WATER: AN EXPRESSIVE MEDIUM WITHIN ARCHITECTURAL DESIGN CONNECTING TO THE CONTEXT OF HAWAIʻI

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Abstract

Humankind and water continue to share a significant relationship among various cultures across the world. The story of water can be interpreted through various arts, as it bridges various cultures with beliefs and values with water, as it is a symbol to life. Designing with water provides an opportunity to enhance the experience of the user, which can be expressed in a variety of ways. However, water's presence may be perceived as something laying in the background, rather than being the subject in the foreground. In regards to water, the overlapping impacts of climate change will ultimately affect man's accessibility to an essential resource for life. Wai is specifically water that can be ingested unlike seawater. Technically Hawaii has abundant fresh and saltwater resources, but the access to freshwater continues to be a growing concern that is reflected on the impacts of increased population; increasing the demand and stresses for resources.

The irony of the current trends on residential high-rises design imply an abstract concept of "water", as it attempts to culturally connect the community with its bourgeois outlook on residential buildings. This D.Arch topic analyzes the application of water as a medium within architectural design and aims to; bridge a prescribed water curtain to "*wai*", or the Hawaiian reverence to water, as it is a significant component within its cultural connection to the "'*āina*", or the land. This design research project will present an adaptable mechanism that enables a celebration of water in the design for humane architecture, advocate for innovative practices of a locally-shared resource, and evoke human sensory-delight, thereby enhancing the quality of life within the user's built environment.

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PART I: Research

1. Introduction

1.1. Cognitive Connection to Water

Humankind and water continue to share a significant relationship among various cultures across the world. The story of water can be interpreted through various arts, as it bridges the various beliefs and values of cultures with water, as it is a symbol of life. As noted in the book, “Water and Architecture”, water is depicted as both the protagonist and antagonist, “water’s apparent significance and values not only lies in the physical makeup of molecules, but in the stories that water’s significance is built upon”.[1] Water can be portrayed as the protagonist that brings nourishment for agriculture and life. However, water in large quantities is portrayed as the antagonist in natural disasters, flooding, or even death. The legacy of water’s significance is to be conveyed in the stories passed on for future generations.

The earliest arts,inscriptions, hieroglyphs, poems, paintings, and sculptures provided so much detail and highlighted the significance of life as it is related to water. While also considering architecture as art, the stories of a Japanese Tea House designed by Sen no Rikyu, a Japanese Zen master, expressed a newly found awareness of water. The site of the tea house is situated along a mountain cliff, full of trees and bushes where the experience of “hand washing” which marks the start of Japanese Tea Ceremonies, can be had. Rikyu describes the humbling relation of water as an entity connected to nature:

[1] Charles Willard Moore and Jane Lidz, *Water and Architecture* (New York: H.N. Abrams, 1994).

"A bit of water here,
There, between the trees--
The sea!"[2]

The act of hand washing urges an individual to kneel and have a visual connection with the ocean. The physical touch of water is experienced within an individual and invokes the notion that connects nature to human senses.[3]

1.2. Designing with Water

Designing with water provides an opportunity to enhance the experience of the user, which can be expressed in a variety of ways. However, the celebration of water in the design for art draws inspiration from nature. The various scenes on display within design and the built environment expresses the impact on nature of water's characteristics. Design with water as a medium also enhances the user's experiences by providing opportunities for self reflection, deep thought, and the recollection of the mind. As demonstrated through the vista shown in Figure 1.

[2] Moore and Lidz.
[3] Moore and Lidz.

Figure 1: Louis Kahn's Salk Institute for Biological Studies.
Source: Author.

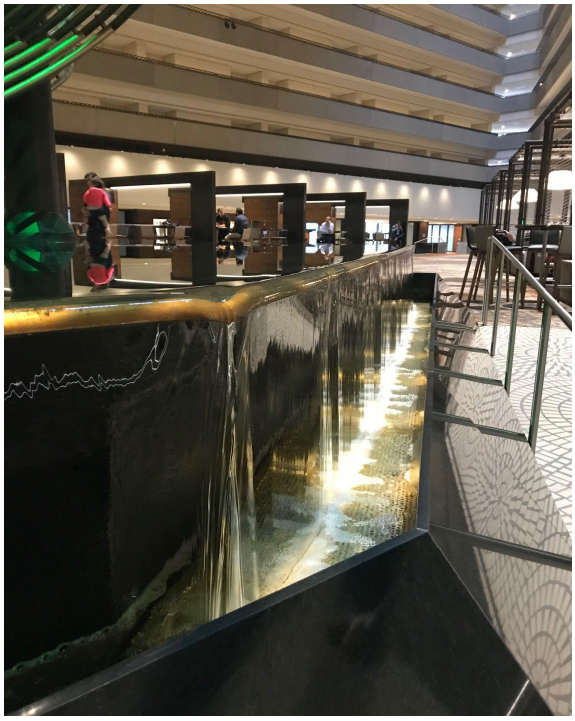

Figure 2: Hotel lobby fountain feature. Flowing sheets of water.
Source: Nathan Toothman.

Exterior water features are common methods in the use of water in architectural design. Various outputs are interpreted in the form of fountains, channels, shallow pools, and scaled waterfalls. Shown in Figure 3, water's presence is manifested by the tranquil sounds of droplets and sheets of water cascading onto surfaces as portrayed in Luis Barragan's "Fuente de los Amantes". Indoor and outdoor pools serve more than just an experience for recreation, but can be used as an opportunity for water and sunlight to interact during the day, posing the potential for maximized luminance under elevated pools.

The most monumental presence for water within the built environment is best interpreted as waterfalls. In Figure 4, Singapore's Jewel Changi Airport houses the tallest indoor waterfall, a spectacle drawing crowds from afar. Moshe-Safdie Architects's variation in scales play within the interconnected network of water features that cascades along pedestrian walkways. The pathway leads users to the record-breaking, 131-foot-tall rain vortex waterfall, dropping seven stories from the roof.[4] Its environmental connection to water is expressed by designing structures in proximity to its existing contextual landscape, as it also provides an opportunity to experience the intimacy of water to the user.

[4] Elizabeth Fazzare, "Moshe Safdie Designs Singapore's Jewel Changi Airport As a Destination Garden," Architectural Digest, accessed December 16, 2020, https://www.architecturaldigest.com/story/moshe-safdie-singapores-jewel-changi-airport.

Figure 3: Fuente de los Amantes.

Source: The Pritzker Architecture Prize, (https://www.pritzkerprize.com/laureates/1980).

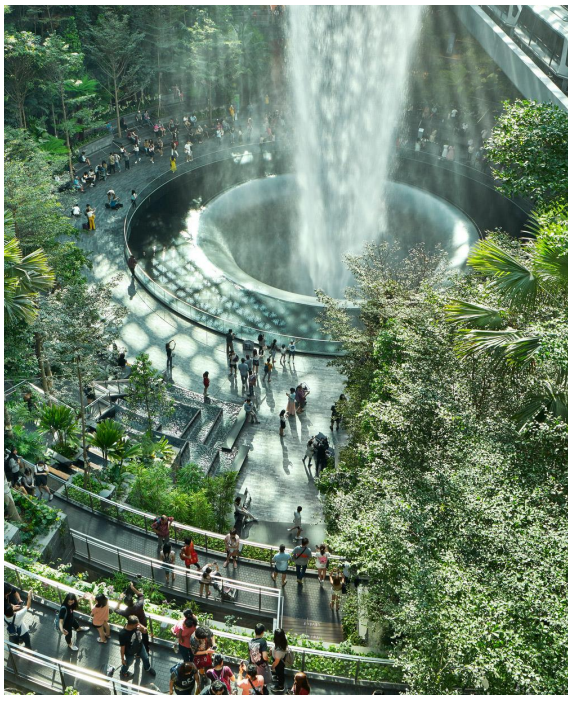

Figure 4: Jewel Changi Airport's Vortex Waterfall.

Source: Safdie Architects, (https://www.safdiearchitects.com/projects/jewel-changi-airport).

1.3. What are the design issues locally?

Increased density directly contributes to the overlapping global, regional, and local issues of global warming, sea level rise, and increased CO2 emissions,. For the general user, preferred thermal relief is generally provided by conventional air conditioning, which relates to an estimated 16% of all electricity use in the United States and is responsible for 43% of energy peak load.[5] High energy demands also correlate to the global demand for the use of mechanized methods for thermal relief. Thus, increasing the effects and risks of environmentally-harmful refrigerants through the use of air conditioning.

As for Hawai‘i, tradewinds provide adequate air movement for cross ventilating interior and public spaces. Other means of cooling are also observed at the shorelines, where locals and visitors participate in water activities, like surfing. Large bodies of water held at a cold temperature, such as the Pacific, regulate moderate temperatures of coastal areas.[6] The Hawaiian cultural outlook on ”wai" or drinking water as a valued resource within the ahupua‘a system has been considered in and inspired architectural designs of all sorts.

Regarding water resources, the overlapping global, regional, and local concerns involving everything dealt by climate change will ultimately have an impact on the

[5] Brian Ford, “Passive Downdraught Evaporative Cooling: Principles and Practice,” *Architectural Research Quarterly* 5, no. 3 (September 2001): 271–80, https://doi.org/10.1017/S1359135501001312.
[6] “Properties of Water,” accessed March 31, 2021, https://www2.nau.edu/lrm22/lessons/water/water.html.

accessibility and need for purist qualities of water. Symbolizing the source of life. As Hawai‘i is located remotely in the Pacific, the access to freshwater continues to be a growing concern while increased population and density may lead to mismanagements and misuse of wai, the islands’ prized resource.

One drastic wakeup call happened in 2010, when many areas throughout Hawai‘i were experiencing drought conditions.[7] The US Drought Monitor claimed that 50% of the state has already experienced some levels of drought conditions. Most recently August 2020 has recorded unusually drier conditions, as it is typically a peak month for hurricane season.[8]

The current trends on residential high-rises design imply an abstract concept to “water”, as it attempts to culturally connect the community with its bourgeois outlook on residential buildings. Fully encased in glazing, a material with a substantial water-resourced footprint, does not do justice to the land it sits on and poorly portrays the Hawaiian respect and value of water. The increased glazing, meant to express the various outlooks of interplay of water and light, has created a hermetic typology that requires energy production for the unnecessary use of air conditioning. Thus, still contributing to the negative impact of global climate change.

[7] Associated Press, “Low August Rainfall Brings Drought Conditions Across Hawaii,” accessed December 2, 2020, https://www.hawaiipublicradio.org/post/low-august-rainfall-brings-drought-conditions-across-hawaii.

[8] Associated Press, “Low August Rainfall Brings Drought Conditions Across Hawaii,” accessed December 2, 2020, https://www.hawaiipublicradio.org/post/low-august-rainfall-brings-drought-conditions-across-hawaii.

Figure 5: Current development with excessive use of glazing and glass material. Source: Author.

1.4. Project Statement/Research Purpose

The excessive need for glazing hinders Hawai‘i’s true potential for tropical modern architecture that enhances day-to-day qualities pertaining to light and air. This presents an opportunity to introduce water and use it in design as it is found within its regional vernacular. This D.Arch topic analyzes the application of water as a medium within architectural design and aims to bridge a prescribed water curtain prototype to “Wai”, or the Hawaiian reverence to water, as it is a significant component within its cultural connection to the land. An adaptable mechanism that enables a celebration of water in the design for humane architecture: advocating innovative practices of a locally-shared

resource; evoking human sensory-delight; enhancing the quality of life within the user's built environment.

2. Literature Review

The literature review will consider the Hawaiian cultural connection to water, water's cooling characteristics, biophilic design use of water, managing the flow of water in Low Impact Development strategies, and biomimicry inspired design represented by water's interaction within local ecosystems and watersheds. These topics will help gain a better grasp on water's application as a design swatch and its impact as an architectural component. The focal point will consider water as a dynamic design medium to celebrate its cultural significance, sense of place, and human restorative impacts related to biophilic design.

2.1. Cultural Connection of Water

Polynesians, in the case of Hawai‘i, are skilled navigators of the pacific. Hawaiian culture has been built on the foundation of ecological knowledge. Pedagogy within Hawaiian culture continues to be a channel of its traditions and practices. Numerous examples of these practices are expressed through the arts, which includes oli (chants), mele (song), and hula (dance).

