintenance of green roofs. They are considered the standard for green roof implementation and are used universally as the basis for installing green roofs (Dvorak, 2011). Although other green roof guidelines are available and in use, such as various North American green roof guidelines, they have been found to be lacking in certain areas compared to FLL. Thus much room for improvement has been identified for other green roof standards in order for them to have the same depth of detail as those of FLL.

The main standards covered by FLL include systems design, structure, waterproofing, drainage, growth media, vegetation, and maintenance (Dvorak, 2011). Included in these guidelines includes in depth recommendations and guidance for design of green roofs.

## 2.3 Green Roof History at WPI

In a past WPI GPS project done in 2009, students were advocating to install a green roof on top of the Recreation Center. In a cost benefit analysis of putting a green roof on the Rec Center roof, it was determined that although the initial cost of installing a green roof would be higher than that of a traditional gray roof, over the course of time the green roof would pay itself off. From their cost benefit analysis, it was determined that after forty years, the traditional roof would cost \$8,000 dollars more than a green roof (Martin et al., 2009). Although the initial upfront cost of installing a green roof would be significantly more expensive than that of a gray roof, over time due to energy expenditure and wear and tear of the gray roof, the green roof would actually pay off its initial installation cost and end up saving the building owner money in the long run.

In Professor LePage's thesis investigating stormwater runoff via green roofs, she investigates the effects of stormwater flow, the quality of the runoff water, and potential areas of research from the storm runoff data. The results of Professor LePage's research showed that the green roof modules were able to retain amounts of stormwater, but that during heavy precipitation, the green roof quickly became oversaturated and was unable to retain large amounts of stormwater. She also investigated phosphorus loading into the runoff water out of the green roof soil. Her findings were that the vegetation was the cause of phosphorus seen in the water runoff, but that additional research would be needed before making further conclusions. For areas of further research, Professor LePage identified phosphorus sorption and desorption as potential topics for continued research as relatively little is known in these areas (LePage, 2010).

Much of Professor LePage's work was done by testing the stormwater runoff from the East Hall green roof. We were fortunate enough to be given a tour of East Hall to see the various



components of the green roof for ourselves. The stormwater drainage system was primarily accessible on the ground floor of the building, through a few clearly marked pipes. Some were used for draining while others were used for sampling to determine the chemical properties of the stormwater. After taking a look at these pipes, we made our way up to the roof.

## 2.4 Types of Green Roofs

There are two major types of green roofs: intensive and extensive. The main characteristics of extensive green roofs are their general simplicity in terms of plants and maintenance (United States Protection Agency, 2023). Extensive green roofs generally consist of hardier plants and grasses and require less structural support due to less soil requirements. Their main functions consist of minimizing heat islands and stormwater runoff. The recommended greenery for such roofs consist of drought, wind, and frost resistant plants. Additionally, due to the lightweight nature of extensive roofs, they can be easily installed on flats roofs and even decks (American Hydrotech, 2023). Extensive roofs are also referred to as “roof meadows” and often do not have public access as they also require little upkeep (Massachusetts Department of Environmental Protection, 2023).

Intensive roofs on the other hand are generally more complex and can even consist of park-like configurations possessing plants as large as trees. Possessing greater amounts of growing material and additional means of water storage, intensive roofs are significantly heavier than extensive roofs. Due to higher maintenance plants, intensive roofs often require frequent landscaping and upkeep. Additionally intensive green roofs demand a higher initial installation investment compared to that of an extensive roof (American Hydrotech, 2023).

## **2.5 Environmental Benefits of Green Roofs**

The largest environmental benefit of green roofs is the extreme reduction in local air pollution and greenhouse gas emissions due to natural insulation and energy the plants provide for the building. As mentioned previously, green roofing systems reduce heat transfer and remove that heat from the air through evapotranspiration, acting as an insulator for the building, ultimately integrating the building more heavily with nature. This green insulation also helps to lower energy efficiency cost which will be further addressed in the economic benefits section. Furthermore, the natural insulation of the green roof system keeps building temperatures more regulated than a conventional system, reducing the need for polluting devices such as an AC unit. On top of the reduced need for polluting temperature regulation devices, the plants themselves remove pollutants from the air through dry deposition and carbon sequestration which provides a healthier atmosphere for the inhabitants as well as the surrounding community. (EPA, 2022)

Another perceived environmental benefit from green roofs in the surrounding community is the management of stormwater. Naturally occurring floods due to precipitation can have their damage reduced due to local green roof systems retaining large amounts of water and as a result, heavily minimizing stormwater runoff (EPA, 2022) Furthermore, the EPA states that in minimizing water runoff, the water itself is actually decontaminated of pollutants, resulting in clean water for the low amounts of runoff. Green roofs are also excellent water retainers and can retain precipitation quite well during the warmer seasons, preventing the need for frequent and widespread watering in order to keep the plants healthy. (EPA, 2022)

## 2.6 Economic Benefits of Green Roofs

A prominent reason for the lack of green roof systems in the United States falls to the issue of pricing (BestAccessDoors, 2020). With higher costs for both installation and maintenance, green roof systems are often overlooked for conventional black roofing to save on initial investments. Despite these higher costs, the numerous benefits of green roofing heavily outclass the “pros” of other conventional styles of roofs and many buildings would benefit from their incorporation (BestAccessDoors, 2020).

Green roof systems act as a packaged system of benefits, in that including one in a design will benefit said design in a multitude of ways. Looking at the economic category specifically, green roof systems are able to reimburse their owners long term in three main ways (gsa, 2020). The first way green roof systems help pay for themselves is through lowering energy costs in the house. This is done by the layer of plants acting as an insulation, effectively reducing the amount of money needed to be put towards an HVAC system - lowers cooling and heating bills. The green roof also utilizes the process of evapotranspiration (evaporation from soil + transpiration from plants) to remove heat from the air. The second method of green roofs paying for themselves is via less frequent roof-replacement due to the greater durability. Green roofs are expected to last much longer than conventional roofing systems at 40 years or more (GSA, 2020). This helps homeowners save a bit of money from needing to replace the roof if they are living in a home long-term. The final way green roofs hold beneficial economic impacts is by reducing stormwater management costs. Green roofs are able to reduce the amount of stormwater that reaches the ground through soaking in a large volume of water within the soil and slowly draining the excess and reducing the peak flow rate by upwards of 90% (mass gov, 2023). This will prevent homeowners from paying large fees in stormwater taxes.

Of course these benefits come with an expensive installation cost. In a study done by the U.S General Services Administration they estimate that the cost to install extensive green roofs is about \$12.50 per square foot more than a traditional black roof and a semi-intensive green roof is \$19.70 per square foot more (Green Roofs, 2023). However, the US GSA estimates that the cost for maintaining green roofs is at most \$0.31 per square foot higher than traditional black roofs. Compounding this with the added benefits that green roofs provide, the GSA estimates that on average a green roof takes 6.1 years to recoup the initial investment made for the system. Despite these higher installation and maintenance costs in comparison to a conventional black roof, the long term payback of a green roof is undeniable and results in economic impacts conventional roof systems would never be capable of having. The higher initial installation cost and maintenance of the green roofing systems is slowly outshone by the energy saving monetary gains. Once that initial cost of installation is paid back, owners are left with a beautiful green roof system creating pure profits on top of the already vast number of non-economic benefits.

## **2.7 Psychological Benefits of Green Roofs**

While there are plenty of tangible benefits, another reason that green roofs are being implemented is due to the psychological benefits that they provide. In a recent study by Science Direct the authors Williams, Lee, Sargent, et al. state that "Many people claim that green roofs have been linked with better moods, as well as improved mental and physical health" (2019). If the long-term profits and energy efficiency alone were not enough to rationalize construction of a green roofing system, the societal impacts they hold may be. Building inhabitants are treated to improved health and comfort primarily through reduced heat transfer through the green system as well as reduction in heat stress which may be associated with a heat wave (US EPA, 2022). Although the surrounding community may not enjoy the green roofing profits, they are exposed to a multitude of other societal benefactors. Some of these range from the simple aesthetic value of a green roof to powerful and beneficial mental health effects through interaction with nature. Scientific studies have proven that nature has a calming effect for the human brain, the creation of a rooftop flora and fauna habitat is able to benefit both mental and physical health primarily through reduced stress and blood pressure (Huelat). These beneficial impacts on human health are further exemplified through the vast environmental benefits these green systems offer.

## **2.8 Green Roof on East Hall at WPI**

The first green roof in Worcester was established on the top of WPI's East Hall residential hall. It was constructed as a demonstration of WPI's commitment to sustainability in addition to achieving LEED gold certification for the building, and stormwater research (Mell, 2008). The green roof was designed as a modular green roof which is the first of its kind in the Worcester area. By having the green roof consist of independent modules, this allows for different sections of the roof to be removed for lab analysis (LePage, 2010). A stratified design, the green roof is multilayered consisting of multiple membranes which include an insulation layer and a drainage layer which also provides heat and sound insulation. The roof has an extensive design and contains a variety of hardy greenery. The plants were chosen due to their low maintenance requirements, as the top of East Hall is not easily accessible. Figure 1, shown below, is a picture of the roof that was taken during its construction in August 2008.



*Figure 1. East Hall green roof, August 2008*

*(Barnes, 2008)*



## **2.9 Summary**

From this literature review, we were able to understand the historical background of green roofs, the two different types of green roofs, and the background into the green roof currently situated on the top of East Hall. From this background review, we came to understand how green roofs came into existence and how they have continued to be used historically due to their many benefits. We also researched and identified the differences between the different kinds of green roofs, and the current extensive green roof located on East Hall at WPI. From this literature review we were able to determine the benefits of green roofs that caused them to be used historically for thousands of years.

