Santa Monica Living Building

Design Report

MJSM
Consulting

Prepared for client

Sunny Wang

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MSJM Consulting Team

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Table of Contents

1. Introduction

1.1. Project Objective

The client, Sunny Wang, is considering the development of a building that will meet Living Building Certification and would like MJSM Consulting to:

1. Identify environmental requirements and infrastructure needed to support a Living Building
2. Develop engineering solutions and design for the supporting environmental infrastructure, and
3. Present a business case to the client if the proposed environmental infrastructure for the Living Building Certification is feasible. If the Living Building Certification option is not feasible, please present one alternative solution.

The following are key requirements requested by the client:

a. Define environmental engineering elements to support a Living Building Certification
b. Identify environmental components needed to support a Living Building, including water supply, power/energy, resource recovery, sustainability, and environmental impact assessment
c. Develop engineering design for key elements of the required environmental infrastructure
d. Identify and provide mitigating solutions to project risks
e. Prepare business case and recommendation

The Santa Monica Living Building Design Project aims to incorporate civil and environmental design into a multi-discipline engineering design team to meet the overall project objectives. MJSM Consulting will work closely with a civil-structural and architectural team at the University of Southern California to ensure the completion of this project.

1.2. Living Building Requirements for Water and Energy (New Construction)[1]

These requirements are the minimum scope of work for the design of the Project.

1. Responsible Water Use	A. Must not use potable water for irrigation B. Must use 50% less water for the project's other needs compared to a baseline regional building C. Must treat stormwater on site without chemicals, through mechanical and/or natural means D. Must manage stormwater based on both pre-development hydrology and current ecological conditions E. If project is on a combined sewer or floodplain, must

[1] https://living-future.org/lbc

	incorporate stormwater detention and avoid sheet flow off the site
2. Net Positive Water Use	A. Must supply 100% of the project's water needs through captured precipitation or other natural closed-loop water systems, and/or recycling used water B. All water must be purified as needed without chemicals C. No potable water may be used for non-potable uses D. If captured precipitation is not adequate to supply the needs of the project after all possible efficiency measures are applied, connection to the municipal water system is allowed E. Must address all grey and black water through on-site treatment and management through reuse, a closed-loop system, or infiltration F. Scale jumping strategies are allowed with limitations: a. Connection is allowed where regulations prohibit onsite treatment b. Connection is allowed if municipal system provides greater environmental benefit than onsite treatment c. Pump energy must be accounted for through renewable energy sources G. Must incorporate a resilience strategy to provide drinking water for at least a week for all regular building occupants through onsite water storage
3. Energy and Carbon Reduction	A. Must achieve a 70% reduction in total net annual energy consumption compared to an equivalent building baseline B. No combustion is allowed for new buildings C. Renewables must be onsite to count towards efficiencies D. Must meter energy used by the project E. Must project a 20% reduction in the embodied carbon of primary materials compared to an equivalent baseline F. Must select interior materials with lower than industry average carbon footprint for product categories for which embodied carbon data is readily available
4. Net Positive Carbon	A. Must be designed to be "zero ready" by designing areas and pre-installing wiring and connections for both electric vehicle charging and future installations of renewable energy systems B. Must supply 105% of their project's energy needs through on-site renewable energy on a net annual basis, without the use of combustion

C. Must sub-meter energy end uses
D. Must account for the total embodied carbon emissions from construction through the utilization of carbon-sequestering materials and/or through a one-time carbon offset purchase through an ILFI-approved carbon offset provider
E. Must develop and incorporate a resilience strategy to allow the building to be habitable for one week, or otherwise participate in support for the local community in a disaster, through the use of batteries, storage

The following are potential additions to the minimum scope of work for the design of the project.

Ecology of Place	A. Must document site and community conditions prior to start of work B. Must assess cultural and social equity factors and needs in the community to inform design and process C. Dedicate a portion of the total project area to growing food (2-5%) D. Must provide access to food for 75% of occupants for a minimum of three days during an emergency E. Provide places for occupants to gather and connect with the community F. Provide secure storage for human-powered vehicles, and facilities for showers and lockers to encourage biking G. Provide one electric vehicle charging station per thirty parking spaces H. Minimize impervious surface parking to no more than 5% of the project area
Indoor Air Quality	A. Must meet ASHRAE 62.1 standards B. Prohibit smoking in building or within 25' of any building opening C. Develop a Healthy Indoor Environment Plan specific to the project building. Must address cleaning protocols and prevention of particulates and toxins D. Provide views outside and daylight for 75% of regularly occupied spaces E. Provide direct exhaust for kitchens, bathrooms, and janitorial areas F. Ability for occupants to influence local airflow and temperature
Materials	A. Must incorporate one product certified under the Living Product Challenge B. 50% of wood products must be FSC, salvage, or