In Keola Donaghy's "He Ahupua‘a Ke Mele: The Ahupua‘a Land Division as a Conceptual Metaphor for Hawaiian Language Composition and Vocal Performance," the importance of water to ancient Hawaiians is depicted through mele. In the sixth verse:

Aia i lalo, i ka honua, i ka Waihu,
I ka wai kau a Kāne me Kanaloa
He wai puna, he wai e inu,
He wai e mana, he wai e ola.
E ola no, ea!
--
Deep in the ground. In the gushing spring,
In the ducts of Kāne and Kanaloa,
A well-spring of water, to quaff,
A water of magic power, the water of life!
Life! O give us this life![9]

Hydrology and Water Quality

Water continues to represent life, which was understood as a prized resource within the Hawaiian ahupua‘a. It continues to be the key element that supplies Hawai‘i with usable groundwater that is known for its purist qualities. Hawai‘i’s resource water is the result of the interactions between specific geographical and climatic conditions--Hawai‘i’s hydrology. For the source of freshwater, O‘ahu is a gem within the island chain. The state’s hydrologic planning program manager Lenore Ohye claims O‘ahu as a “sweet spot” for freshwater aquifers.[10] The geographical conditions of O‘ahu’s Ko'olau (Windward) and Waianae (Leeward) mountains allow for perfectly timed rainfall and groundwater recharge opportunities.

[9] “He Ahupua‘a Ke Mele: The Ahupua‘a Land Division as a Conceptual Metaphor for Hawaiian Language Composition and Vocal Performance,” Ethnomusicology Review, accessed April 6, 2021, https://ethnomusicologyreview.ucla.edu/journal/volume/18/piece/698.
[10] “Our Water World - Hawaii Business Magazine,” accessed December 2, 2020, https://www.hawaiibusiness.com/our-water-world/.

The atmospheric pressure of gravity forces rainfall to move downward, where it takes 25 years to travel through a complex labyrinth of underground rock and reach the underground aquifers.[11] Elements found within its local watersheds also assists with the movement of rainfall, making way for water to percolate past the understory and recharge underground aquifers. This acknowledges the significance of Pearl Harbor as a self-sustaining ecosystem in the Hawaiian Kingdom. It presents itself as O‘ahu’s largest underground aquifer due to the several ahupua‘a systems feeding directly into the naturally conformed harbor.

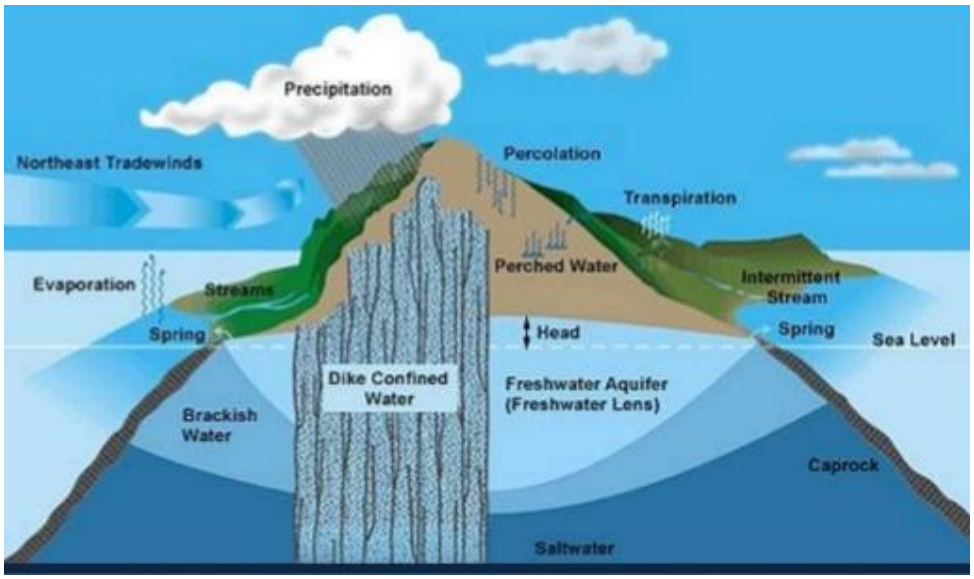

Figure 6: Hawaiian freshwater lens and underground aquifer resources.
Source: The Honolulu Board of Water Supply
(https://www.slideshare.net/KumuPaNakea1/global-watercylcle).

[11] “Our Water World - Hawaii Business Magazine.”

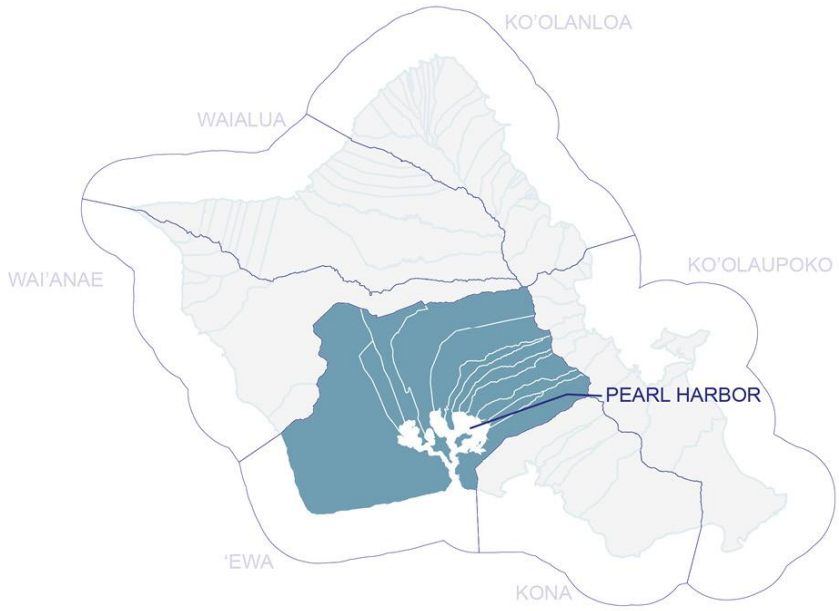

Figure 7: Multiple ahupua‘a direct connection to Pearl Harbor.
Source: Author. Modified with ArcGIS and Illustrator.

Ahupua‘a System and Early Lifestyle

Early Hawaiian’s reverence to wai (water) coincides within ahupua‘a systems, as wai resembles wealth for other supporting resources vital for Hawaiian agricultural lifestyles. The ahupua‘a system was a practical way that devised the distribution of resources and management of the land and coastal waters.[12] As noted in “Management of Hawai‘i’s Watershed, advocating and cultural practices for healthy watersheds ensures the readability of accessing local resources (Cox et. al, 2).[13] Land and coastal management

[12] Linda J Cox, Sandy Swan, and Carl I Evensen, “Managing Hawaii’s Watersheds,” n.d., 2.
[13] Cox, Swan, and Evensen.

was appointed to the konohiki, the selected member of the community who was responsible to delegate day-to-day tasks and operations for the ahupua‘a systems.[14]

Management of resources and access within an ahupua‘a was determined by elevated ecological zones that had been differentiated by cultural religious beliefs and specified program of materials and resources.[15] Wao Akua, the highest zone, is the core of local watersheds. This was understood as the cloud forest or the wilderness of the Ancient Hawaiian deities and forbade common access and gathering of resources. Moving lower to the Wao Kele and Wao Nahele are composed of saturated forests. These zones support the native biodiversity that bear the significance of ancient Hawaiian culture, such as an ‘ahu ‘ula, a red feather cloak. Other resources used for construction and medicine were harvested within the Wao Wa‘alu. The zone along the coast (and also occurring to the nearest ocean reef) is where much of the action happened. Designated areas within the Wao Kanaka allowed for areas to be available for agricultural cultivation, religious worshipping, inland- and ocean-farming.

Healthy watersheds and man-made interventions within an efficient ahupua‘a system exhibits Early Hawaiian understanding of the local ecological processes. Constructed fishponds and irrigation systems assisted in carrying out strict water usage and allowed for a thriving and self-sustainable lifestyle prior to high levels of foreign contact outside of Polynesia. The needs for drinking, bathing, and irrigation were carefully managed, as

[14] Cox, Swan, and Evensen.
[15] D. Mueller-Dombois, “The Hawaiian Ahupua‘a Land Use System: Its Biological Resource Zones and the Challenge for Silvicultural Restoration,” 2007, /paper/The-Hawaiian-Ahupua%E2%80%98a-Land-Use-System%3A-Its-Resource-Mueller%E2%80%90Dombois/4d6f69c1fb8260bd4f9e9277f5e32e5244df25a6.

access to freshwater was available, but not freely to be used. Though local resources on the island were in abundance and sustainable, every ahupua‘a were not the same and provided resources that were unique within its watershed. Hawaiians often shared resources among members within the ahupua‘a, but also shared resources to other communities from neighboring ahupua‘a. Each ahupua‘a was unique in the availability of resources, in which social interaction among communities embraced the mantra of working together, as one.[16]

[16] “Ahupua‘a ‘Anomalies,’” Images of Old Hawai‘i, March 26, 2020, http://imagesofoldhawaii.com/ahupua%ca%bba-anomalies/.

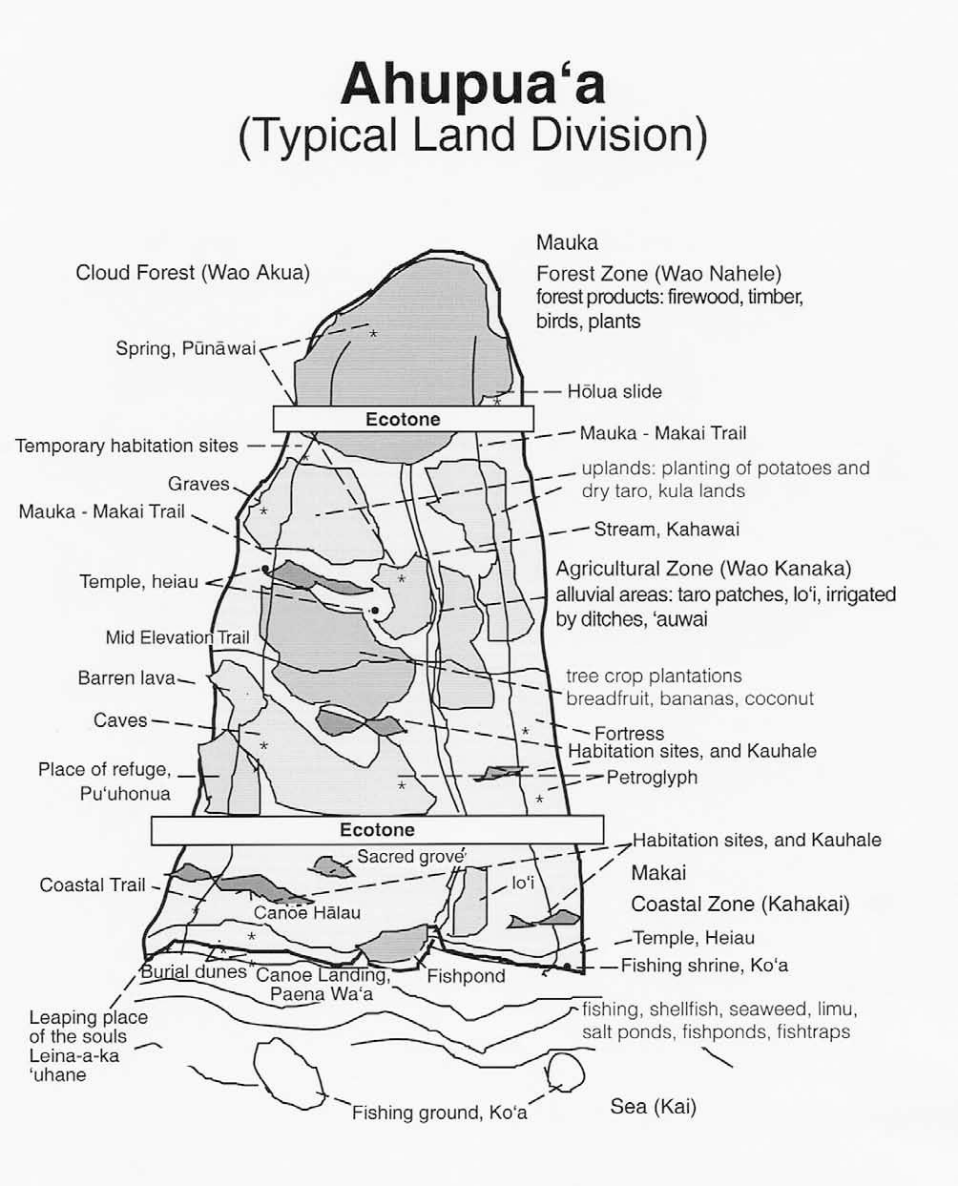

Figure 8: Ahupua‘a Land Use Diagram.

Source: Dieter Mueller-Dombois, “The Hawaiian Ahupua‘a Land Use System: Its Biological Resource Zones and the Challenge for Silvicultural Restoration,” Bishop Museum Bulletin in Cultural and Environmental Studies, 2007, 28.

2.2. Expression of Water in Architecture

Applying water to the design of the built environment can be expressed as fountains, rivers, pools, and oceans.[17] Historically, fountains are key indicators of a specific location and time that people gathered, where settlements flourished, and where cities were established. As noted in “Experiencing Architecture”, architecture separates from traditional art and utilizes design elements as the special and functional art developed by the specific urban design framework.[18] The pockets of space created within the landscape is the result of using water-related architectural design mechanisms; recognition of a significant presence to specific culture and site-context specifics.