### **3. Methodology**

The goal of this project is to inform students at WPI of the environmental, economic and psychological impacts of green roofs and to investigate and determine areas of additional study on the subject. In order to achieve this goal we have outlined the following objectives:

1. Gather relevant data and information on the uses of green roofs in addition to their environmental, economic, and psychological impacts
  - a. Data gathering through a literature review
  - b. Data gathering through interviews
2. Assess the current knowledge of and interest in green roofs within the WPI community through a distributed survey
3. Analyze the current state of the current green roofs at WPI through a literature review and through a direct investigation of the green roof on East Hall
4. Identify previous areas of green roof research and investigate potential options for new green roof sites at WPI

The following sections outline our strategy that we followed to achieve these objectives and accomplish the goal of this project. The objectives above consist of various techniques that we followed to provide us with valuable information that was essential to accomplishing the goal of this project.

To educate the WPI community on the environmental, economic, and psychological impacts of green roofs we extensively researched green roofs in order to understand their functions, benefits, and drawbacks. Once having a strong understanding of green roofs, we were

able to gain consumer insight through conducting interviews with green roof specialists, architects, and psychologists. We surveyed populations of the WPI community to gauge a sense of their understanding of green roofs. From that information we were able to determine knowledge gaps and where further education of green roofs and their benefits could be shared with the WPI community. We also identified different areas of potential studies for undergraduate and graduate research and projects related to green roofs. From our collected data, we were able to identify multiple areas for research for green roof related studies.

### **3.1 Gathering Relevant Data on Green Roofs**

To gain a strong understanding of green roofs, we conducted both a literature review and interviews. In the literature review, we researched green roofs both in a broader sense through government sites and general green roof websites. Further in depth research was accomplished through review of scientific articles and research publications on green roofs. We gained an understanding on general green roof knowledge through our more surface level research, and we attained specific attributes on green roofs through our more in depth literature review of scientific publications.

In the interviews we conducted, we gained knowledge on specific areas of green roofs through the different specialists that we spoke with. We gained knowledge in areas ranging from green roof maintenance and architecture, stormwater runoff, psychological benefits of nature associated with green roofs, and also the variation of vegetation in green roofs.

### **3.1.1 Literature Review**

During the early stages of our project, we conducted a literature review. This involved looking over existing publications, research, scientific articles, and government reports on green roofs. This literature review provided us with both a general understanding of green roofs and also knowledge of specific areas of green roof research. This overview of the components comprising green roofs gave us a framework for determining the environmental, economic, and psychological benefits and drawbacks of green roofs. Furthermore, through a thorough literature review we not only gathered valuable qualitative and quantitative information but we were also able to identify the current state of research on green roofs both in the US and globally. From our literature review, certain gaps in current green roof knowledge were found, and we were able to identify areas where further research is needed. These knowledge gaps highlighted areas where further work could be done, and we identified these topics as possible student projects that could be dedicated to green roof development and research.

### **3.1.2 Interviews**

Another way that we accomplished this objective of gathering green roof knowledge was through the conducting of interviews. We submitted an IRB form for this data collection, and our request was approved. All the data we collected was obtained via the consent of the interviewees and was stored in a secure location to ensure the privacy protection of those we interviewed. We interviewed green roof experts, architects, green roof owners, psychologists, and plant biologists, all who were knowledgeable in areas of interest surrounding this topic. We used these interviews to gather qualitative and quantitative data on the technical aspects of green roofs as well as their environmental, economic, and psychological impact. These experts were able to provide valuable insight and perspectives which were able to be used to develop an effective understanding of green roofs. Additionally, the information gained from these interviews was used to identify further areas of potential research for green roof research and development at WPI.

We talked with a variety of experts including the Senior Project Manager at Recover Green Roofs: a green roof design and maintenance company functioning in the New England area. From this interview we sought to gain insight into green roofs from an expert within the green roof industry. Additionally, to be informed about the architecture necessary to support a green roof, we sought out an interview with either HMFH Architects or Nitsch Engineering to talk with one of the leaders of the companies. We also interviewed Brigitte Servatius (A.1), a WPI Professor in the Mathematical Sciences department, as she has a green roof at her personal residence and she could provide beneficial insight based on her own experience with her green roof at home. Additionally, we interviewed Soroush Farzin (A.7), a WPI Professor in the Civil, Environmental, and Architectural Engineering department, to gain his insight on structural considerations and limitations when constructing green roofs. From the sources we interviewed,

we hoped to gain understanding of the green roof business and understand the current limitations that hinder more universal implementation of green roofs, and what sort of steps could be taken to promote construction of green roofs. We hoped to identify areas requiring further research to bring as a potential topic of study at WPI.

### **3.2 Green Roof Knowledge and Interest**

In order to assess the green roof knowledge and interest at WPI, our primary method of gauging students was through the survey shown in Appendix B. The survey asked questions on the participants' knowledge of green roofs, their interest in learning more about green roofs and their willingness to participate in green roof-related research or educational programs. In particular, our anonymous survey was composed of questions asking the participants if they know what a green roof is, what sorts of benefits they are believed to provide, and if further construction of green roofs would be considered beneficial to those in the WPI community. Based on the responses from the survey, we were able to determine the general understanding of green roofs in the WPI community and the amount of information needed to be shared in promoting knowledge of green roofs at WPI. Additionally, we hoped to gain insight into students' perspectives to understand the potential benefits green roofs could provide in enhancing the environment at WPI.



### **3.3 WPI Green Roof History**

To determine what previous work was done on green roofs at WPI, we analyzed local green roof case studies and reviewed the interviews that we conducted with the green roof specialists to determine, based on our data, areas with knowledge gaps that could serve as future research opportunities. Local case studies were primarily composed of past WPI IQP and MQP works and allowed us to cipher through prior collected information and data necessary to our research. These were key contributions to understanding the potential of promoting green roofs at WPI. The knowledge from the interviews helped us to gain an understanding of the areas with less knowledge that could be expanded upon with further research and studies. Furthermore, these interviews provided us with the opportunity to network with individuals and groups that would be inclined to sponsor and aid in future Green Roof oriented projects and research at WPI.

Many of the WPI green roof projects we studied involved the East Hall green roof, which we scheduled a visit to check out for ourselves. In doing this, our goal was to determine the current state of the green roof and learn more about it.

### **3.4 Stimulating Green Roof Research**

To promote green roof research at WPI, we identified areas through our literature review and interviews that we found were lacking and we presented them to professors in these fields as potential areas of research and project topics. By bringing these topics to professors, we were able to bring awareness of these areas for research for undergraduate and graduate student research at WPI. We were able to determine that stormwater runoff had significant areas of unknown and further research was needed before conclusions could be made. From the interview with Suzanne LePage (A.5), in addition to the information gained from reviewing her thesis, we were able to identify certain areas of unknown relating to stormwater runoff. LePage is a WPI Professor in the Civil, Environmental, and Architectural Engineering department. Additionally, we also identified areas of research for the vegetation used in green roofs. Due to the differences in plant coverage and absorption, we determined that there are opportunities for research in the differences, drawbacks, and benefits of the different plants used in constructing green roofs. We determined from our interview with Pamela Weathers (A.6) that professors in the biology department at WPI could use this sort of research as potential MQP and graduate research studies. Weathers is a WPI Professor in the Biology and Biotechnology department.

### **3.5 Summary**

Through our objectives, we were able to identify the many benefits of green roofs and how these could further benefit the WPI community. We also were able to formulate suggestions of green roofs areas of research and to inform the WPI community about green roofs and their plethora of benefits. Completion of our five main objectives resulted in a deep understanding of green roofs and the many potential different research opportunities at WPI.

## **4. Results and Discussion**

The data presented in this chapter shows the results of our research. We discuss our findings on the uses of green roofs, through their environmental, economic, and psychological impacts. We also discuss the results of our research on the current knowledge and interests of green roofs in the WPI community. We analyze and also evaluate the current status of the green roof currently on East Hall. We found that green roofs provide tremendous impact environmentally, economically, and psychologically. Although many of these effects do not become evident immediately, in the long run, green roofs are incredibly beneficial and they provide many benefits. We also analyzed the status of green roofs at WPI. We investigated the green roof at WPI, and we were even granted access to go on top of East Hall to investigate the current situation of the vegetation there. We observed that even despite the lack of maintenance the green roof had received since creation of the building in 2006 that the vegetation was flourishing after 17 years. We were able to identify at least four of the original species of plant in addition to a lot of moss.

## **4.1 Environmental, Economic, and Psychological Impacts of Green Roofs**

Our findings showed that green roofs have significant impacts that fall into three general categories: environmental, economic, and psychological. We conducted nine interviews with people who we believed could provide insight into green roofs at WPI and the surrounding area. The significant impacts of green roofs that were discussed fell into three general categories: environmental, economic, and psychological. In addition to their impacts, we also discussed the potential for the expansion of green roofs at WPI. Our interview questions were tailored to the specialties of each interview subject. The interviewees (Appendix A) were specifically chosen to provide us with a varied, yet detailed set of data which would impartially encompass the environmental, economic, and psychological benefits from sections 2.5, 2.6, and 2.7 respectively. Below are our key findings, sorted into each of these 3 categories.

### **4.1.1 Environmental Impacts**

In our interview with Professor Servatius, she expressed that her own green roof attracted a diverse selection of wildlife, including insects, birds, chipmunks, squirrels, and even an opossum. The green roof's flora and the local fauna can often work in conjunction with each other and live symbiotically. In our interview with Coleman Horsley (A.2), he explained that the green roof on top of the building that he works from has hive boxes to raise bees. Horsley is a Project Engineer at Nitsch Engineering, a civil engineering company with a focus on green infrastructure. Horsley added that a restaurant within the building even used the honey from the hives in their food.

Discussing the importance of green roofs, we discovered from our interview with Horsley the importance of green roofs in reducing the impact of the heat island effect on cities. This occurs where an urban area has a significantly higher temperature than its surrounding rural areas. Vegetation on green roofs absorb sunlight and reduce the overall temperatures of the buildings beneath them. Green roofs also provide some amount of insulation, reducing the amount of energy required to heat buildings during periods of cold temperatures.