	harvested on site, and the remainder must be from low risk sources C. 20% or more of the materials construction budget must come from within 500 km of the construction site, 30% of total materials must come from within 1000 km of the construction site, 25% must come from within 5000 km, rest has no limit D. Must divert 80% of construction waste material from the landfill and provide dedicated infrastructure for the collection of recyclables and compostable food scraps E. May only use up to 10% of materials budget on the "Red List"
Net Positive Waste	A. Must feature at least one salvaged material per 500 square meters of building area, or be an adaptive reuse of an existing structure B. Must create a Materials Conservation Management Plan that explains how the project optimizes materials in design, construction, operation, and end of life
Equity	A. Must make all externally focused primary transportation equally accessible to all (including the homeless) B. Must provide for and enhance public realm through design measures and features accessible to all members of society C. Must be accessible in accordance with the ADA or Principles of Universal design D. Must not black access to fresh air, sunlight, or natural waterways

2. Resiliency & Project Risk

In order to guarantee the reliability of the building, it is necessary to ensure that the designed systems have a back-up plan in case of failure so activities can continue without interruption in due normality. These support systems can be divided in the two main components: water and energy.

2.1. Water

General

As mentioned in section 5.2.1, water is scarce in the region. Even though efforts will be maximized in order to utilize water in the most efficient manner, it is crucial to provide a connection to the central water distribution network in order to satisfy the daily demand for water. Monitoring will occur at all points along the treatment system to verify that the water meets potable standards. Alarm setpoints will be set along the treatment processes as well, to alert the attention of staff and shutdown processes as necessary.

Rainwater

Even though unlikely, it is important to consider the scenario where rainwater is at its maximum collection volume. This occurs in the month of February with a volume of 607 gallons. To account for this possibility, two 650 gallon tanks will be provided. Under low rain conditions, one of them will remain unused (though ready to be utilized at any moment). Tank rotation will take place in order to perform maintenance on the one being used. Also, an additional pump will be provided as a back-up.

Greywater Reuse

The possibilities of failure will depend on the system in question. The most likely approach to be deployed will likely be a membrane bioreactor. In such a system, the mechanisms prone to malfunction are the pumps and the filtering system, particularly membrane fouling. Two pumps will be provided.

Groundwater

Potential points of failure include pump failure and sediment accumulation that can lead to breakage of pipes and intrusion into the water supply, with pump breakdown. To avoid such consequences, two pumps will be provided, while casing will maintain the underground sediments firm, preventing collapse.

2.2. Energy

One of the most frequent issues with electricity is the possibility of power outages. Even though this risk is minimized by not relying on a centralized power system, there might still be inconveniences. When energy is being harvested through solar panels, it is mandatory to count with energy storage methods. As discussed in section 6.1.1, in order to hold enough energy for a week's worth of energy supply, the building would need approximately 45 Tesla Powerpack batteries.

If an excess amount of energy is in storage, electricity could be provided back to the surrounding community, as part of the building's effort to provide 105% or more of the energy necessary for the building. Any energy that exceeds battery storage can be used to provide energy resilience for the community as a whole, and not just the building.

2.3. Risk Management

As of this stage of design, many aspects of design have not been fully developed nor has the site been fully evaluated in detail, which opens up the possibility of risks in the project, such as inaccurate assumptions and unexpected geotechnical or groundwater site issues. Other risks include a tight schedule that may limit the amount of work the group is able to complete due to the small number of employees and lack of practical experience in the team. This is a difficult risk to address, but the goal of the team will be to create the most detailed and effective project possible within the time allotted, and to advance design as far as practically possible.

All treatment systems used in the Santa Monica Living Building have had several full-scale installations in industrial applications, and therefore should have less inherent risks than lesser explored technologies. Potential risks can be managed if shared and studied between different entities throughout the process of design and construction.

Risks in failure of the water treatment system at any point can be mitigated by including back-up tanks and staying connected to the main water line in Santa Monica. Similarly, the energy production system can avoid risk by having several solar grids able to generate energy independently, so if one goes down, the others can pick up the slack. In the worst case scenario, we can remain connected to the energy grid as well.

2.4. Test Plan & Performance Guarantee

If the living building design is chosen by the client, a preliminary implementation schedule will be created as a method to test the water treatment and energy mechanisms designed by MJSM Consulting. After the building is constructed and all energy and water infrastructure has been completed, the building operations will be tested at full capacity for a period of four weeks. Throughout this testing period, water quality from the various treatment trains will be tested to ensure compliance with the water quality criteria outlined later in this report. Following this testing period, MJSM will compile a detailed performance report showing how all goals were met by the systems set in place, any shortcomings witnessed throughout the test process, and, if needed, corrections at the design phase to meet requirements. If a redesign or maintenance is needed after the trial, another testing period of two weeks, along with an updated performance report, should follow to ensure that all problem areas are addressed.