Water’s influence on architectural and urban design elements are best expressed in Lawrence Halprin’s Open Space Sequence in Portland, Oregon. Kenneth Helphand, Knight Professor Emeritus at the University of Oregon, acknowledged that the master plan is a masterpiece of modern design among the great landscape architects of the twentieth century.[19] The Portland fountains in the urban design scheme are known worldwide for changing the concept of the urban fountains; a catalyst for revivification of fountains and urban open space design.[20] Pools, too, create an opportunity as a resting point and gathering area. The urban design as a whole is carefully composed. Different water feature elements are staged at specific points and create an orchestrated

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[17] Moore and Lidz, *Water and Architecture*.
[18] Steen Eiler Rasmussen, *Experiencing Architecture*, 33th printing (Cambridge, Mass: MIT Press, 2005).
[19] “Halprin Open Space Sequence,” accessed December 17, 2020, https://www.nps.gov/nr/feature/places/13000058.htm.
[20] “Halprin Open Space Sequence.”hal

experience when pedestrians are navigating the area. Channels of water resembling rivers guide the user to a point of mystery found in garden design. The feeling in its entirety expresses an urban condition, yet the presence of water brings the user to an experience of the natural environment of Halprin's interpretation of the Cascade Range and the Columbia River.[21]

Biophilic Connection of Water

Eric Fromm first coined the term, *Biophilia*, which was understood as the idea that humans are intrinsically drawn to everything living. The "Biophilia Hypothesis", popularized by Edward O. Wilson, tests the innate nature in humans needing to seek nature.[22] The translation, "love of life", has become a design tool to embrace the cognitive connection to nature and the outdoors.

In contemporary design, principles of biophilia and biophilic design continue to be a solution for static and lifeless spaces within the built environment. Supported by environmental psychology studies and research, biophilic design is the successful strategy in connecting nature and adaptive human functions that assist with restoration

[21] Alison Bick Hirsch, *City Choreographer: Lawrence Halprin in Urban Renewal America*, 15th ed. (University of Minnesota Press, 2014), http://0-site.ebrary.com.fama.us.es/lib/unisev/Doc?id=10906492.
[22] Edward O Wilson, *Biophilia.* (Cambridge: Harvard University Press, 2009), http://qut.eblib.com.au/patron/FullRecord.aspx?p=3300337.

qualities to the brain--enabling health benefits that mitigates everyday stressors and anxiety.[23] It also aids with productivity and creativity.[24] [25]

Similar themes observed within biophilia were later composed into the 14 Patterns of Biophilic Design. The published work by Browning et al. addressed common biophilic design applications and was categorized by: Nature in the Space, Natural Analogues, and Nature of the Space.[26] Water, as a pattern of biophilia, is a prominent element recognized as a symbol for life and is the most common substance we interact with. Found in all three categories found in biophilic design, Browning et al. implies that the use of water (within design) correlates to the direct, physical and ephemeral presence of nature, creating “a condition that enhances the experience of a place through seeing, hearing, or touching water.”[27]

[23] Stephen Kaplan, “Meditation, Restoration, and the Management of Mental Fatigue,” *Environment and Behavior* 33, no. 4 (July 1, 2001): 480–506, https://doi.org/10.1177/00139160121973106.
[24] “Workplace Possibilities Program,” The Standard, March 2, 2018, https://www.standard.com/employer/products-services/insurance-benefits/workplace-possibilities-program.
[25] William Browning, Catherine Ryan, and Joseph Clancy, “14 Patterns of Biophilic Design,” *Terrapin Bright Green LLC*, 2014, 64.
[26] Browning, Ryan, and Clancy.
[27] Browning, Ryan, and Clancy.

Figure 9. Moses Pedestrian Bridge.
Source: RO&AD architecten (https://www.ro-ad.org/projecten/moses-bridge).

Placebonding Facilitated by Water Design Features

While biophilic design highlights natural patterns of plants and greenery, the use of water design could also be the focal point within the built environment. Coined by Texas A&M University Assistant Professor Hope H. Rising, Aquaphilia is a sub-branch of biophilia and can be defined as the innate attachment to water. Rising (2017) suggested that the conceptualized subset of biophilia-based mechanisms focused on place-bonding and facilitating wayfinding through the presence of water features.[28] Rising supports this

[28] Hope H. Rising, "Aquaphilia: Water-Based Spatial Anchors as Loci of Attachment," *Landscape Journal* 36, no. 2 (February 2017): 73–89, https://doi.org/10.3368/lj.36.2.73.

notion of aquaphilia on the foundation of historic civilizations that have originated from water sources or areas in close proximity to surface waters.[29]

Studies have suggested the expanded insight of water-based place attachment, which can be an emotional connection or understanding of a person's sense of place. The aquaphilic water-based sense of place covers four constructs: familiarity, comfort, place dependence, and place identity.[30] Water-based spatial anchors allow individuals to gain a sense of familiarity, while regulating stress that is related to experiencing an unfamiliar environment. Landmarks and waterscapes with recognizable forms that are visible from a person's eye-level present markers for sequencing spatial information that assist with one's cognitive map.[31]

Rising (2017) highlights the surveyor insights in regards to water-based place attachment as an effect of aquaphilic sense of place, relating to four constructs: water-based familiarity, water-based comfort, water-based place dependence, and water-based place identity.[32] Water-based spatial anchors allow individuals to gain a sense of familiarity, while regulating stress that is related to experiencing an unfamiliar environment. Landmarks and waterscapes with recognizable forms that are visible at the user's eye-level present markers for sequencing spatial information that assist with an individual's cognitive map.[33] It also contributes to the user's experience by providing benefits of wayfinding. Allowing the presence of water to produce stress-reducing effects

[29] Rising.
[30] Rising.
[31] Rising.
[32] Rising.
[33] Rising.

through water's recognizable fractal textures and restorative sounds.[34] The observer's visual preference and emotional response to water features has the opportunity to evoke increased sensation of tranquility and decreased blood pressure and heart-rate.[35]

2.3. Cool Operator

Water used as a medium for cooling is associated with fire-sprinkler systems and safety. Water's cooling properties have been tested in Balner et. al's study in 2017, which evaluated the attenuation of infrared radiation through the use of a misting water curtain and proved that water droplets brought significant cooling effects, reducing the effect of thermal radiation during heat transfer.[36] The physical principle of water curtains was understood by the rates of absorption and dispersal of radiation. The study demonstrated how strong absorptive and anisotropic scattering characteristics was determined by the several tens to several hundred droplets in comparison to water vapor that only absorbs radiation.[37]

[34] Browning, Ryan, and Clancy, "14 Patterns of Biophilic Design."
[35] Kaitlyn Gillis and Birgitta Gatersleben, "A Review of Psychological Literature on the Health and Wellbeing Benefits of Biophilic Design," *Buildings* 5, no. 3 (September 2015): 948–63, https://doi.org/10.3390/buildings5030948.
[36] Dalibor Balner, Karla Barčová, and Michal Dostál, "Attenuation of Infrared Radiation When Passing Through a Water Curtain," *TRANSACTIONS of the VŠB – Technical University of Ostrava, Safety Engineering Series* 12, no. 1 (March 28, 2017): 1–8, https://doi.org/10.1515/tvsbses-2017-0001.
[37] Balner, Barčová, and Dostál.

Evaporative Cooling

Although conventional air conditioning systems provide necessary thermal relief for inhabitants, evaporative cooling is emerging to be an alternative method for thermal comfort and has been applied to schools and office buildings in arid climates.[38] Eliminating the use of environmentally harmful refrigerators, direct evaporative coolers draw the outside air through wetted pads. This increases the humidity and lowers the air temperature within the inhabitant's space. Similar studies have also demonstrated that buoyancy forces are effective in the increased rates of air changes, which avoids 30-40% of the energy required for the use of power-driven fans.[39]

Passive Downdraught Evaporative Cooling

Passive Downdraught Evaporative Cooling (PDEC) has been a long tradition of thermal comfort without the use of air conditioning found within regions of the Middle East.[40] Emeritus Professor of University of Nottingham and an architectural-environmental design consultant, Brian Ford, notes that the cooling of air when adding moisture also considers the density of air, which is enough to encourage downdraught of air within spaces.[41] Ford also notes that its initial application of PDEC originated in Egypt and later influenced other areas of the Middle East, Iran, northern India, and southern Spain.[42]

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[38] Mahesh Iyer and Brian Ford, "Passive Downdraught Cooling for Schools in India: A Study on Iira International School in Baroda, Gujarat, India," *Architectural Science Review* 55, no. 4 (November 2012): 287–306, https://doi.org/10.1080/00038628.2012.722072.
[39] Ford, "Passive Downdraught Evaporative Cooling."
[40] Ford.
[41] N T Bowman, "Passive Downdraught Evaporative Cooling," n.d., 8.
[42] Ford, "Passive Downdraught Evaporative Cooling."

Key features found in Mughal architecture utilized water as an evaporative cooling application, which brought innovations of 30-meter high cool towers employed with high-pressure water misting nozzles (micronizers) to induce downdraught cooling.[43] Other methods also include the combined use of wind catchers and porous clay pots that assists with downdraught effects necessary for PDEC. The use of Salsabil featured thin water chutes to create an internal refuge from the summer's external extremes of dry heat and dust. The changes in daytime temperatures were carried by dampening mass of stone and earth causing the evaporation of water in air movement.[44]

[43] Ford.
[44] Ford.

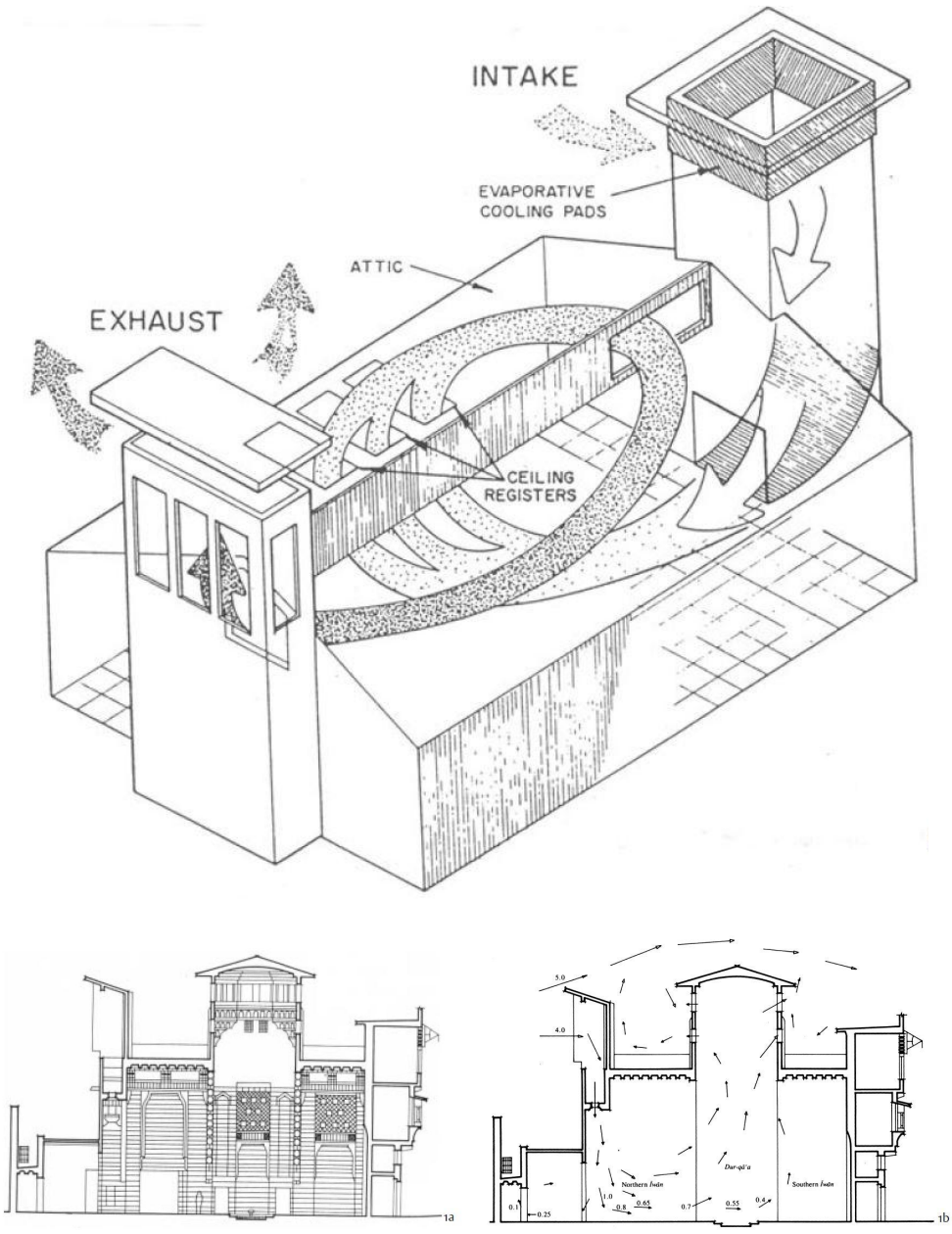


Figure 10: Passive Downdraught Evaporative Cooling Principles.