The impact in reducing stormwater runoff from green roofs was also discussed with Horsley in the interview. Since a great deal of the water is absorbed by the soil and the plants, significantly less water will run off of a green roof than a gray roof. In addition, the water that does run off of a green roof usually contains fewer contaminants than water that runs off of a gray roof. This is not always true, however, as studies have shown that when fertilizer is used in the soil, the water that runs off of a green roof can contain high amounts of phosphorus which is toxic to many wild animals. In our interview with Professor LePage, we discussed how the ability of green roofs to reduce stormwater runoff can prevent flooding. This is because in many

cities the sewer systems were not built to accommodate increasing levels of rainfall caused by climate change. These cities become more prone to flooding overtime as their sewer systems overflow with water.

In our interview with Professor Farzin, we discussed the architectural considerations required to accommodate green roofs. The designs for green roof integrations must be sustainable. To determine whether or not this is true, it is a good idea to compare what a given building consumes and what it gains. If this exchange would become more beneficial after a green roof is added to a building, it would be a beneficial endeavor to pursue. Another thing to consider is which materials would be used to construct the green roof, and whether or not these materials would be more supportive of the surrounding environment. If the materials would be better for the environment, the green roof should be constructed.

### 4.1.2 Economic Impacts

Throughout the interviews we determined that while there are certain economic disadvantages connected with green roofs, they provide numerous noteworthy economic benefits. In this section we will discuss information that we received in our interviews with Professor Servatius and Horsley.

In our interview with Professor Servatius we learned that her green roof works in tandem with her greenhouse in order to keep the climate in good condition. She said that her green roof heats her greenhouse in the winter and cools it in the summer. This sentiment was also expressed by Horsley, who highlighted in his interview that buildings with green roofs save money by cooling themselves and reducing heating costs. As an added benefit, the green roofs clean the inside air as well. Along with energy savings, Professor Servatius highlighted that there are extra savings that she experiences as a result of being able to grow her own food and herbs. Furthermore, in our interview process we learned through Horsley that Green Roofs are considered an investment that is unlikely to become obsolete in the future. This is concurrent with a GSA study that states that a green Roof is estimated to last forty years or longer if they are maintained and built properly. On the other hand Asphalt/Metal Roofs last on average 20-25 years (Hunter, 2022). The information discussed shed light on the economic advantages offered by green Roofs.

In our interview with Horsley one of the factors that hinders green roof development is “the large cost” of installation and he adds on by saying “it requires salesmanship to clients.” Later in this interview Horsley adds that “mimicking nature is very expensive.” This is supported by the US GSA study which estimates that the cost to install extensive green roofs is about \$12.50 per square foot more than a traditional black roof and a semi-intensive green roof is



\$19.70 per square foot more (Green Roofs, 2023). The aforementioned information details the economic challenges associated with Green Roofs that hinder their widespread installation and implementation.

Although green roofs have many benefits, there is an initial monetary cost to install them. However, in most cases, green roofs can quickly provide a return on investment with their energy savings. After this point, green roofs will actually be a net gain.

### 4.1.3 Psychological Impacts

From our interviews with WPI faculty members working in the psychology department, we were able to draw a conclusion that access to nature, even just two hours spent in nature a week, holds significant power in bettering both mental and physical health. In this section, we will discuss information discerned and collected from our interviews with Professor Jim Doyle (A.3), a WPI Professor in the Social Science and Policy Studies department, and Charles Morse (A.4), the Dean of Student Wellness at WPI.

In our interview with Professor Doyle, he made sure to emphasize the powerful healing effects nature can have on the human body both short and long term. Professor Doyle noted that hospital patients have been found to physically heal faster when there is a window in their recovery room, denoting an obvious physical benefit in correlation with a bit of access to nature from indoors. This causes him to believe in long term benefits towards nature exposure, but he admits it can be hard to decipher as there have allegedly been few studies contributing towards this knowledge. It should be important to note that Professor Doyle believes spending time in nature is not a remedy or cure for depression, but rather just to reduce stress.

One of the most important ideals we learned from Professor Doyle was that the reduction of stress from green roofs highly correlates with cognitive performance benefits. Therefore, a more nature-integrated WPI could certainly lead to better academic performance for most if not all students. The stress reduction leads to clearer thought processes, improving learning, studying, and both short and long term memory abilities. Combining these beneficial aspects with the Biophilia Hypothesis - the idea that people are inherently drawn to nature, it would make sense for a majority of students to feel these effects if green roofs were implemented more commonly on campus. In noticing this incredible academic incentive from nature, we found it

would be most sensible to have a green roof be set up as a passive location where lanes of egress for students and faculty already exist rather than having students be actively required to access the roof of East Hall if they want to be immersed in a green roof ecosystem. Professor Doyle argued that because the current green roof on East Hall is both unviewable for most and unvisitable, it does not contribute much to benefitting mental health on campus. A potential location for a green roof that already has plenty of egress options and student traffic would be the walkway located in between Kaven Hall and Fuller Laboratories. This location was recommended to us by our advisors Professor Mathisen and Nicole Luiz, as well as Professor LePage in our interview with her.

A final note Professor Doyle left us with was a source titled “Psychology for Sustainability” (Kroger and Scott, 2016) which provides a plethora of great insights into the modern world and how humans are prone to leaving nature behind as newer and greater pieces of technology are introduced to society. This source highlights the phenomenon of modern living erasing nature in our lives. In the early 90’s “ecopsychologists began promoting the idea that modern living erodes people’s connection to nature, leaving them developmentally deprived and psychologically distressed (Roszak, 1992; Roszak, Gomes, & Kanner, 1995).” (Psychology for Sustainability, 2016). It is supported that worsening mental health is correlated with this subconscious ideology of leaving nature behind, therefore the reintroduction of nature in our daily lives would help the entire generation to better their mental health. Among this point and many others, both Professor Doyle and the source he provided have been quite beneficial to our insight in nature/green roof mental health contributions and progressing our project.

Our second psychology focused interview was with Morse. Morse affirmed that he had read through studies which have found that spending time in nature, even for just two hours a

week, can greatly improve mood, reduce stress, and heal the body. Being immersed in nature draws you out of your own mind and leads to relaxation. Morse also noted that even small amounts of nature can make a huge change in urban environments in helping them to seem more natural.

With consideration to WPI specifically, Morse oversaw the “Center for Wellbeing” creation as he had been having students asking for more nature on campus. Having visited this space, it is a nature-imbued setup that provides an incredibly calming and stress-relieving feeling. Per WPI’s words on the Center for Wellbeing, directly from their site: “The CWB takes a holistic approach to well-being that empowers individuals to foster a sense of vitality (managing cognitive, physical, emotional, social, and spiritual energy), meaning and purpose, enjoyment, connection, and community.” Morse asserts that the introduction of more flora in the indoor area has further evolved the space into encompassing the serene atmosphere which many students had requested. In this way, both productivity and mental health applications of the Center for Wellbeing have been improved for the students.

As with Professor Doyle, Morse also concluded our interview by leaving us with a source relating to the topic of plants in correlation with mental health titled “Ecopsychology: How Immersion in Nature Benefits Your Health” (Robbins, 2020). The writing cites the origination of the ideology that two hours per week in nature is beneficial for mental and physical health. A study of 20,000 people was conducted by a team at the University of Exeter which indeed found and confirmed that people who spent at least two hours per work in green spaces were substantially more likely to report good health and psychological well-being than people who did not spend at least two hours in nature. In fact, the study showed that people who did not reach the two hour mark but still spent time in nature experienced no benefits from their exposure.

Furthermore, the study helped to confirm that nature was directly linked to reduced stress and improved mood, among many other benefits: “These studies have shown that time in nature — as long as people feel safe — is an antidote for stress: It can lower blood pressure and stress hormone levels, reduce nervous system arousal, enhance immune system function, increase self-esteem, reduce anxiety, and improve mood.” (Robbins, 2020). Furthermore, the source details that being in nature can lessen effects of ADD and aggression-based disorders. With this knowledge, WPI would be able to benefit the academic environment as a whole with more integration of nature, especially those with a form of ADD or ADHD. Another study cited within the reading affirms that exposing patients in a psychiatric unit to two hours of nature per week drastically reduced their feelings of isolation and promoted both calm and lifting moods.

From our interviews with Professor Doyle, Morse, and attributed sources, we were able to find that the integration of nature is quite beneficial to mental health and if WPI were to implement more nature into campus, we would see an increase in academic performance from students. We would see reductions in stress, blood pressure, anxiety, nervous system arousal, and more while simultaneously seeing increases in student happiness, academic performance, and self-esteem. These conclusions and proven benefits should be a huge push for WPI to integrate more nature within campus, especially with student wellbeing and academic performance being strong points of interest for the school.

#### **4.1.4 Summary**

Overall, our literature review and interviews have shown us that while green roofs have significant environmental and psychological benefits, there is a somewhat substantial upfront cost. It is up to each individual to decide whether or not the benefits of a green roof outweigh its initial cost, however, out of the green roof experts that we interviewed, every one of them agreed that the benefits were more than worth the cost.

## 4.2 Assessment of Survey Results

As an integral part of our project we conducted a survey of the WPI community to gauge the current level of awareness and interest in green roofs. Appendix B contains all of the questions that we asked the survey respondents. It is important to note that this survey was conducted among civil engineers, mechanical engineers, architectural engineers, staff, and faculty at the school from which we received a total of 171 respondents. This likely caused a small degree of bias in our results.