Source: Brian Ford, “Passive Downdraught Evaporative Cooling Principles,” Architectural Research Quarterly 5, no. 3, 2001, 273.

PDEC Precedents

Application of this rediscovered technique has been demonstrated in the 2010 Solar Decathlon Nottingham Home Optimizing the USE of Solar Energy (HOUSE). The team of students from the University of Nottingham, under the guidance of Professor Ford, aimed to explore the self-sufficient PDEC potential for residential restructures. Under parameters of the competition entry, students tested the thermal performance of the proposed design.

Aimed to provide PDEC within regions of central and southern Spain that is known for its arid conditions, HOUSE tested the thermal performance of the high-performance envelope with integrated spray mist systems and an outdoor terrace. HOUSE determined that the guiding principles of buoyancy and air induced movement supported the integration of PDEC, as it can deliver significant energy savings while achieving comfortable thermal conditions throughout unusually warm seasons of the year.[45]

[45] Brian Ford et al., "Passive Downdraught Evaporative Cooling: Performance in a Prototype House," *Building Research & Information* 40, no. 3 (June 6, 2012): 290–304, https://doi.org/10.1080/09613218.2012.669908.

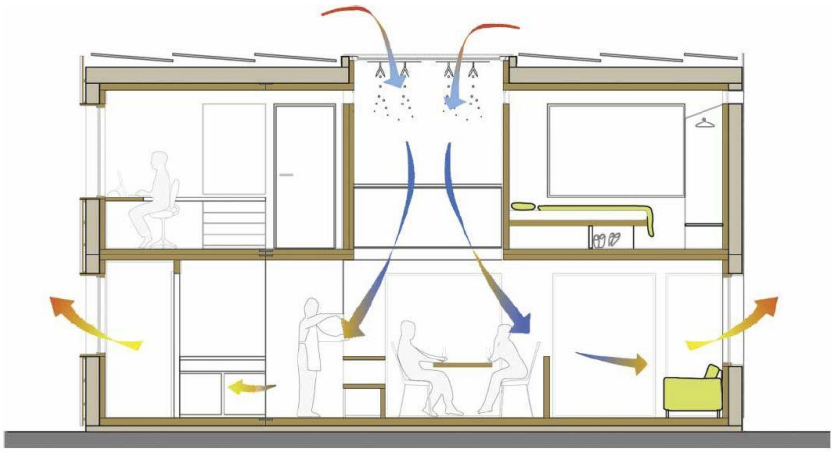
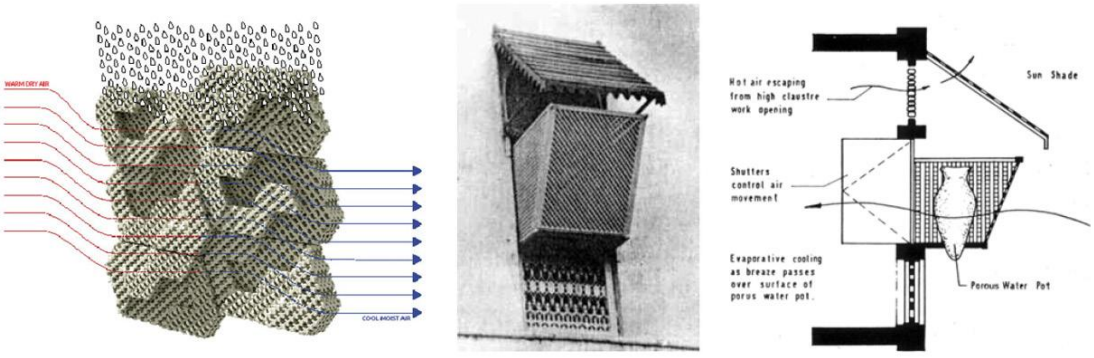


Figure 11: 2010 Solar Decathlon Nottingham HOUSE Section.
Source: Brian Ford et al., "Passive Downdraught Evaporative Cooling: Performance in a Prototype House," Building Research & Information 40, no. 3 (June 6, 2012): 293.

Early uses of Muscatese evaporative cooling openings demonstrate the cooling potential when outside dry air passes through the wooden screens and along the contours of a water-cooled porous ceramic vessel.[46] [47] PDEC happens as the air that passes through the ceramic vessel and is delivered to habitable interior spaces.[48] Current applications of 3D ceramic brick mimics the PDEC principle. Emerging Objects, makers of the products, designed the ceramic modular unit that allows for water to be absorbed like a sponge and allows air to easily pass through, which allows direct evaporative cooling to occur.[49] Moisture held in micropores evaporates and allows the passage of humidified air to appropriately lower temperatures within the interior environment.[50]

[46] Radwan M. Kassir, "Passive Downdraught Evaporative Cooling Wind-Towers: A Case Study Using Simulation with Field-Corroborated Results," *Building Services Engineering Research & Technology* 37, no. 1 (January 2016): 103–20, https://doi.org/10.1177/0143624415603281.
[47] Ahmed Faggal, "Using Ecooler Technique to Enhance Thermal Comfort in Hot Desert Arid Climate in Egypt" (2015), https://doi.org/10.13140/RG.2.2.13135.48803.
[48] Kassir, "Passive Downdraught Evaporative Cooling Wind-Towers."
[49] Jessica McMathis, "Cool Bricks," *Ceramics Monthly* 64, no. 2 (February 2016): 26–26.
[50] McMathis.



Porous 3D Ceramic Brick

Muscatese Evaporative Cooling Window

Figure 12: Cool Bricks: Muscatese inspired 3D ceramic brick.
Source: Jessica McMathis, “Cool Bricks,” Ceramics Monthly 64, no.2, 2016, 26.

While the supporting research claiming PDEC is most appropriate in arid conditions, the opportunity in applying evaporative cooling within subtropical climates may be more appropriate than what experts initially claimed. Research conducted by Farnham, Emura, and Miuno suggests that the use of evaporative spray cooling systems can be implemented to bring thermal relief on hot days within subtropical regions of Japan.[51] The experiment integrated a water mist spray fan system to an outdoor space. The focus group of 141 participants surveyed individual thermal sensation, general comfort, degree of wetness, and skin temperature measure before and after entering a mist. Findings suggest that the cooling effect of the mist and fan combination is highly efficient and

[51] Craig Farnham et al., “Measurement of the Evaporative Cooling Effect: Oscillating Misting Fan,” *Building Research & Information* 45, no. 7 (October 2017): 783–99, https://doi.org/10.1080/09613218.2017.1278651.

exceeds the thermal sensation of the focus group, which brought a significant decrease in skin temperature.[52]

2.4. Biomimicry within the Built Environment

Biomimicry, as a design tool, can be intended to help solve major issues that exploit natural resources for the benefit of industrialization.[53] Biomimicry, or biomimetics, allows designers to investigate models, systems, processes, and elements found within nature. [54] It is through inspirations found in our natural environment that makes us want to mimic characteristics of the living that aspires to creatively solve human problems. Janine Benyus, a science writer and conservationist, expressed that everything found within nature (animals, plants, and microbes) are the consummate engineers: “They have found what works, what is appropriate, and most important, what lasts here on Earth”.[55]

Blue-Green Infrastructure for Urbanized Ecology

It is critical for designers to consider stormwater drainage mechanisms to reject unwanted water and flush it away from a building’s structure. Low Impact Development (LID) facilities are considerable elements when designing for a building, as it is

[52] Craig Farnham, Kazuo Emura, and Takeo Mizuno, “Evaluation of Cooling Effects: Outdoor Water Mist Fan,” *Building Research & Information* 43, no. 3 (May 2015): 334–45, https://doi.org/10.1080/09613218.2015.1004844.
[53] “Biomimicry 3.8 - Innovation Inspired by Nature,” Biomimicry 3.8, accessed March 31, 2021, https://biomimicry.net/.
[54] Andrea Rinaldi, “Naturally Better: Science and Technology Are Looking to Nature’s Successful Designs for Inspiration,” *EMBO Reports* 8, no. 11 (November 2007): 995–99, https://doi.org/10.1038/sj.embor.7401107.
[55] “Biomimicry 3.8 - Innovation Inspired by Nature.”

recognized as an engineered ecological watershed.[56] The primary purpose is to finesse the presence of rainwater and stormwater runoff--mimicking similar interactions of slow, spread, and soak associated with natural, healthy ecosystems.[57] Healthy watersheds are built on the principles of enhanced landscape biodiversity, maximized water infiltration and hydrological distribution networks, protecting pre-development vegetation and erosion, and restoring ecological services.[58] [59]

Blue-Green Design within a Building

Somehow, these similar applications to blue-green design also reconnect us back to past architectural structures, as green roofs and green facades were key elements observed in the Hanging Gardens of Babylon.[60] Gardens and courtyards found in Mughal Palaces and Spanish Islamic architecture exploited the dynamic use of water to bring visual delight and thermal comfort for occupants.[61] Rainwater harvesting has been, and continues to be a useful strategy to access water in regions of India, where water may be scarcely available.

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[56] Fayetteville University of Arkansas et al., *Low Impact Development: A Design Manual for Urban Areas* (Fayetteville, Ark.: University of Arkansas Community Design Center : Fay Jones School of Architecture, University of Arkansas Press, a collaboration, 2010).
[57] University of Arkansas et al.
[58] University of Arkansas et al.
[59] OW US EPA, "Urban Runoff: Low Impact Development," Overviews and Factsheets, US EPA, September 22, 2015, https://www.epa.gov/nps/urban-runoff-low-impact-development.
[60] Andrew Kaufman et al., "The Potential for Green Roofs in Hawai'i," 2007, 16.
[61] Raha Ernest and Brian Ford, "The Role of Multiple-Courtyards in the Promotion of Convective Cooling," *Architectural Science Review* 55, no. 4 (November 2012): 241–49, https://doi.org/10.1080/00038628.2012.723400.

Filtration, treatment, and storage are primary roles within applications of blue-green infrastructure at the building's zone.[62] Roofs and facades of buildings are generally the initial surfaces rain comes in contact with because it is higher off from the ground--similar to how rain contacts the canopies of rainforest trees. Thus strategies utilizing rainwater harvesting and green roof techniques are the first line of defense that combats stormwater runoff and risk of flooding hazards.

[62] University of Arkansas et al., *Low Impact Development*.

3. Methodology

The approach of this design research project has been conducted using mixed-methods: precedent study; case study; observational analysis; prototyping and testing. Observational analysis and precedents includes describing characteristics of using water as a design medium and evaluating the cause and effect relationships of water and architecture. Case studies will be done by comparative analysis (subjective and objective). Prototyping will allow for closer interaction with the design medium of water.

3.1. Water Feature Design Precedents

The presented precedents will utilize an observational analysis approach to water focused design. It will determine the impacts of the local site and cultural context that is influenced by Moore and Lid's interpretation of fountains, rivers, pools, or the natural environment. It is important to consider the aspect of water to be seen as a resource and its local climate, which calls for carefully schemed plumbing systems and perfectly tuned infrastructures found in healthy watersheds.

Precedent Study: Tapping into Water

The Board of Water Supply is an obvious precedent on the topic of water design. The Board of Water Supply has taken the role of managing water usage throughout O'ahu, as it taps into the island's freshwater reserves in local aquifers. For O'ahu, reports of an

estimated average of 1.8 billion gallons of rainfall on a normal day.[63] Total rainfall dispersed onto the land accounts one-third to replenish the island's aquifer, the second one-third to be absorbed by vegetation/soils and evaporates, and the remaining is discharged as runoff that can gravely impact local resources.[64] To mitigate the potential crisis of regional water scarcity and misuse of the island's purest quality water, the County of Honolulu has implemented a Stormwater Utility Plan that addresses environmental risks and hazards related to stormwater runoff. This is a serious matter in which, historically, O'ahu has been mismanaging water since the "1879 Boom of Water" that attracted ranchers and plantation developers.[65]

Sea Water harvesting Air Conditioning (SWAC) is an emerging strategy that aims to provide sufficient thermal relief without the reliance on fossil fuel energy. This system presents sustainable strategies found in open spaces, with already implemented projects and has established success in Kona and parts of North America. This method requires access to deep, cold sea water. Ongoing project within downtown Honolulu taps into the Pacific Ocean and runs through underground pipes to an inland cooling station. The cold temperature provided by ocean water transfers to a freshwater closed loops system at the cooling station.[66] The ocean water is fed back out into the open waters after the

[63] "Hawaii's Water Cycle - Board of Water Supply," accessed December 2, 2020, https://www.boardofwatersupply.com/water-resources/the-water-cycle.
[64] "Hawaii's Water Cycle - Board of Water Supply."
[65] "Oahu's Water History - Board of Water Supply," accessed November 21, 2020, https://www.boardofwatersupply.com/about-us/oahus-water-history.
[66] "C-MORE : SWAC," accessed December 5, 2020, https://hahana.soest.hawaii.edu/cmoreswac/cmoreswac.html.

thermal transaction, where the much cooler freshwater supplies sufficient cooling for other buildings.[67]

Precedent Study: Locally Grown Living Structure

Living towards a sustainable future, Haleola‘ili Ainapono strives to be the greenest house in the world.[68] This single-family dwelling is a precedent of a lLiving Building within the lush contextual site within the O‘ahu’s ahupua‘a. Led by architect and homeowner, Aaron Acker, the initiative for this design is a structure that takes advantage of sustainable practices and relies on environmental factors for energy and water to minimize their carbon footprint. The site and structure employs a variety of native and indigenous vegetation for food and stormwater services. The use of sloped roofs and vegetated gardens help protect the site from erosion. All potable and nonpotable water demands are achieved by the cleverly integrated watchmen and water reuse systems.[69]

[67] “C-MORE : SWAC.”
[68] “Haleola’ili’ainapono Featured in Building Industry Hawaii Magazine - June 2018 - Livable Communities,” LIVING BUILDING CHALLENGE HAWAII, accessed April 2, 2021, http://www.livingbuildingchallengehawaii.com/outreach/2019/8/14/haleolailiainapono-featured-in-june-2018-building-industry-hawaii-magazine.
[69] “Haleola’ili’ainapono: Living Building Challenge – Bowers + Kubota,” accessed April 2, 2021, https://www.bowersandkubota.com/project/6437/.

Figure 13: Haleola‘ili Ainapono.
Source: (http://www.livingbuildingchallengehawaii.com/)

Precedent Study: Waikiki District

The coastline along Waikiki, as well as other beaches on island, is an obvious element related to the natural environment of design featuring water. A multifunctional space for recreation and interactions brings life to the hospitality district. From previously observed fountains and pools applied to hospitality and residential building typologies, it is clear that these kinds of water design features heighten an individual experience. Like these individual experiences, public fountains and pools are placed along Kalakaua Avenue. Sculpted Water Features along the Diamond Head-side of Waikiki play a significant role in the way-finding, where it is recognized to run parallel to Waikiki’s shoreline. The pools and fountains stand uniquely on their own, as it can refer to individual landmarks in a pedestrian-heavy area.

The presence of water can also be found within the retail and commercial spaces of the Royal Hawaiian and International Marketplace in Waikiki. Elements are again expressed

as fountains and shallow pools. Each space expressing the presence of water provides a portal to the cultural landscape of the Hawaiian Kingdom. The integration of contemporary water features enlightens the space with visual delight accompanied with biophilic design patterns. The surrounding furniture and material swatches of natural elements, too, enhance the notion of biophilia.

Figure 14: Waikiki Fountain Features.

Source: Author.

Figure 15: International Marketplace Water Design Features.

Source: Author.

Precedent Study: Downtown Honolulu

The common themes of fountains and pools are implemented within the civil and business district of downtown Honolulu. The presence of the ocean and Honolulu Harbor can be somewhat be observed on the makai end of downtown--within proximity of Aloha Tower. However, due to the forest of high-rise buildings, our orientation is lost until we recollect the direction of mauka.

Larger-scaled water design features implemented in the area present a visual marker within a place of significance. The most notable piece of architecture is the State Capital of Honolulu, as it draws on the influence of Hawai‘i’s geographical location within the vast Pacific--water playing a role as representing the ocean. Water elements found within Honolulu’s Bishop Square enhance the walkability and wayfinding. Water within this design is channelled from one end to another, guiding pedestrians along the pathways and human sensory delight.

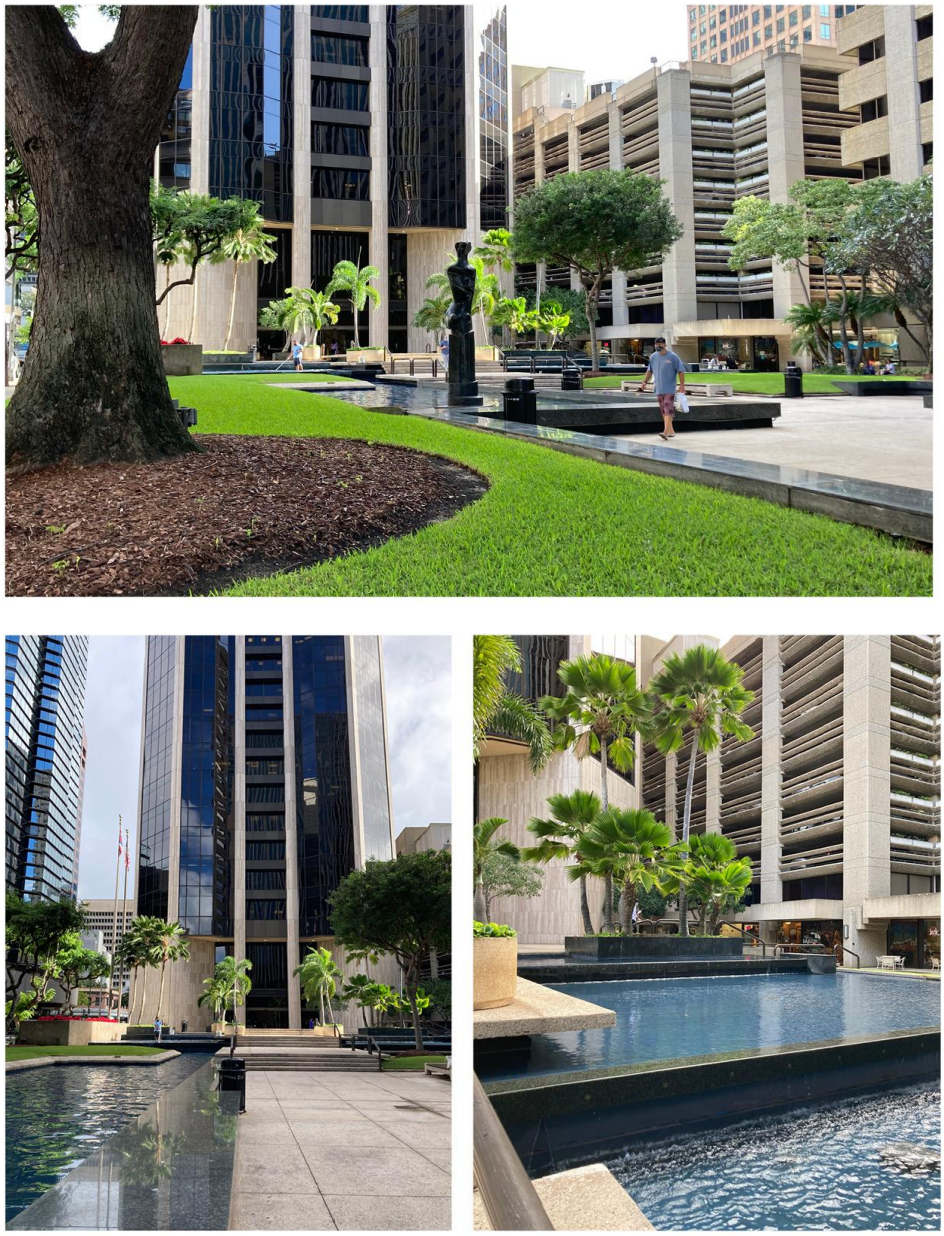

Figure 16: Honolulu’s Bishop Square.

Source: Author.

Figure 17: Water fountain design in relation to Hawaiian culture.

Source: Author.

3.2. Residential Typology Case Studies Analysis

The analysis for the chosen case studies will evaluate water-related design applications for mixed-used residential high rise buildings. Harbor Court and Anaha will be considered in the analysis as both structures are situated along Honolulu's coastline. Harbor Court overlooking Honolulu Harbor and Anaha establishing its presence in proximity to Kewalo Basin Harbor.

Harbor Court Residential Building

Along the perimeter of downtown Honolulu, Harbor Court overlooks Aloha Tower Marketplace and Honolulu Harbor. Designed by Norman Lacayo, Harbor Court is a mixed-use condominium houses 120 residential units and a number of commercial office spaces. While there are residential amenities linked to water, such as spa and pool areas, the context of water is expressed by other elements found within its structure.

Anaha Residential Condominium

In partnership with local firm, Benjamin Woo Architects, Anaha is the second residential condominium tower completed in Howard Hughes's Master Plan and redevelopment of Honolulu's urban core within the Kaka'ako district. Anaha is a LEED Silver-Certified building that holds 311 units and offers a variety of amenities. Although Anaha draws on

an abstract representation of reflecting light from water sources found in nature, the focal point of this condo is its salt water infinity pool that cantilevers into the street.

Comparative Analysis

The perceived presence of water in Harbor Court's design is expressed by fountains, pools, and the environment. Large, theatrical waterfall fountain featured within the design stimulates our auditory and visual senses. This compliments the urban fabric that situates the structure on a busy roadway and also a beacon along the harbor's edge. Pools found on the makai end of the structure contrasts to the waterfall fountain, as it evokes a sense of tranquility within an automotive-dominant site. Harbor Court's residence amenities also feature a pool area that overlooks Honolulu Harbor and expresses the environmental aspect.

Anaha's perceived presence is expressed by the building's undulating form, which draws on the shimmering reflections of rippled waves of the ocean and the cascading nature of waterfalls. The infinity pool at the residential amenity deck is another obvious detail, as the pool's edge is cantilever above the street. The application results in a constant play between daylight and water, and literally have the shimmering reflections projected into one's experience at street level. The pool featured at the amenities level allows the user to experience the grand vista when looking south, as the pool blends with the horizon of the ocean. The fountain element found at the street level entry provides a pleasant experience while moving on the sloped pathway.

The overall awareness of water that is expressed by fountains, pools, and the environment. User experience that affects auditory senses is determined by the type of water design element. Calm pools or trickling water elements can provide a tranquil ambience, but to factor the flow and quantity of water will completely flip the mood. Harbor Court’s loud thrashing of water from the waterfall fountain drowns out the cacophony of the automotive nuisance.

Visual perception assists with our psychological connection to water and can be applied to having water features present in our vision. This was demonstrated well in Harbor Court's design when observed at street level--pools and the fountain is in one’s direct point of view. Whereas Anaha presents an infinity pool but to observe it, one must look upward at street level. Objectively, the infinity pool can be observed at one’s direct line of vision from a couple blocks away. This implies that the visual cues within our vision assist in the cognitive recollection to water is expressed by the environment as a water design element.

Figure 18: Harbor Court Residential Condo.

Source: Author.

Figure 19: Anaha Residential Condo.

Source: Author

3.3. Water Curtain Prototype

The objective for this prototype was to test the method of cycling water in a closed-loop system. The use of a submersible pump system will channel water above ground level and let it flow downward naturally by gravity. A closer investigation of water's tendencies that are influenced by elements of architectural interventions, like a water curtain. Preliminary sketching and digital modeling assisted in the physical build, as it helped with proper handling of materials--measuring, cutting, and assembling. The one-to-one scale mock-up has initiated wet-runs to observe and evaluate efficiency of water within a closed-loop system. Adjustments to the mock-up will be addressed for following wet runs.

The supplies needed for the build consisted of lumber, cement board, polyvinyl chloride (PVC) pipe, PVC caps and elbow, plastic sprinkler nozzle tips, tube straps, decking screws, metal hose shut-off valve, silicone, wood glue, threaded eye hooks, quikrete thin-set, and an 800 GPH submersible pump. For the build, I referred to a typical door frame as the primary structure for the water curtain. Prone to wood rotting from water, I felt that a timber structural system seemed appropriate for the prototype testing to observe the flow of water. Also, I planned to apply a skim coat of cement to exposed wood to imply strength and integrity of concrete systems.

First Wet Run

The tensile strength among fishing line members was not taught; the tension was not consistent among members. Wet run did allow water to flow from the top and drip down to the water reservoir and is channeled in a continuous loop fed by the submersible pump. Certain points of the water curtain were shown to work without the use of a tensile fishing line as it cycled through the mechanism by water pressure and gravity. The use of nozzle tips is considered to be the most helpful, as the water would stream downward directly as opposed to bored-holes in the PVC pipe. The bored-holes would only allow for water to flow out and disperse in all directions versus a nozzle tip that forces a consistent stream of water in the prescribed direction.

Second Wet Run

Using the scrap lumber for modifications to the frame's structure will allow the mechanism to be free standing. In order to keep the tensile element consistent, a second pass of threading longer leads of the tensile segments was necessary and having a weighted mass for the segments to anchor to. For this case, a piece of lumber was used as the base. Threaded eye hooks were used to anchor tensile members to be secured into the base. And the new tensile segments were 30-inches longer than the initial run, as it allowed me to adjust the slack and tension when securing.