One of the first questions that our survey asked was “Which of the following best describes your level of interest in green roof research?” To this question, 80.7% respondents were interested and 30 were neutral or unsure. We then asked the follow-up question “Would you be interested in participating in a green roof focused project?” To this question, only 59.1% respondents said that they would be interested. The answers to these two questions suggest that within the WPI community, among the groups that we surveyed, students (and staff / faculty members) would generally be interested in green roofs and green roof research. The complete results of these two survey questions are shown below in Figures 2 and 3.



*Figure 2. Responses to the survey question “Which of the following best describes your level of interest in green roof research?”*

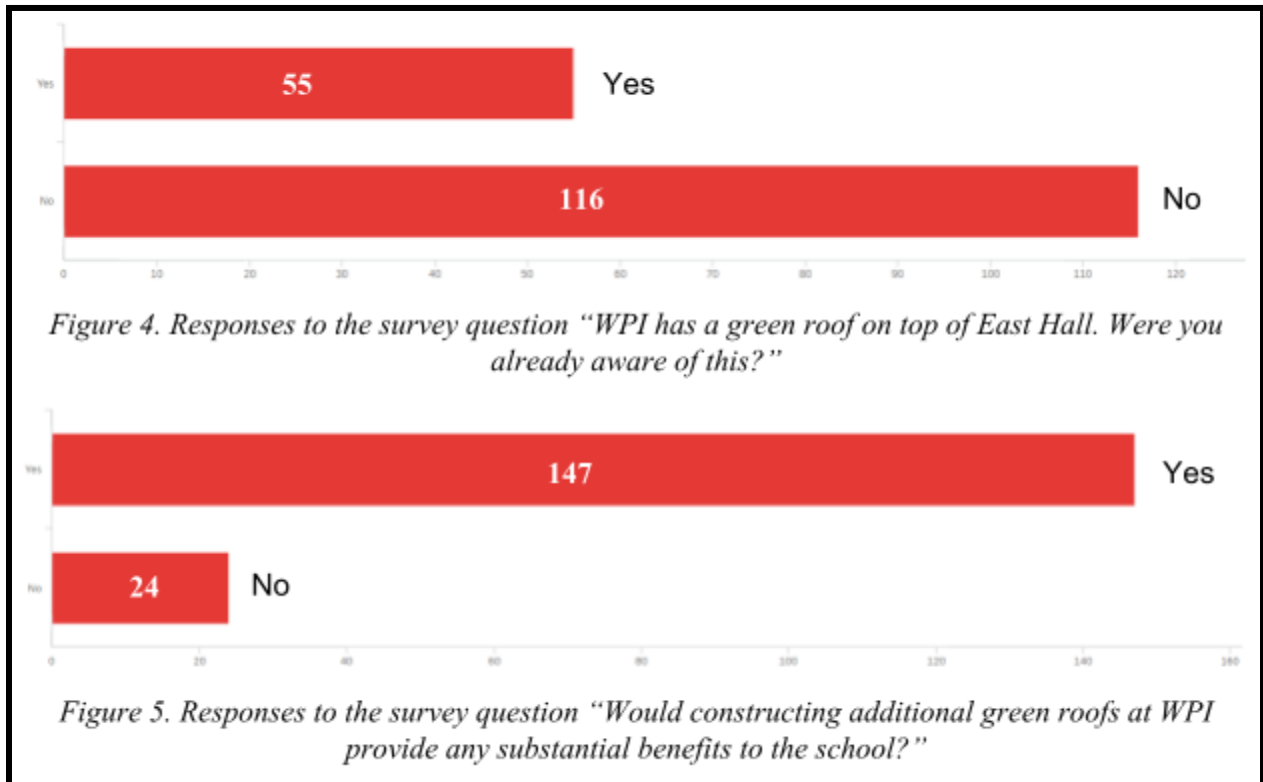


*Figure 3. Responses to the survey question “Would you be interested in participating in a green roof focused project?”*

Next, we asked the respondents whether they were aware of the existence of a green roof on East Hall. To this question, 67.8% respondents answered that they were not aware of the green roof’s existence. We found the responses to this question particularly meaningful, since it meant that many of the individuals that were interested in green roof research were simultaneously unaware that WPI already has one. One of the next survey questions was “Would constructing additional green roofs at WPI provide any substantial benefits to the school?” 85.9% of respondents believed that having more green roofs would be beneficial to the campus community. The respondents that answered in this way were subsequently asked in question 6 to describe what some of the benefits of having additional green roofs at the school might be. One response was “I think this type of vegetation adds to the beauty of the school, uplifting moods and the mental health of students.” The sentiment expressed in this response was echoed by



many other respondents. Other common views were that having additional green roofs would provide more green space for students to socialize and relax in and that they would improve the overall sustainability of campus. The complete results of these two survey questions are shown below in Figures 4 and 5.



In addition, to get a more complete picture of the opinions expressed in question 6, we created a word cloud to display the most frequently used words out of all the responses to this question. In Figure 6, which is shown below, larger text indicates that a given word was used more frequently than a word with smaller text.



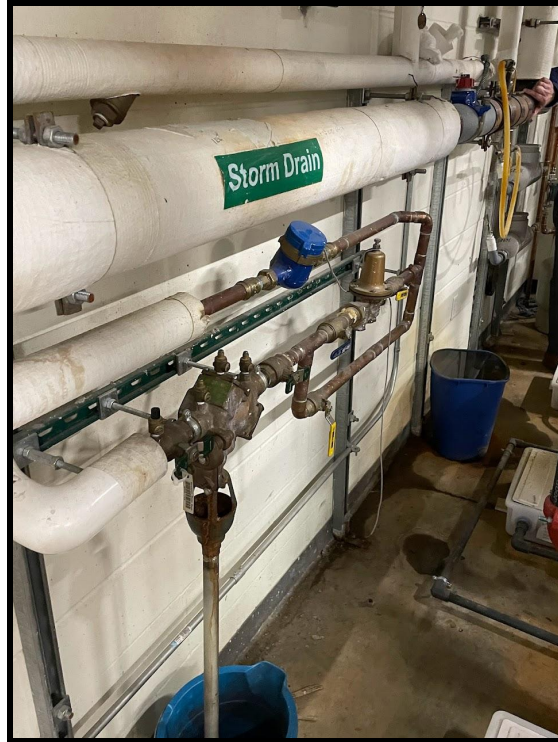
Hall shows the importance of increasing the promotion of green roofs on campus. If more green roofs were to be constructed, as the respondents appear to be in favor of, they would be of little benefit if no one was aware of them.

### 4.3 East Hall Green Roof Visit

While visiting East Hall, we were first shown the water sampling stations connected to the green roof. These are shown in Figures 7 and 8 below.



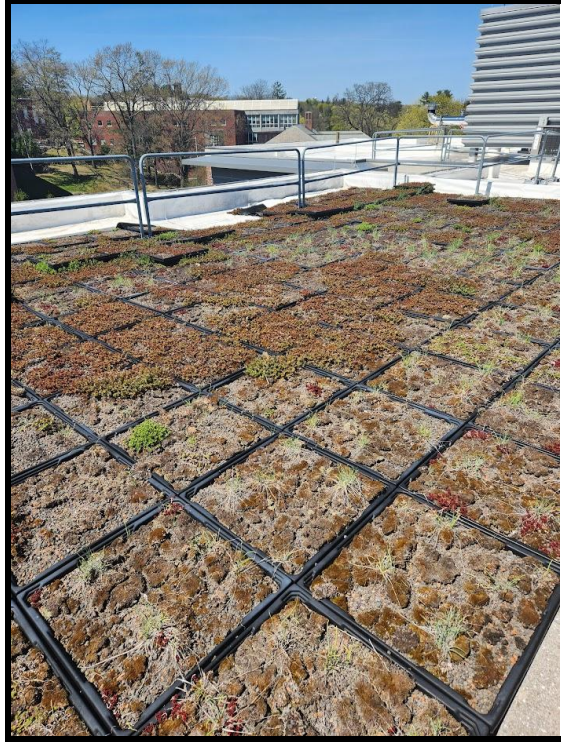
*Figure 7. East Hall water sampling station in the lobby, April 2023*



*Figure 8. East Hall water sampling station in the maintenance room, April 2023*

These stations appeared to be in an acceptable condition, despite them not having been used for some time, however they might benefit from being flushed out to remove any accumulated debris. After examining the water sampling stations, we made our way to the roof.

We found that the green roof still had plants growing in its soil. We visited in April, so most of the plants were flowering. Originally, the plants growing on the green roof included sedums, chives, hens and chicks, and ice plants (Mell, 2008). After more than a decade on the roof, it seemed unlikely that the original plants would still be present. However, we were able to identify the sedums, chives, and ice plants as shown in Figures 9 through 14.



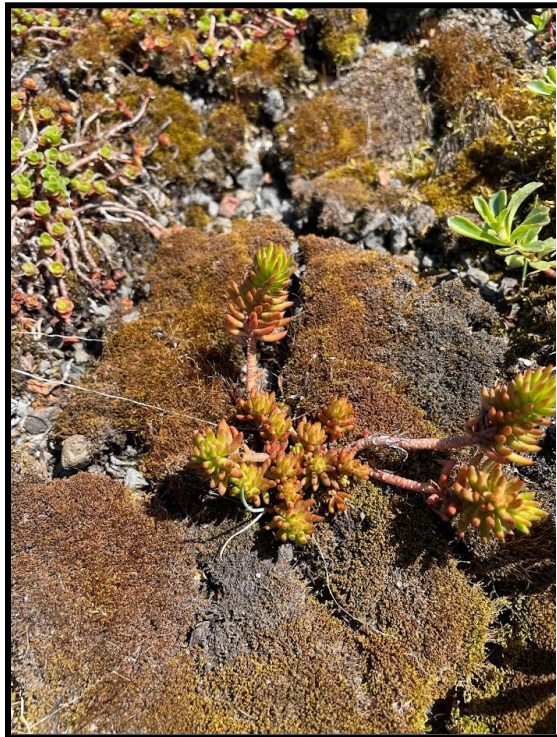
*Figure 9. Plants on the East Hall green roof, April 2023*



*Figure 10. Green sedums on the East Hall green roof, April 2023*



*Figure 11. Red sedums on the East Hall green roof, April 2023*



*Figure 12. Orange sedums on the East Hall green roof, April 2023*



*Figure 13. Chives on the East Hall green roof, April 2023*



*Figure 14. Ice plants on the East Hall green roof, April 2023*



Much of the soil seemed to have been washed away over time, as can be seen by the exposed rocks in the above photos. In addition, there was a great deal of moss that appeared to be thriving in this seemingly nutrient sparse environment. When the above photos are compared to the 2008 picture of the green roof seen in Figure 1, a significant difference becomes apparent in the overall density of the plant life on the roof. When the roof was first constructed, the plants were packed closely together and the roof was a vibrant green color. Now, the plants that remain are spread apart and subsisting off of the little soil left on the roof.