Third Wet Run

Given that the water curtain prototype was fully operational, the final wet run provided an opportunity to observe how the mechanism interacts with the external conditions of wind movement. An anemometer was used at the time of testing,--recording an estimated, constant flow of 5 miles per hour (mph). The wind conditions also brought wind gusts measuring up to 20+ mph, which tested the prototype's structure and water displacement within the mechanism. The wind gusts of 20+ mph made the prototype topple over, but luckily the structure and plumbing scheme held together and only the cement board sheathing was warped from the structural frame.

The water displacement from the free-flowing nozzle tips exhibited noticeable effects from constant air flow of 5 mph. However, the tensile members of running water showed little to no effects from provided air movement conditions. The most noticeable effects of the tensile water flow displacement were observed from wind gusts of 10+ mph. The more aggressive air gusts of 20+ mph showed obvious water displacement, where the wetness sensation can be felt within 3 feet from the prototype.

Wet Runs Takeaways

The second and third wet runs showcased the water curtain prototype to be fully operational and proved that it was capable of holding and distributing water throughout the system. The second run was deemed to be much improved than the initial run, as

the flow of water was much better with the consistency in tensile members. This allowed the water to follow the direction of tensile members and provided a pathway for water to travel. Wind factors that affect water displacement for tensile members were observed when wind conditions brought 10 - 20+ mph gusts.

The prototype has also provided an example of a closed-loop cycle--water is channeled upward by the submersible pump and letting water naturally flow downward due to atmospheric pressure. This posed another design challenge of its application towards multi-storey structures. With the correct components, this mechanism can utilize drain pipes and bell siphons for adequate drainage to achieve a gravity fed water system.

Water Curtain Prototype Wet Run video 1: (https://vimeo.com/657730814).
Water Curtain Prototype Wet Run video 2: (https://vimeo.com/657731713).
Water Curtain Prototype Wet Run video 3: (https://vimeo.com/657732087).
Water Curtain Prototype Wet Run video 4: (https://vimeo.com/657731860).

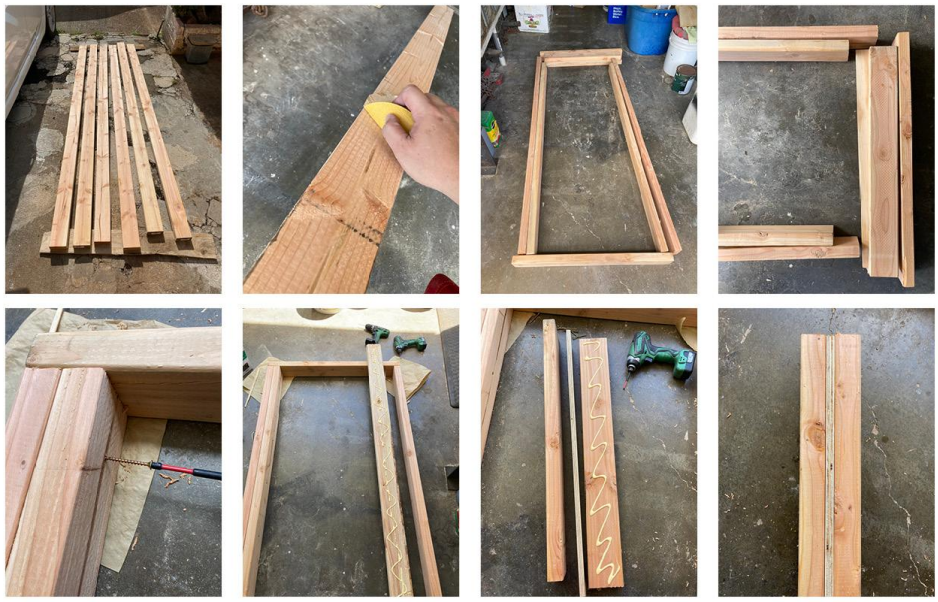

Figure 20: Prototype process photos I. Using lumber as the primary structure of the exploration.

Source: Author

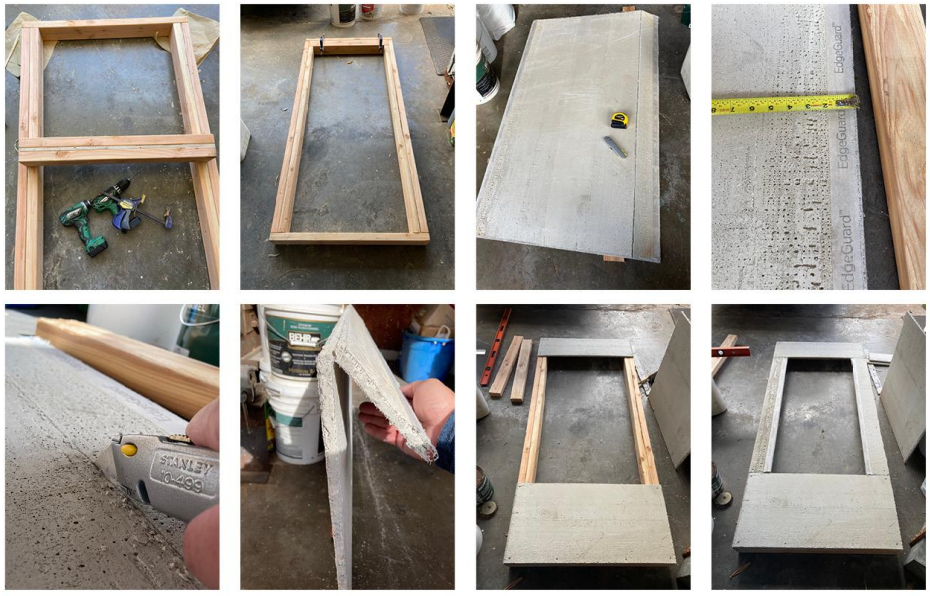

Figure 21: Prototype process photos II. Using cement board as a sheathing surface.

Source: Author.

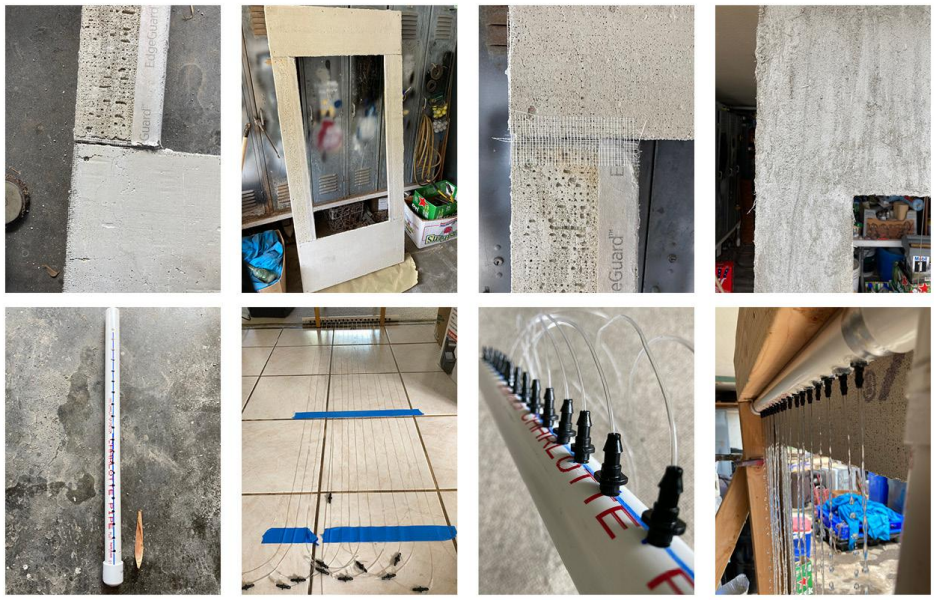

Figure 22: Prototype process photos III. Continuing the plumbing system for the prototype. Utilizing PVC pipe, sprinkler nozzle tips, and fishing line.

Source: Author.

Figure 23: Prototype process photos IV. Testing prototype with operational valve.

Source: Author.

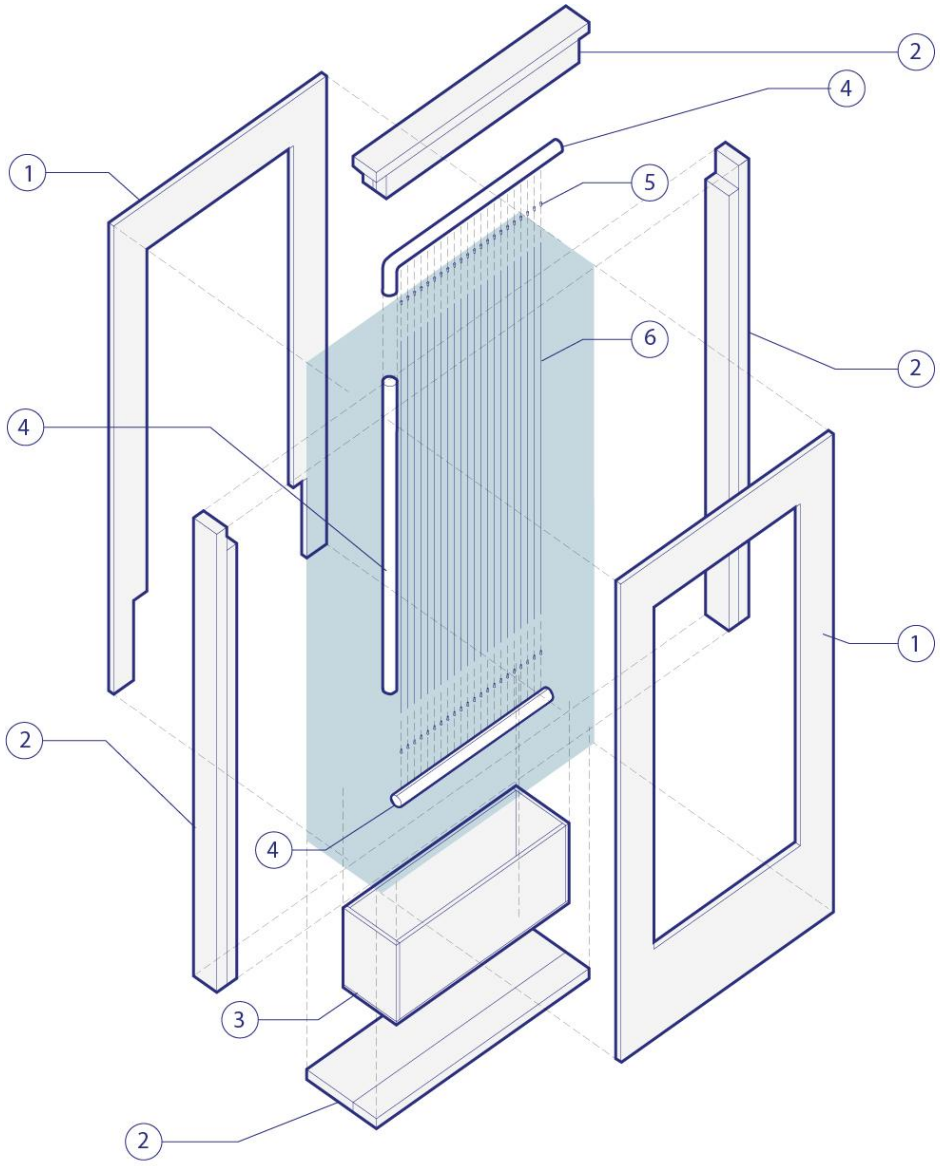

Figure 24. Exploded Axonometric Diagram Prototype.

Source: Author.

4. Summary of Findings

4.1. Precedents and Case Study

Water (as a design swatch) applied to Honolulu's architecture is expressed by the use of fountains and pools. Although typical recreational pools are featured within a building's amenities, alternative features of pools and fountains are often observed in the public realm, serving as sculptural markers expressing Hawaiian culture and signifying a place of importance within Honolulu's urban context. Other features expressing gestures of rivers were observed as key elements of in way-finding in Honolulu's urban context.

The environmental aspect that expresses the presence of water is conveyed by the ocean's horizon and flowing rivers found along popular hiking trails. More elements capable of expressing the vernacular found in Hawai'i can raise the awareness of water resources and their regional hydrology.

4.2. Material Swatches within the Urban Honolulu

The ongoing urban development by Howard Hughes envisions a refreshed focal point of architecture in Kaka'ako. However, the need for specific materials (intended to convey aspects in Hawaiian culture) are being brought here, rather than being a locally sourced material for design. We are still reminded of the notion of the reliance on carbon emissions that is expressed in the look of the luxurious residential sculpture of patterned

glazed surfaces. Surely, there must be an alternative method in expressing water. Literally, and figuratively, from a resource within the proximity of Hawai‘i.

Also considering the influx of invasive materials found in the ongoing development, increased hardscapes negatively impact the quality and quantity of stormwater runoff. It is understood that increased impervious surfaces push harmful chemicals and pollutants into our environment, as well as overwhelming the existing urban infrastructure.[70] The extensive risk entails mixing into waste systems that can overflow, flood, and spread pollutants into existing resources we rely on, like water.

It also contributes to the effect of urban heat island, increasing outside temperatures and energy demand for thermal comfort.[71] Impervious surfaces expressed as asphalt and heavy hardscapes have impacted the majority of O‘ahu’s coastline, seen in Figures 25 and 26. The correlation of moisture zones, impervious surfaces, and the heat index of O‘ahu is that the island is composed of seven microclimates, with Arid conditions seen in urban Honolulu and other similar conditions.

There is a particular appreciation in a building’s design concept that links to cultural aspects significant to its contextual site. However, the recent updates within Honolulu's urban fabric is falsely portraying Hawai‘i’s vernacular. Taking the form of glass, hermetic shelters that call on energy for inhabitants to feel a sense of comfort. The heavy reliance on air-conditioning evidently increases human impact on the global carbon footprint.

[70] Lei Zhao et al., “Strong Contributions of Local Background Climate to Urban Heat Islands,” *Nature* 511, no. 7508 (July 10, 2014): 216, https://doi.org/10.1038/nature13462.
[71] Zhao et al.

Alternatively (and highly considered), allowing air movement and cross ventilation within habitable spaces can bring a perceived sense of comfort in the subtropics. Gentle breezes from the northern-north-eastern tradewinds provide adequate comfort and provide suitable thermal cooling. By incorporating water into the mix of thermal comfort, it poses a potential for evaporative cooling to work in tropical climates. The exploration of the prototype and Farnham et. al's study on oscillating misting cooling suggests that cross ventilating evaporative cooling may be achieved.

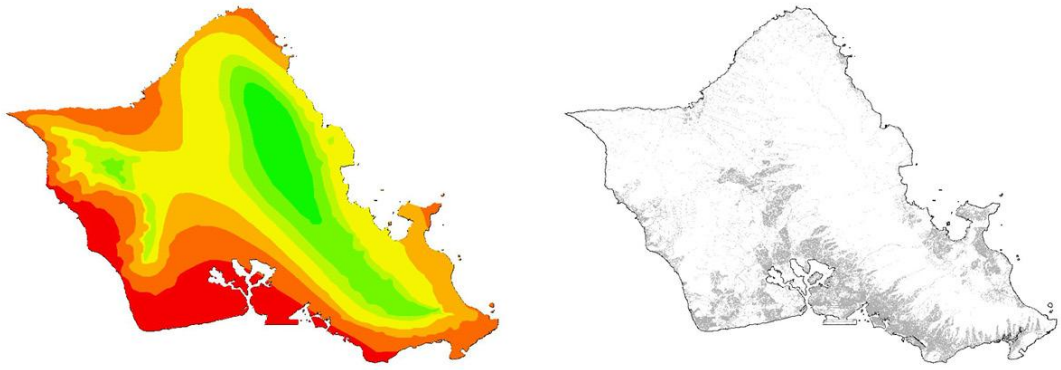

Figure 25: Microclimate and Impervious Surfaces of O‘ahu.

Source: Modified with ArcGIS.

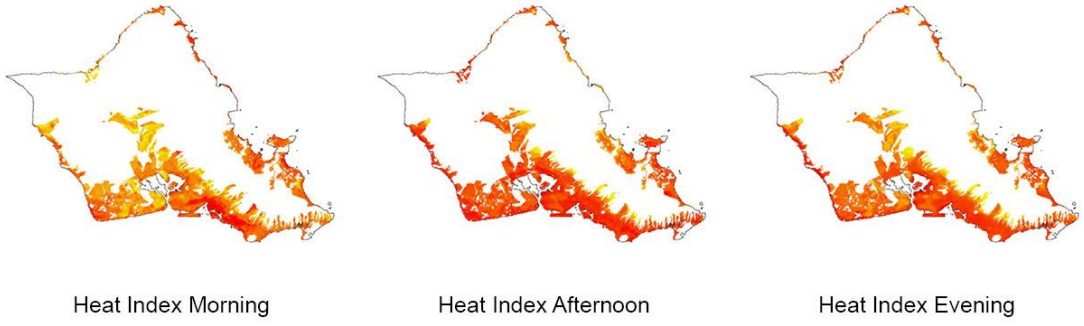

Figure 26: Heat Index of O‘ahu.

Source: Author; Modified with ArcGIS.

4.3. Mechanism for Expressing Water's Presence

Water's use has a biophilic role for quality livability, as it brings the outside into the inside. Edward Wilson claimed that human's innate connection to biophilia as "the love of nature, the attraction for natural environments is so basic that most people will understand it right away".[72] The incorporation of biophilic materials and patterns promotes self healing qualities that are beneficial to mental, as well as physical, health.

The notion of Biophilia can be expressed through biomimicry influenced design. An approach to inspire innovations in advanced systems that imitate the various biomechanic is a testament of nature's success.[73] Consider the combined roles of a tree and/or organisms that are found in healthy watersheds while maintaining its ecological infrastructure--avoiding erosion or flooding. The resurgence of healthy watershed principles expressed in LID facilities also utilize specific key players found in nature to mitigate stormwater runoff, drawing a notion to biophilia. Love for life is expressed through the living mechanisms in nature.

And to recognize the regional source of Hawai'i's water can be influenced by the idea of its unique geographical characteristics and hydrologic cycle that assisted with purist qualities of freshwater found within the islands. Drawing towards nature and biomimicry, buildings now have essential roles for filtration, treatment, and storage for LID strategies.

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[72] "A Conversation With E.O. Wilson," accessed November 22, 2020, https://www.pbs.org/wgbh/nova/article/conversation-eo-wilson/.
[73] Luke Lee and Robert Szema, "Inspirations from Biological Optics for Advanced Photonic Systems," *Science (New York, N.Y.)* 310 (December 1, 2005): 1148–50, https://doi.org/10.1126/science.1115248.

[74] The way we design architectural structures can adopt the Slow, Soak, and Spread phases within LID as it has potential to help mitigate the impacts of flooding and climate change.

4.4. Discussion

Bring water as a swatch for design that expresses biophilia and inspires further designs in biomimicry. Design as a self-sustained system found within the cultural practices and knowledge of specific ahupua‘a systems. The interactions found in healthy watersheds and its regional hydrology is another approach to see biomimicry design. It mimics the processes found in nature that are carried out by LID facilities. This presents an opportunity of considering the slow, soak, and spread phases within the water curtain mechanism.

For this design research project, Hawai‘i’s reverence to water will be the inspiration as it should be acknowledged as a valued presence found among the vast saltwater desert of the Pacific. Water’s use as a design swatch can refresh the urban- and hardscaped-environment by: evoking sensory triggers capable of human self-healing qualities; serving as a spatial-element of importance or guiding a element in way-finding; and to be the beacon that conveys the strong connection of water to Hawaiian culture. This strives to explore an adaptive gesture in the building’s form with a mechanism that harnesses water for cross ventilating evaporative cooling. A potential strategy to achieve

[74] University of Arkansas et al., *Low Impact Development*.

a notion of evaporative cooling within the subtropical context of Hawai‘i. It also considers the relationship between man and nature as a building to its environment--a perceived harmony between the makaainana and aina.

PART II: Research Application

5. Design

The water curtain design is to be applied towards the continuation of “Hawai‘i Primitiva Proletarian Tower,”-elective course provided by architecture professor Martin Despang. Primitiva’s iterative nature in exploring design strategies mimicking natural processes was inspired from the concept of ElevateStructures. Designed by Nathan Toothman, ElevateStructures draws on similar applications for direct evaporative cooling. Demonstrated by the living green wall, the sprinkler system devised on the structure’s facade allows for the same gesture of air passing through moist and cool surfaces.

5.1. Opportunity within Urban Honolulu: Kaka’ako

The applied research will consider the arid conditions of urban honolulu. Kaka‘ako in the phases of redevelopment offers a chance to celebrate water. Water is a significant component in Hawaiian culture and the island’s continuous interaction of elements within its geographical context. And stepping forward into the 21st century, Kamehameha Schools are in the continual phase of the Kaiaulu ‘o Kaka‘ako Master Plan (KKMP). The progressive quality of living communities will act as a catalyst for innovation and nurture the evolution of a vibrant urban-island culture within a beautiful, healthy and sustainable neighborhood.``[75] With the state’s approval, the proposed master plan will feature additional affordable and reserved housing. This offers an opportunity to invite the

[75] “KKMP-Fact-Sheet.Pdf,” accessed November 9, 2021, https://ourkakaako.com/wp-content/uploads/2021/01/KKMP-Fact-Sheet.pdf.

presence of water within the overall vision and could reveal a highly sociable environment that activates the urban qualities of Kaka'ako.

One area of potential focus is the planned green belt connection of park spaces, which could be suggested in the cultural mauka to makai relationship. The Honolulu publication, Star-Advertiser, states from the interview with Kamehameha Schools' Director of Planning and Development, Serge Krivatsy:

> "Another element in this phase of the master plan calls for widening the sidewalks along Cooke Street, each side of which would be planted with a double row of trees to provide a distinct greened corridor between Kaka'ako Waterfront Park and Mother Waldron Park."[76]

Increment II, the second phase of KKMP, aims to provide Affordable/Workforce and Market Housing.[77] Blocks C and D will be the dedicated areas for affordable/workforce housing and poses a potential site for Primitiva Residential Tower. The vision of an active green corridor along Cooke Street provides an opportunity for a responsive building type to adapt towards urban-arid conditions and be a component within the progressive community. The design expectations for this research application is to enhance the qualities of livability by involving the human outlook to water. Embracing aspects of biophilia and biomimicry in the design, the applied structures could potentially be a

[76] "Kamehameha Schools Plans to Build More Affordable Housing in Kakaako | Honolulu Star-Advertiser," accessed November 16, 2021, https://www.staradvertiser.com/2021/02/01/hawaii-news/kamehameha-schools-plans-to-build-more-affordable-housing-in-kakaako/.
[77] "KKMP-Fact-Sheet.Pdf."

supporting element within the community, as it can recall one's cultural connections to the site and the environment as an entirety.

A refreshed-generalized understanding in the use and management of O'ahu's municipal water supply should continue to advocate water conservation techniques as it is a prized resource within the island. Potable water to be distributed within the building design specifically for the use of agriculture/garden, cleaning/washing, and hygiene. Municipal water that taps directly from our underground aquifers shall be, and only used for the purposes of human consumption. This will affect an inhibitant's experience of water from the tap and urge the user to access freshwater from a communal freshwater supply.

The perceived understanding of Hawaiian culture focuses on the kuleana as a makaainana and contemporary alludes to the due diligence in the caretaking of the land we reside on. A component within an ecosystem composed of the natural and built. The water curtain design itself is to be interpreted as the perpetuated motion of Hawaiian culture, as it continues to instill its traditions and practices to future generations.

Figure 27: Potential and proposed site within the KKMP.
Source: KKMP-Fact-Sheet.pdf. Modified by Author.

5.2. Complementary Materials to Prescribed Water Curtain

Water as a design swatch and a component within the water curtain application will complement other materials that compose the structure of Primitiva, as well as the KKMP. The materials within Primitiva embrace the patterns and swatches associated with biophilic design. The materials will cohesively evoke biophilia, as it will allow the presence of the outside to be experienced within its interior spaces. The building itself is an integrated system within its urban fabric, just like a tree within a watershed system.

Primary Tectonic System

Starting with the most dense material needed for the structural integrity. The tower will call on the strong and supportive nature of Volcrete, Basalt Concrete. Lava Rock, or similar. An example concrete that will utilize local ingredients of water, basalt as aggregate and grinded basalt acting as sand.

Secondary Technoitic System, Finishes, and Furniture

Local sourced timber will be preferred in the design. Primitiva looks to utilize Albizia, Bamboo, Coconut, and Reclaimed Wood as it can be modified to meet structural systems of Cross-Laminated Timber or Nail-Laminated Timber. Wood will also be made durable through local thermal modifications. Serving as sun and breeze screen, or or be applied as finished surfaces, fabricated and modular furniture.

Taut, Tensile, Threads, and Thresholds

The notion of repurposing and refreshed look at the use of vinyl fishing line and nets. Its application will provide components with a vertical green wall screen for viney and leafy plants. Water sprinkler system integration for cross ventilating evaporative cooling, or similar to living wall applications. To be also used as a threshold for lanai openings of dwelling spaces. Alternative will consider the use of "*XTend"* stainless steel mesh. Galvanized Steel, or similar material to match Hawai‘i's climate-specifications, will be used as structural rebar and considered for handrails and guard railings.