According to Daniel Sarachick, the Director of Environmental Health and Safety at WPI, the green roof had not received its scheduled maintenance (which should occur roughly every 6 months) for years. In addition, we were told that the roof, despite it being a part of the original building's design, was not ideal for East Hall. This was because of the OSHA requirements regarding rooftop work specifying a certain height for parapets and railings for safety. The building did not meet these requirements originally, which required additional railings to be installed around the green roof.

Overall, the East Hall green roof appeared to be in stable condition, but definitely not in its best condition. Restoring the roof to this state would be extremely beneficial to the WPI community.

#### **4.4 Potential Green Roof Sites at WPI**

After visiting East Hall, we investigated which locations the WPI administration viewed as the most viable candidates for implementing additional green roofs on campus. After reaching out to Eric Beattie, the Vice President of Campus Planning Facilities at WPI, he provided us with a list of 6 viable options, including the one that our advisors and Professor LePage had suggested previously.

The primary consideration behind selecting these locations was that the locations should be relatively flat and receive adequate amounts of sunlight for plant life to thrive. Additionally, there were structural and administrative guidelines that needed to be followed, such as not exceeding the weight capacity for the roofs and excluding buildings that were already being considered for solar panel installations. The locations that we recommended are those that are not potential solar sites according to Beattie, and thus these areas for green roofs would not infringe on the roof space that could be used for solar panels. To know for certain whether these locations would be valid candidates for green roofs, a more thorough investigation would need to be made in order to determine whether or not the locations could fulfill the requirements of a given green roof design. The potential green roof locations are highlighted below in Figure 15.



*Figure 15. Potential green roof sites at Worcester Polytechnic Institute as of May 2023*

- 1. Between Daniels Hall and Morgan Hall*
- 2. Between Innovation Studio and Messenger Hall*
- 3. Sanford Riley Hall*
- 4. Salisbury Laboratories*
- 5. Between Fuller Laboratories and Kaven Hall*
- 6. Institute Hall*

It is important to note that, based on our interview with Professor Farzin and talking with Sarahick, we discovered that a hefty investment is required in order to retrofit buildings with green roofs that were not originally designed to accommodate them. For these reasons we

recommend that, for any future construction of buildings at WPI, significant attention should be directed towards incorporating a green roof into the designs of the buildings.

## **5. Conclusions and Recommendations**

This chapter describes our recommendations for maintaining the East Hall green roof so that it may once again be used for educational purposes and selecting the location for a new green roof at WPI. These recommendations are based on our thorough analysis of the current research on green roofs, our interviews with various green roof professionals regarding the benefits and drawbacks of green roofs, as well as our survey of the WPI community designed to gauge the local interest in green roofs.

## **5.1 The Future of the East Hall Green Roof**

The first thing WPI should prioritize is revitalizing the East Hall green roof. To do this, WPI should begin by completing a more detailed inspection of the current status of the green roof. We would recommend hiring a company that specializes in green roofs to do this. Then, the administration should complete the changes that are recommended by this company. After this is done, the required maintenance should be completed on a regular basis. With the green roof restored, many project opportunities would arise that involve the roof, and these opportunities should be highlighted by the school.

The next crucial step is putting the East Hall green roof back in the spotlight. When the building was first constructed, the East Hall green roof was mentioned in many WPI newsletters. Nowadays, according to our survey results, the majority of students are not even aware of the green roof's existence. To increase the popularity of the East Hall green roof, the WPI administration should consider sponsoring projects involving the roof and subsequently writing about these projects in school newsletters.

## **5.2 New Green Roofs on Campus**

In addition to giving more attention to the East Hall green roof, WPI should also consider the potential for creating new green roofs on campus. In our interview with Theresa Rosato (A.8), a junior year biomedical engineering student and President of the Greenhouse and Horticulture Club at WPI, she expressed interest in having a new green roof that could be managed by her club. Here, students could grow a variety of plants including fruits and vegetables to harvest and consume. This hypothetical green roof could even be located adjacent to the greenhouse on top of Salisbury Laboratories.

Additionally, our advisors Professor Mathisen and Nicole Luiz, as well as Professor LePage, recommended a spot on the walkway connecting Fuller Laboratories and Kaven Hall as illustrated below in Figure 16.



*Figure 16. Potential green roof site between Fuller Laboratories and Kaven Hall as of May 2023*

Our advisors and Professor LePage recommended this location due to it not needing any infrastructural support or changes to bear a green roof system. It is situated in a relatively high-traffic spot at Worcester Polytechnic Institute, and it is not in an area where the plants may be endangered by careless passersby. Furthermore, the spot between the two buildings yields a



healthy amount of sunlight despite the two buildings adjacent to it, providing a healthy environment for part-sun flora.

### 5.3 Final Thoughts

The findings of our project have revealed that green roofs have many environmental, economic and psychological benefits. These benefits should demonstrate the importance of renewing the East Hall green roof and considering the construction of new green roofs elsewhere on campus.

Regarding environmental impacts and benefits, we spoke with a few particular interviewees who gave us the information we were most seeking. Through conducting the interviews, we have found that green roofs are indeed beneficial to the environment in a multitude of ways. We were able to confirm from Professor Servatius the successful operation of her green roof as an insulator, replacing large amounts of much less environmentally friendly insulation with a rooftop garden. More importantly, the added green roof insulation also reduces the need for harmful utilities such as an ac unit, a pollutant device. The green roof she cultured attracted and built an ecosystem in an otherwise non-green area, further benefiting the health of the local environment. In addition, our interview with Horsley confirmed that inviting more plant life in the space around you leads to a healthier, less polluted atmosphere. With these offered positives, we were able to confirm all of our suspected environmental benefits that green roofs give us through our interviews. The one negative environmental impact we found in our interview with Professor LePage was actually a perceived benefit in section 2.5. Professor LePage informed us that the usage of fertilized soil in a green roof system may contaminate stormwater runoff from the building and increase the level of phosphorus (a pollutant) in the water; however, Horsley informed us there are green roof systems focusing on bioretention in order to prevent this specific issue. Considering these results, we ultimately found green roofs to be quite beneficial to the environment, in both preserving and expanding what already exists as

well as creating green in an otherwise gray area. The widespread future utility of green roofs would lead to the preservation of a healthy environment through the spread of infrastructure. Worcester Polytechnic Institute's environment would certainly thrive from the incorporation of more green roof systems and bring the arrival of healthier air, healthier nature on campus, and promote a diverse ecosystem for students to enjoy and explore.

The economic impact was fairly straightforward. Our interviews confirmed that the upfront price of a green roof with promises of long term benefits can be off-putting for those who are not financially comfortable to make the purchase. Specifically, Horsley mentioned the price of a green roof and mimicking nature in combination with clients preemptively fearing their green roof may fail can lead to a difficult sale. However, Horsley, Pete Ellis, and a number of other interview subjects stated that in the long run a green roof will be saving you money through its ability to reduce household energy consumption as well as the potential for reductions in stormwater taxes. Ellis (A.9) is a Senior Project Manager and Estimator for Recover Green Roofs, a company which designs, builds, and maintains green roofs. The implementation of green roofs in new residence halls on the Worcester Polytechnic Institute Campus would reduce the energy consumption of the building while keeping students just as cool or warm given the respective season. In reducing energy consumption and keeping the local environment cleaner, it would also yield large savings in the form of energy bills for Worcester Polytechnic Institute.

Our interview results for the psychological benefits of green roofs complimented the data we collected while researching and supported the conclusion our team drew. Specifically, the interviews conducted with Professor Doyle and Morse fully supported the ideology that exposure to nature increases both mental and physical health on the human body. They confirmed being around nature can create a calming or de-stressing effect on the body which can actually increase

focus and thus academic performance in turn. This exposure can also minimize effects of certain learning disabilities such as ADHD. Worcester Polytechnic Institute's community would greatly benefit from this green roof exposure and it's almost certain the further implementation and expansion of green roof systems on campus would make for a happier average student as well as a better academically performing one.

To conclude, the results yielded from our interviews heavily supported the background research we conducted and even provided new information to support our verdict. Green roofs are beneficial to the local environment, they're economically beneficial, and lastly they are beneficial to human health, both mental and physical. Throughout our interviews and discussions with campus personnel, we also discovered that the walkway between Kaven Hall and Fuller Laboratories is a great candidate to house a new campus green roof system. Given the information we collected, we can conclude that the expansion of green roofs would be both feasible at Worcester Polytechnic Institute and immensely useful to the campus and community.

Another key part of our project was to gauge the WPI campus community's interest and knowledge of green roofs. Acknowledging that there may have been some bias due to the groups that were surveyed, the survey results displayed that there is significant interest in green roof research and projects. Furthermore, the survey respondents displayed a great interest in the construction of more green roofs on campus. Given these responses there it can be inferred that there is a demand for green roof related projects but a lack of projects for those that are interested. The planning and construction of accessible green roofs on campus would enable those interested to become more involved with the planning, construction, maintenance and usage stages of green roofs in the form of projects or educational material. Another option is to use the East Hall green roof as a tool to site for potential projects as well as educational material

for those interested as many survey respondents were unaware of the current green roof that is present on East Hall. To sum up what we have learned, the survey results indicate that there is a strong interest in implementing as well as learning about green roofs on campus and that there are several ways that the WPI administration can support this interest.

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## **Appendix A: Interviews**

### ***A.1: Professor Brigitte Servatius***

#### **WPI IQP: Green Roofs**

#### **Interview with Professor Servatius**

2/20/2023

9:00am - 9:30am

Type of Interview: In person

Facilitator: Jack Arabian

Attendees: Jack Arabian, Sarah Chen

#### **I. Description of project goals and objectives**

The information gained through this interview will be used for academic purposes in promoting green roofs and green roof research at WPI. We endeavor to learn about green roofs from a green roof owner in order to educate students at WPI on the environmental, economic, and psychological impact of green roofs, as well as to motivate further research on the topic.

#### **II. Interview questions**

##### **1. What caused your interest in green roofs?**

- Fridenriech (peace rich) Hundertwasser: he wanted cities to be green, and the best way through green roofs. His main idea: how do you use a city space and have green space?
- Also can have animals integrated with green roof for instance, goats grazing on green roofs in Norway.

##### **2. How long have you had your green roof?**

- 15 years.
- She was a big advocate for one and they built one on their house because she wanted one so badly



3. Has your green roof system saved you money?
  - Yes, it provides insulation and works in tandem with the green greenhouse below. Additionally the green roof keeps the climate for the greenhouse in good condition, provides good heat regulation: heat in the winter and cool in the summer.
  - Professor Servatius takes part in “Pajama gardening.” No need to spend money at gym or physical exertion, can just garden on the green roof instead.
  - In her green roof she has chives, parsley, strawberries, pumpkins, and other herbs.
  - Not everything is measured in money, although there is also money saved in being able to garden from the physical exertion that it provides. Additionally the green roof attracts a lot of birds due to the wild strawberries on green roofs which brings immeasurable joy and entertainment from nature. This joy is not something money can buy.
  - There is also the cost savings from being able to grow herbs instead of buying them from the grocery store.
4. What do you do to maintain the aesthetics and functionality of your green roof?
  - Invests 10 minutes a day in upkeep of the green roof, and also the insects and weeds are part of the upkeep and part of the enjoyment.
  - One hassle is clearing off snow (mostly due to a personal design flaw- has to lift snow off instead of pushing straight off the roof).
5. What is your favorite aspect of your green roof system?
  - Watching the sunrise or the moon from a chair on the green roof.
- b. Has your green roof resulted in any unforeseen negative or positive aspects?
  - Nothing negative except the snow: the negative accumulation which has to be shoveled off and the water leaks into the windows because they are at a lower height than the black railing. However, she considers it always fun even in the winter.
  - Unexpected positive aspects are the animals on the roof. There is a different dynamic with the animals on the green roof than those interacting

in gardens on the ground. An opossum burrowed in the green roof soil, and squirrels come up onto the green roof.

6. If you were to move to a new location, would it be important for that location to also have a green roof? Is it a necessity for you?
  - They built the green roof as an addition onto the house in addition to the greenhouse. Neither green roof nor green house require that much upkeep. The green roof enhances life so much that they would miss it a lot if they were to move.
7. How has the green roof system elevated your lifestyle if at all?
  - Yes very much, brings more joy and quality of life
8. Was the implementation of the system “worth it” what is the trade-off?
  - The green roof brings a lot of enjoyment and elevates quality of life
  - It was almost impossible to find someone to install the green roof, there was a lot of hesitation in the value and cost of building it, but the installation was not that different cost wise in terms of an addition of the house with or without the green roof.
  - Also they needed a permit from the city of Worcester. They brought up the soil themselves. Bottom layer is sand 3 inches then another 3 inches of soil. Waters the potted plants, but the rest of the green roof survives as any regular outdoor garden would.
9. Is there anything you would change about your green roof system after living with it for 15 years?
  - She would change the roof barrier and have a railing installed instead, and possibly get a glass fence. Additionally she would add larger glass windows to see into the green roof instead of asphalt shingles on the roof of the greenhouse.
10. Do you think there are any potential opportunities for additional green roofs on campus?
  - Argued for green roof on stratton hall since currently under renovation and roof broken, german philosophy all roofs should be green. Green roofs

provide a lot including research opportunities with not a lot of increased cost, also provides space for relaxation

## *A.2: Coleman Horsley*

### **WPI IQP: Green Roofs**

#### **Interview with Horsley**

3/16/2023

2:00pm - 2:50pm

Type of Interview: in person

Facilitator: Jack Arabian

Attendees: Jack Arabian, Sarah Chen

#### I. Description of project goals and objectives

The information gained through this interview will be used for academic purposes in promoting green roofs and green roof research at WPI. We hope to learn about the structural requirements of buildings needed to support green roofs and what sort factors need to be considered when making potential roof suggestions for green roofs.

#### II. Interview questions

1. What inspired you to specialize in green roof design, and how did you get started in this field?
  - He is passionate about promoting healthier human building relationships.
  - Started by land surveying and from this found that he wanted to create a positive environmental impact.
2. Can you explain the basic principles and benefits of green roofs, and how they are different from traditional roofs?
  - Traditional roofs are referred to as gray roofs, with no improvements.
  - The basic principle is green design. Nature is good at multitasking and better at it than humans. So the best thing is to try to mimic nature. Since we cannot produce nature ourselves, the best thing we can try to do is mimic nature. We can learn so much from nature.
  - Green roofs are large scale, and provide long term benefits.

- Bioretention systems: for instance the rooftop field and the church, in between is a bioretention area, which is water filtered by roots, where pollutants are removed and clean stormwater is released. The Unity Hall parking lot is another example.
  - Preserve rivers for instance the output of Salisbury pond now overflows after being made into a pipe instead of remaining a stream
3. What are some of the challenges you have faced in designing green roofs, and how have you overcome them?
- Cost is a large factor and mimicking nature is a lot more expensive. Additionally getting clients over fear of green roof failing is another major challenge. Salesmanship to clients is very expensive.
  - Green roofs require a lot of space and maintenance.
4. How do you approach the design process for a green roof, and what factors do you consider when selecting the appropriate plants and materials?
- There are both intensive and extensive green roofs. Intensive roofs consist of large trees and plants, while extensive roofs consist of CeDair mats: flat grass, which can be used with solar.
  - Another option that we consider is purple roofs: green roof with blue roof below (stormwater storage). This has a few inches below to store water and rehydrate plants, and it stores excess water that the soil cannot retain. Saves water and serves as flood retention.
  - SemperGreen is the Netherlands company that came up with purple roofs.
  - It is a risk having water stored on roofs, and people are often uneasy about it but there is no substantial evidence of failure yet.
  - When choosing between solar vs green roofs, consider the location and the type of roof
  - Taller buildings are generally chosen to have green roofs due to wind negatively impacting solar panels
  - If the building is low enough to the ground, the green roof can support bees and butterflies

- Bee Downtown is a startup in North Carolina that puts beehives on roofs and properties, it partners with green roofs.
  - For instance, there are beehives on top of the Nitsch Engineering roof, and the honey produced is used by a local restaurant on the ground level floor of the building.
5. What role does sustainability play in your green roof designs, and how do you ensure that your projects are environmentally friendly?
- Green roofs are long term savings rather than short term. It is necessary to sell people on this idea: futureproofing
  - Makes sense to keep close to nature, and they increases the GDP
  - Spending some money up front for green roofs is worth it in the long term
  - Green roof benefits include: cooling down buildings and cleaning the air. They also reduce the heat island effect, which decreases cooling costs.
  - Heat island effect: cities around 5 degrees warmer than surrounding areas
6. Can you discuss some examples of green roofs you have designed, and how they have impacted the local environment and community?
- Designed low income housing in Boston, the green roofs installed on the top of the buildings are helping to improve the heat island effect and the quality of life in these areas
7. How do you work with clients to educate them about the benefits of green roofs, and what role do you play in securing permits and approvals for green roof projects?
- A lot of help educating the public comes from the cities passing regulations to allow and promote green roofs
  - The city of Cambridge MA recently approved construction of green roofs
  - Municipal education is the best way to sell green roofs
  - Need to convince companies to use green roofs instead of larger alternatives to manage stormwater
  - There is pushback from students, but university related projects tend to be more interested in adopting green infrastructure

8. Can you discuss the maintenance requirements for green roofs, and how do you work with building owners and maintenance crews to ensure that they are properly cared for over time?
  - Green roof maintenance is relatively minor. It consists of trimming plants, and de-weeding. A lot of architects recommend checking or replacing the green roof every 5-10 years.
9. Finally, what advice would you give to young architects who are interested in specializing in green roof design?
  - There is a lot of business in green roofs at the moment. They are very impactful and beneficial to the surroundings with a city/state/worldwide impact.
  - Really good idea to work in environmentalism related fields, it is very popular right now. Green “clout:” lab buildings want to attract large companies with intelligent, green-focused employees. They look for green buildings
  - Working with green roofs has a measurable and direct impact, and it is a very rewarding career. Works to create a greener and healthier world
  - Never had client share bad review on green roof after installation

### *A.3: Professor Jim Doyle*

## **WPI IQP: Green Roofs**

### **Interview with Professor Doyle**

3/16/2023

3:00pm - 4:00pm

Type of Interview: in person

Facilitator: Jack Arabian

Attendees: Jack Arabian, Sarah Chen, Bennet Kracz, Atharva Tiwari

#### I. Description of project goals and objectives

The information gained through this interview will be used for academic purposes in promoting green roofs and green roof research at WPI. We endeavor to learn about the psychological benefits of green roofs in order to educate students at WPI on the environmental, economic, and social impact of green roofs, as well as to motivate further research on the topic.