Plant Types and Species Alike

Vegetation as a material is commonly associated with water, as water is essential to all kinds of life. Given that the contextual site and envisioned progressive community is striving to strengthen the beliefs and values of Hawaiian culture, the cultivation of Native Hawaiian plant species is one of the much needed opportunities to thrive for future generations. Also considering the arid conditions for urban O‘ahu, native Hawaiian plants will be one of the supporting elements within the overall design, including the KKMP. Bornhorst and Rauch, authors of a report on suggestive native Hawaiian plants for local landscaping, claimed that the native species expresses the reputation of being insignificant “weeds” or impossible to grow.[78] However the report suggested two points that highlights its potential presence accompanying the water curtain mechanism:

> “Many natives, especially those native to coastal and dry forest areas will help reach Hawai‘i’s goal of reducing wasteful watering practices (xerophytic or drought-tolerant landscaping)...
>
> Many native plants such as Myoporum, Dodonaea, Vitex, Sida, Scaevola, and Sapindus have a broad range of elevation adaptation. Thus they can be grown in coastal, inland, and upland Hawaiian gardens. Once established in the cooler, wetter areas, these plants have a minimal water requirement.”[79]

[78] Heidi Bornhorst and Fred Rauch, “Native Hawaiian Plants for Landscaping, Conservation, and Reforestation,” 2003, 19.
[79] Bornhorst and Rauch.

5.3. Water Distribution

Modifications applied to the prior iterations of Primitiva will integrate a hybrid system for the prescribed water curtain. The mechanism will demonstrate a refreshed outlook on plumbing schemes, as it will combine the processes of water pumps and atmospheric drainage techniques. What water pumps will act as the supporting element to this design, as it will channel water vertically to help initiate the water curtain design. The drainage components within the elevated reservoirs will evidently allow water to move in a downward motion throughout the mechanism and water to be caught in a continuous loop for enhancing the livability and self-healing qualities to inhabitants and evoking the notion of biophilia.

Habitable and Wet Zones

The prior iterations invite social interactions that are accompanied with water, as it brings water from the core to the exterior. The reconfiguration of the plumbing scheme is to be noticeable in the modification for Primitiva, as it is programmatically located along the floor plates' outer edge. The outer zone of a dwelling unit will be situated as the Wet Zone of the living space, as it associates to the prescribed uses of water--cooking, cleaning, and hygiene.

The opposing end to be considered as the Habitable Zone. The open-space configuration allows for flexible programming in dwelling spaces, as it provides sufficient space for resting, working, or leisure. The tectonic nature of Primitiva allows for additional units to be larger habitable spaces for multigenerational families and other coliving spaces.

Closer Detailed Section of Water Curtain Mechanism

The water curtain will utilize a water pump for water to be drawn vertically and will take advantage of gravity to direct the flow of water downward. A series of valves within the mechanism's plumbing scheme will provide user's an adaptive switch to regulate the flow of water in the water curtain. Allowable to be: completely off on colder days; enabling 50% flow on slightly warmer days; initiate fully on hotter days of the year.

The incorporating bell siphons within the water curtain scheme can also provide effective drainage for the overflow of the elevated reservoirs. Common components in the grow beds for aquaponics, as bell siphons are used to efficiently regulate the flow of water without human intervention.[80] The fundamental principle based on hydrostatics, the relationship between height of a water column and its pressure, can carry out the task of moving water through a series of reservoirs.[81] This exhibits the action of filtration inspired by the relationship of contextual O'ahu and Hydrology. The percolating water expresses

[80] Go Green Aquaponics, "What Is Bell Siphon and Why We Use It in Aquaponics?," Go Green Aquaponics, accessed November 18, 2021, https://gogreenaquaponics.com/blogs/news/what-is-bell-siphon-and-why-we-use-it-in-aquaponics.
[81] "Automatic Bell Siphon Explained," Practical Engineering, accessed November 18, 2021, https://practical.engineering/blog/2017/3/6/automatic-bell-siphon-explained.

rainwater’s journey within healthy watersheds of O‘ahu. Water as it is a symbol of life, a significant element within Hawaiian culture, and its purest quality of freshwater within the Pacific Island Gem.

Figure 28: Typical floor plan for dwelling unit.
Source: Author.

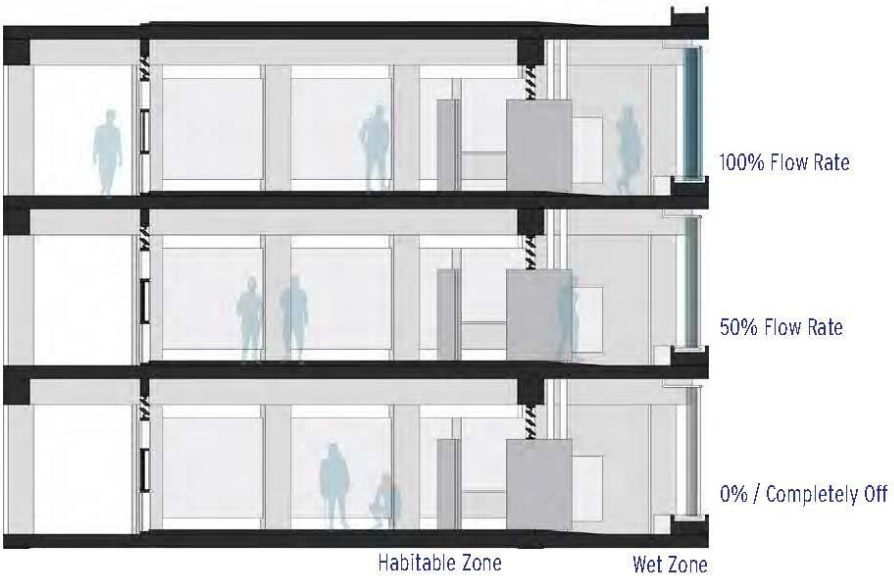

Figure 29: Prescribed Water Curtain Scenarios.

Source: Author.

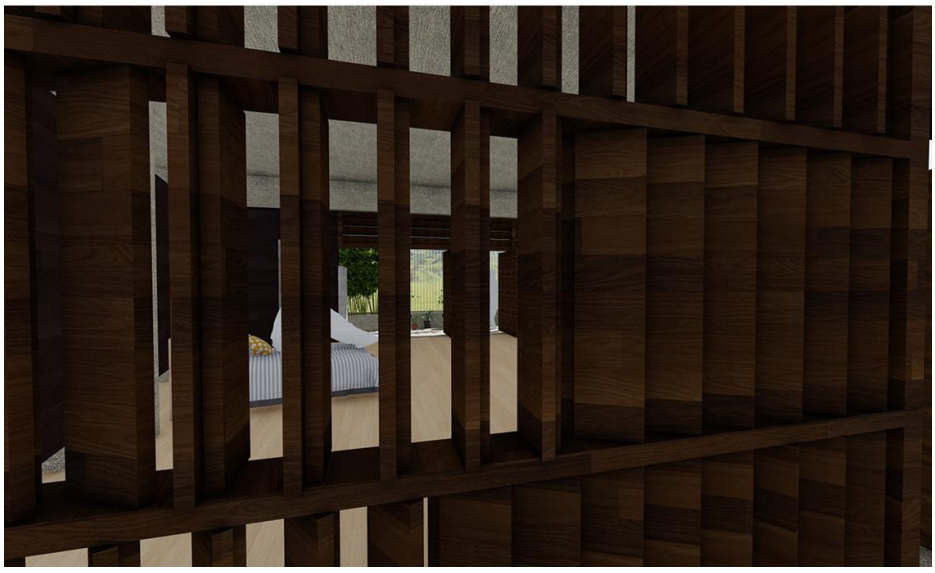

Figure 30: Render I.

Source: Author.

Figure 31: Render II. Habitable zone.

Source: Author.

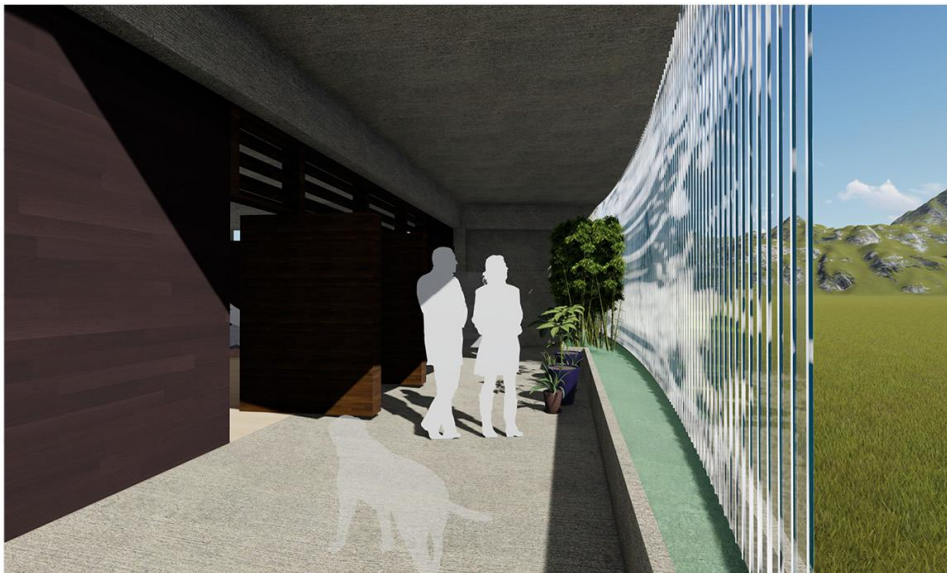

Figure 32: Render III. Water Curtain.

Source: Author.

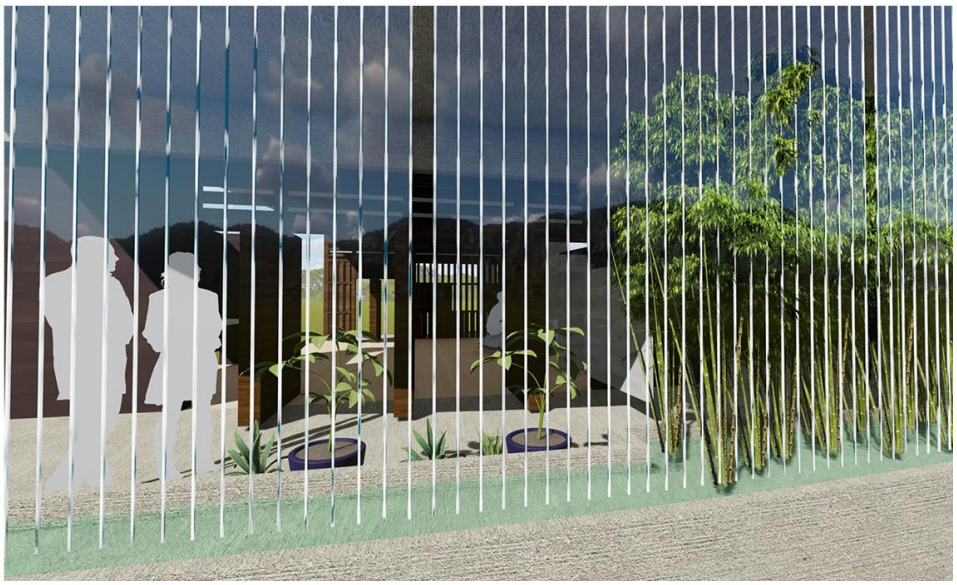

Figure 33: Render IV. Water Curtain.

Source: Author.

6. Conclusion

In the prescribed application of the water curtain, the visual appeal of the mechanism mimics the action of falling water. Its expression provides a natural flow of water traveling along the tensile lines and exhibits a method of perceived cooling with the prevailing trade winds. The tranquil rhythm of water trickling into the water reservoir achieves a sense of calmness. In contrast to this calmness, when the user adjusts the operational valves, the mechanism's water flow increases in intensity, volume, and sound.

Driven by the submersible water pump, the prescribed water curtain is capable of expressing rainwater's movement as it performs a phase for water percolation that is also observed in healthy watersheds and O'ahu's underground aquifers. The elevated reservoir of the water curtain is interpreted as the pockets of water found within our underground aquifers and the water curtain as a whole mimics the filtration element of hydrology. The water curtain's expressive nature exhibits the geographical and contextual connection, which expresses the island of O'ahu as a reservoir of one of the many purest sources of freshwater. It is through aligned values and responsibilities of preserving the resources within its culture, that a progressive community will in the future.

In a carefully schemed village for resiliency, architectural building designs must be considered as role players within a dynamic system, which is similar to the natural

processes found in healthy watersheds, biodiversity, and ecosystems. A marriage and joined interaction between the built and the natural.

The heightened awareness of water as a valued resource will be best achieved through the integration of Architectural design with an emphasis on LID principles. Thoughtful sequencing at property and street level allows LID services to control the flow runoff and divert it into preferred areas, such as bioswales, retention basins, and rain gardens. The spread-and-soak function enhances the existing hydrological infrastructure. This additionally promotes biogeochemical interactions to manage and treat runoff, as it does within nature.[82] The possibilities are endless with vast open space, as it can be configured as a water harvesting park as a means for decentralized water for both public and private uses.[83]

Figure 34: Render V. Integration of Primitiva Wet Towers envisioned in KKMP.
Source: Author

[82] University of Arkansas et al., *Low Impact Development*.
[83] University of Arkansas et al.

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