#### II. Interview questions

1. What is your educational background?
  - Mental models, PhD UColorado 1991
2. What psychological impact can nature have on people?
  - Spending time in nature can relieve stress but won't cure depression, it doesn't even take much to relieve stress.
  - Hospital patients that can look out the window heal faster on average. Getting away from others, and peace and quiet are valuable aspects of experiencing nature but there should be balance, should not be completely alone but not in a giant crowd either.
  - Doyle thinks that there will be long term benefits to nature exposure, hard to say though since hard to track for years, few studies.
3. What benefits are provided by having areas of nature within urban environments?



- Biophilia hypothesis - people are inherently drawn to nature
  - Raising the shades in classroom for exact reason of allowing students to view nature: the sunlight and trees outside
4. What are your views on green roofs?
    - Green roofs should be in a passive location where people already travel, not one you actively go to.
  5. Do you believe green roofs can be used to provide the same psychological benefits as nature in general?
    - The WPI quad is a similar example, but the quad may or may not be enough nature, depends on the circumstance
  6. Do you know about the green roof on top of East Hall?
    - Current green roof on East Hall is not doing much for mental health as people cannot see it or visit it.
  7. Do you believe having a green roof that is more accessible to students would be beneficial to the WPI community?
    - Current green roof on East Hall is not doing much for mental health as people cannot see it or visit it. Have green roofs be at a passive location where people already travel, not one you actively go to.
  8. Do you think the additional nature provided by a green roof could aid students that suffer from conditions such as ADHD, anxiety, stress, and depression within the WPI community?
    - Over time, spending time in nature can relieve stress - stress related to many mental health problems.
  9. Could green roofs be a significant factor in improving the educational environment by reducing psychological disorders?
    - Interaction with nature, even sunlight can improve mood and thus learning capabilities. Cognitive performance benefits as well, learning, studying, remembering etc.
  10. Do you have any other information that you believe may be relevant to our project?

- Idea to survey different groups then compare the results instead of studying all the results at once. Captive audiences - administer the surveys to people already gathered, hand out surveys to group/class/meeting.
11. Any negative effects from too much exposure to nature?
- In moderation; like everything too much of anything can be bad

#### *A.4: Charles Morse*

### **WPI IQP: Green Roofs**

#### **Interview with Morse**

3/17/2023

3:00pm - 4:00pm

Type of Interview: in person

Facilitator: Sarah Chen

Attendees: Jack Arabian, Sarah Chen, Bennet Kracz

#### I. Description of project goals and objectives

The information gained through this interview will be used for academic purposes in promoting green roofs and green roof research at WPI. We endeavor to learn about the psychological benefits of green roofs in order to educate students at WPI on the environmental, economic, and psychological impact of green roofs, as well as to motivate further research on the topic.

#### II. Interview questions

1. What is your educational background?
  - Masters in counseling
  - Bachelor's degree in psychology
2. What psychological impact can nature have on people?
  - Studies have shown that at least two hours a week in nature significantly helps with mental health and physical health
  - What degree of this is exercise vs nature? This is still unknown.
  - What is nature? Birds chirping, leaves rustling, sunshine?
  - Microbiomes in nature to help physiology
  - Center for well being designed with the idea to create more plant life around students
  - Students asked for more nature

3. What benefits are provided by having areas of nature within urban environments?
  - Areas of green and sense of peace and comfort provided by nature to make urban environment seem more natural
4. Do you believe green roofs can be used to provide the same psychological benefits as nature in general?
  - Mindfulness, meditation helps anxiety
  - Nature draws you out of your own mind to help you relax
5. Do you believe having a green roof that is more accessible to students would be beneficial to the WPI community?
  - Green roofs are part of LEED certification
6. Do you think the additional nature provided by a green roof could aid students that suffer from conditions such as ADHD, anxiety, stress, and depression within the WPI community?
  - Mindfulness - nature tends to draw us out
7. Could green roofs be a significant factor in improving the educational environment by reducing psychological disorders?
  - If they could help in contributing to one of the 4 things that are essential for good mental health: eat, sleep, exercise, and social connection
  - Mental health crisis, likely due to cell phones, especially social media
  - Can only see “perfect images” of people on social media, which causes crisis
  - Big picture (nature) vs little picture (social media). It is necessary to return back to the big picture
8. Do you have any other information that you believe may be relevant to our project?
  - Rec Center green roof previous IQP
  - Talk of having a community garden on campus. However, there was pushback with the concern that not many students would be in Worcester over the summer, but looks like it will still happen as integration with pre-existing summer programs
9. Any negative effects from too much exposure to nature?
  - Everything in moderation
  - Exposure to the sun important

- Too much nature (isolation, escape) probably not great for mental health
- Insects, sunburn, and natural hazards

## *A.5: Professor Suzanne LePage*

### **WPI IQP: Green Roofs**

#### **Interview with Professor LePage**

3/27/2023

4:00pm - 5:00pm

Type of Interview: in person

Facilitator: Jack Arabian

Attendees: Jack Arabian, Bennet Kracz, Atharva Tiwari

#### I. Description of project goals and objectives

The information gained through this interview will be used for academic purposes in promoting green roofs and green roof research at WPI. We endeavor to learn about green roofs from the perspective of someone with a master's degree in green roof studies to gain insight to educate students at WPI on the environmental, economic, and psychological impact of green roofs, as well as to motivate further research on the topic.

#### II. Interview Questions:

##### 1. What's your background surrounding green roofs?

- Suzanne's master thesis revolved around green roof research
- She researched phosphorus count in stormwater, whether it was dissolved or attached to sediment, and in what circumstances phosphorus built up.
- Looked to use silica sand in removal of sediment and pure phosphorus from stormwater.
- She ran tests on water composition before and after running through green roofs.

##### 2. What have you learned about green roofs/East Hall?

- Water runoff leaving the green roof had more phosphorus picked up from the soil than water leaving a normal roof. So the water quality of stormwater was actually lower when it came into contact with a green roof system.

- LePage found research that suggested phosphorus leaching from green roofs into “clean” water would be short term until more fertilizer washes away. Therefore the drastically reduced quality in stormwater after running through a green roof system is a temporary issue.
  - Fertilizer frequently washes off green roofs during spring storms, allowing it to spread to unwanted areas.
  - Green roofs can delay water from hitting the ground level to help protect against flooding situations
3. What kind of benefits could there be to having another green roof on campus and do you have ideas for a location?
- More vegetation in urban environments is always good despite phosphorus leaching. More = better.
  - More accessible location on campus? Would have to be “fortified” or have heavy time restrictions to protect the plants.
  - Potential for WPI to grow its own food/herbs.
  - The Kaven rear walkway was listed by LePage as a great choice for a second green roof/growbed location.
  - We also explored the potential for a green roof maintenance team at WPI to accommodate for the expansion of green roof systems and increased variation in plant choices.
4. What do you know of the energy and sustainability costs? Money saved?
- LePage did not look at this category particularly in-depth as her research did not focus on this topic; however, she acknowledges it as a known benefit.
5. Any challenges associated with implementing another green roof system focused on stormwater management on WPI campus?
- An underdrain system would be required as clogging issues are imminent without proper piping and filtration.
6. How could cities incentivize green roof implementation?
- Tax breaks
  - Donations

- Waiving of the clean water act fee for applicable cities - some cities have implemented the clean water act which has created a fee on water usage from stormwater

7. Why do we not build green roofs everywhere?

- Maintenance time and costs can be heavy if the green roof is not built to be maintenance free
- The structure needs to be able to support the weight. Most buildings in place now would not be able to structurally support the addition of a green roof without major renovation



## *A.6: Professor Pamela Weathers*

### **WPI IQP: Green Roofs**

#### **Interview with Professor Weathers**

3/27/2023

12:30pm - 1:00pm

Type of Interview: in person

Facilitator: Sarah Chen

Attendees: Sarah Chen, Jack Arabian, Bennet Kraz

#### I. Description of project goals and objectives

The information gained through this interview will be used for academic purposes in promoting green roofs and green roof research at WPI. We endeavor to learn about potential plants from a plant biology professor to understand different plant specifications that have to be accounted for in green roofs. This knowledge will aid in the general knowledge of green roofs that will be used to educate students at WPI on the environmental, economic, and social impact of green roofs, as well as to motivate further research on the topic.

#### II. Interview Questions

1. What's your background?
  - Pam - plant biologist
2. In terms of extensive versus intensive roofs, what do you think of the two in terms of plants?
  - Extensive roofs - more water, soil
3. Have you seen the green roof on East Hall?
  - Pam went up on East Hall green roof when it was first installed, and observed the plants do not require much water
  - She advised us when we go up to investigate the green roof to see if original plants are still on East Hall roof

- Look at images of plants, take pictures, compare, count, etc
  - Look at early list of plants that are up on east hall green roof, can identify when we go up to investigate
  - Keep eye out for weeds or new species
4. Do you think there would be opportunities for research related to green roofs at WPI?
- During/after thunderstorm, nitrogen in air, visible greening
  - Haber process - thunderstorm helps fertilize
  - Lightening conversion to ammonia and it comes down as fertilizer
  - Need control sample of rainwater that has not gone through the system
  - In addition to the sample that has gone through the system
  - MQP potential: different plots of plants but would need to span multiple seasons  
-collect runoff from the plants separately
  - Mix and match plants- find ideal mix
5. Do you think you would have any potential MQP options with Green roofs?
- No, not her personally because she has too much going on already but she would be interested
  - In terms of an MQP relating to the types of plants and their impacts, this sort of study would span longer than a year and would require either graduate students or undergrads that would spend multiple years of study on this project

## *A.7: Professor Soroush Farzin*

### **WPI IQP: Green Roofs**

#### **Interview with Professor Farzin**

4/3/2023

11:00 am - 12:00 pm

Type of Interview: in person

Facilitator: Bennet Kraz

Attendees: Sarah Chen, Jack Arabian, Bennet Kraz, Atharva Tiwari

#### I. Description of project goals and objectives

The information gained through this interview will be used for academic purposes in promoting green roofs and green roof research at WPI. We endeavor to learn about the architectural considerations when constructing and adding green roofs to building. This will aid in the knowledge used to educate students at WPI on the environmental, economic, and psychological impact of green roofs, as well as to motivate further research on the topic.

#### II. Interview Questions

##### 1. Background?

- Degree in Urban Planning/Architecture

##### 2. What green-based works do you have? How do you integrate nature within design?

- Green design is an important part of architecture. We as architects have a moral obligation to take care of the environment
- Need to think about ourselves and the future needs: this is the whole philosophy of design
- Design needs to be sustainable
- Need the long term vision: how can the building contribute to the environment when constructing architecture? Need to consider energy consumption, incorporating solar gain, and heat exchange
- Taking into consideration the heat island effect when looking into building designs

- In terms of material choice, using material that is less damaging to the environmental, requiring less energy, and is more supportive to the environment,
  - What sort of resources does the community have to offer? Looking for material with less impact
  - Substitute for concrete- concrete is one of the largest CO<sub>2</sub> producers in the world of materials
3. What is your drive to work with green roof structures? Aesthetics? Environmental Health? Human health?
- These aspects are not separable. Buildings need to have all the aspects
  - If the building is beautiful but contributes to the green island effect this is not good
  - Small microclimate from the building- this is beautiful
  - It is a bonus if it is also beautiful but function comes first
4. Do you believe all buildings should be built with green roofs or some green aspect if possible?
- Some of them is not possible, some building systems use hvac, or heating/cooling system which can also work
  - Some roofs cannot be green roofs
  - High rise buildings can be more damaging to convert to green roof due to wind, and maintenance
  - Need to consider what is the environmental consequence? Long term consequence?
5. Are there green options for pre-existing structures that cannot support the weight of an add-on green roof?
- Things to consider when adding green roof: not necessarily just weight of roof, there are plants to consider
  - A lot of dead load because on the surface of the roof and many layers to protect the roof from the plants in the green roof
  - Dead load will be less with certain plants (plants that require less soil, can occupy small flower pots for example), and less cost of materials depending
  - MQP on green roof Umass Amherst was looking at structural analysis, and there was safety factor of 1.5 dead load already
  - Possible to add if not compromising the structure of the building
6. Have you seen the green roof at WPI?
- No, only pictures
  - Climate is something to consider- moderate climate might be better for green roofs because they need maintenance otherwise, might cost a lot more to maintain

- Could look at Salisbury greenhouse
- BIG Architect - video about green roof integration in design process, overall sustainability

*A.8: Theresa Rosato*

**WPI IQP: Green Roofs**

**Interview with Rosato**

4/4/2023

5:00pm - 5:20pm

Type of Interview: in person

Facilitator: Sarah Chen

Attendees: Sarah Chen, Bennet Kracz

I. Description of project goals and objectives

The information gained through this interview will be used for academic purposes in promoting green roofs and green roof research at WPI. We endeavor to gain insight into types of plants that may be feasible in having on a green roof, and learn about the greenhouse club on campus and their potential interests in green roofs in order to educate students at WPI on the environmental, economic, and social impact of green roofs, as well as to motivate further research on the topic.

II. Interview questions

1. Background?

- Junior year, BME major, Bio minor
- President of greenhouse & horticulture club

2. What does the WPI greenhouse club do?

- Greenhouse found structurally unsound last year
- Get students involved with care of plants
- Club does activities like plant themed crafts
- Reached out to for plant related projects on campus
- Talking to the library about setting up garden
- Annual plant sale hosted by club
- Typically host meetings in the greenhouse
- Pushing for pollinator garden

3. What sort of plants does the WPI greenhouse club interact with? Are these plants indoor or outdoor plants primarily?
  - Greenhouse has indoor space with roof
  - No plants are currently on the roof
  - Looking to add planters to roof area (hoping to start a farmers market to sell fruits and vegetables)
  - Inside greenhouse are house plants
    - i. Plants that wouldn't survive outside in Worcester climate
    - ii. Cacti, succulents, lemon tree, pitcher plants, etc
4. What do you know about green roofs?
  - Doesn't know much
  - Knows of green roof on East Hall
5. Do you think the greenhouse provides benefits to the WPI community? If so, what are the benefits? And also, do you think that green roofs that students could interact with would also provide similar benefits?
  - Absolutely, one of the best parts of greenhouse club it is very relaxing and comforting, good to take care of something, nice to watch it grow and thrive
6. Do you think there would be interest in green roofs that students could interact with on campus?
  - Would provide a lot of interest to campus
  - Hundreds of people in greenhouse club
7. If there were research opportunities with the green roof/ potential green roofs on campus, do you think there would be interest?
  - Would be of interest to a lot of people on campus
  - A lot of people are wanting to do research- physics majors working in the bio-labs

**A.9: Pete Ellis**

**WPI IQP: Green Roofs**

**Interview with Ellis**

4/6/2023

11:00am - 11:20am

Type of Interview: Online

Facilitator: Jack Arabian

Attendees: Jack Arabian, Bennet Kracz

1. What is your background and what caused you to get interested in green roofs?
  - Working with green roofs for 11-12 years
  - Recover Green Roofs out of Somerville, MA originally from Washington D.C.
  - Commercial construction, limited background in agriculture, design and fabrication work in construction
  - Recover has grown from 2-3 to 30+ members
2. What is your perspective on green roofs and their functions?
  - Super important
  - Provide a lot of benefits
  - Stormwater management, improved biodiversity, air quality (reduced heat island), look at context for each building individually
  - Great way to encourage nature and nature-based solutions within cities
  - As industries evolve, more and more options
3. What are the most significant needs for green roofs of the future?
  - Well developed/well installed building envelope
  - Well designed roof and waterproofing system
  - Need stronger quality control around waterproofing to benefit green roofs
  - Buildings need to have structural loading capacity to support the green roof
  - Having components that have a track record of success (quality materials, plants)



- Drainage layer, protective layer, roof barrier
  - The most important thing to consider is the functionality of the plantings on top of the system
4. In a sentence - why are green roofing systems superior to conventional?
- “Stacked benefits” → refers to having multiple benefits from a single entity or opportunity
  - With a green roof you get - waterproofing, keeping the environment out of the building, and other stacked conventional/known benefits of green roofs. Return investment on roof space
5. What is being done to increase the number of green roofs?
- Decentralized in united states (popularity has not expanded from Europe quite yet)
  - Based on municipal laws
  - Rebate programs → incentivize green roofs through grant funding/saved money
  - Currently many locations around the US pushing for different usages of green roof systems
  - Incentive through reduction in stormwater taxes
  - Encouraged through “political network” primarily via monetary incentives
  - ESG’s (investment portfolio → quantifying biodiversity)
6. Can you give any examples of how green roofs have been used for community engagement, education or public access?
- Somerville green roof (Cala), murals, art, events, community engagement
  - Rooftop farms in Boston area
    - Roof in Kendall square, used to be Google’s HQ in Boston
7. How can green roofs be designed to encourage public use and enjoyment?
- Accessibility - making sure roofs are accessible to public (ADA compliance, multiple routes of egress, proper safety measures, designing the roof for engagement)

8. How do you stay current with advancements in green roof technology and what resources do you rely on to stay informed?

- Journals (Green Roofs for healthy cities → living architecture monitor, NA News)
- Research Papers
  - Lots of research coming out from all over the world on green roofs in modern day
- UK Organizations (GRO)
- Networking, publications, industry connections

## **Appendix B: Survey Questions**

The information gained through this interview will be used for academic purposes in promoting green roofs and green roof research at WPI. We endeavor to learn about the current level of knowledge of green roofs in the WPI community in order to promote knowledge and research of green roofs at WPI.

Green Roof definition: A vegetated roofing system that is integrated into a roofing area (World Green Infrastructure Network, 2021).

### **Survey Questions & Complete Multiple Choice Results**

1. Which of the following best describes your status at WPI?
  - a. Undergraduate Student (chosen 103 times)
  - b. Graduate Student (chosen 4 times)
  - c. Staff Member (chosen 44 times)
  - d. Faculty Member (chosen 21 times)
2. Which of the following best describes your level of interest in green roof research?
  - a. Interested (chosen 138 times)
  - b. Neutral / Unsure (chosen 30 times)
  - c. Not Interested (chosen 3 times)
3. If you answered "Yes" for the previous question, would you be interested in participating in a green roof focused project?
  - a. Yes (chosen 101 times)
  - b. No (chosen 53 times)
4. WPI has a green roof on top of East Hall. Were you already aware of this?
  - a. Yes (chosen 55 times)
  - b. No (chosen 116 times)
5. Would constructing additional green roofs at WPI provide any substantial benefits to the school?
  - a. Yes (chosen 147 times)
  - b. No (chosen 24 times)

6. If you answered "Yes" for the previous question, what do you think the substantial benefits would be?
7. Do you believe that green roofs positively impact mental health?
  - a. Yes (chosen 152 times)
  - b. No (chosen 18 times)
8. How would you prefer to receive educational information regarding green roofs?
  - a. Email (chosen 108 times)
  - b. Social Media (Twitter, Reddit, Discord, Instagram, TikTok) (chosen 80 times)
  - c. Club Meetings (chosen 25 times)
  - d. Posters (chosen 66 times)
  - e. Others (chosen 7 times)
9. If you answered "Other" for the previous question, describe your preferred method of receiving green roof info.
10. If you would like to opt in to the raffle for a \$20 Dunkin' gift card, enter your WPI email address below.