3. Building Overview

3.1. Building Overview

Our campus will consist of two primary office buildings, one on the north side and one on the south side of the property. The majority of office space will be within the north building, while the south building holds office, retail, and maintenance spaces. The recreational space will span overtop the metro rail line and connect the north and south building.

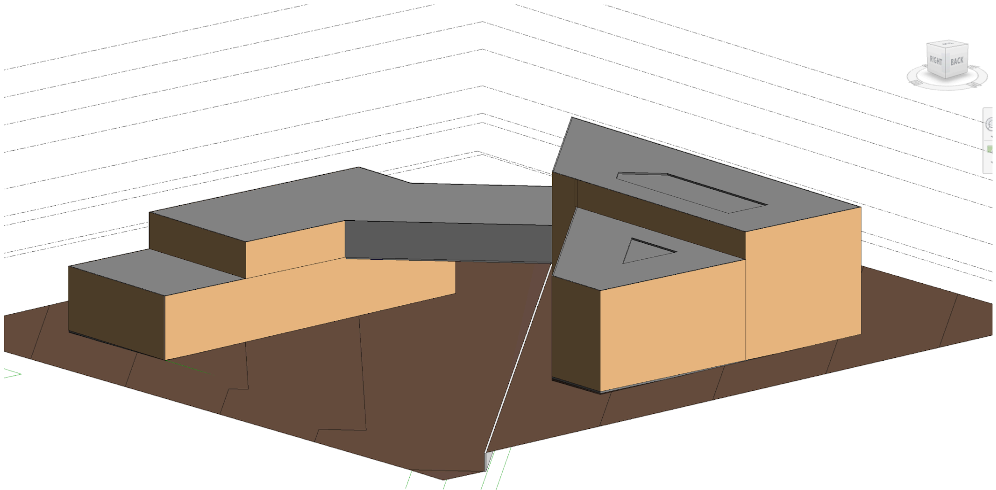

Figure 3.1.1: Building model from eastern side view

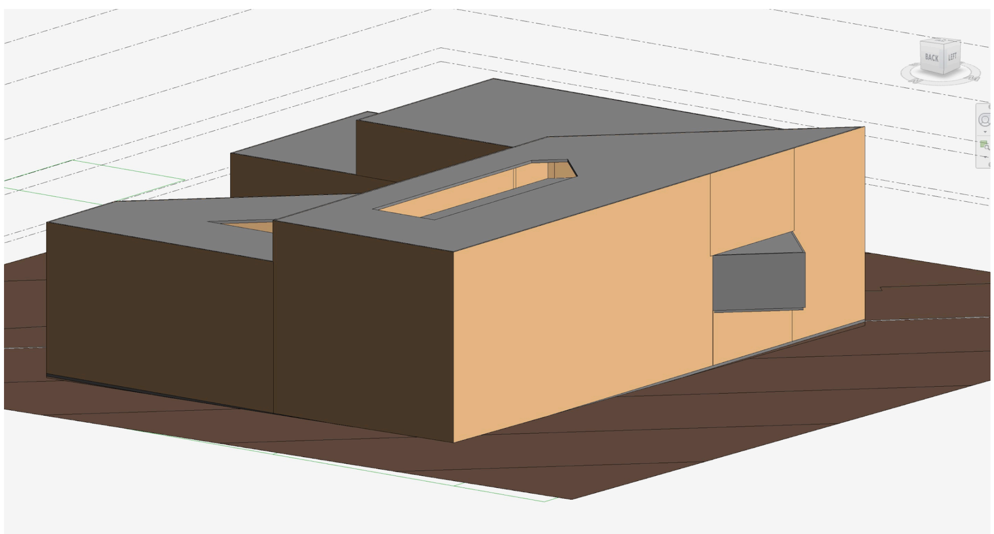

Figure 3.1.2: Building model from northern side view

Figure 3.1.3: Building model from aerial view

3.2. Size, Spatial Distribution, & Occupancy

Table 3.2.1: Square footage distribution of project and maximum occupancy

Office Space	109,700 square feet
Office Space Per Capita	180 square feet/person
Coffee/Cafe	1,300 square feet
Grab and Go Food Stand	700 square feet
Recreation Center	16,000 square feet
Shower Rooms (x6)	600 square feet
Control room/Treatment Space	16000 square feet
Total Space	144,300 square feet
Visitors	40
Total maximum occupancy[2]	650 persons

As summarized in Table 3.2.1, the maximum total occupancy is 650 persons. Approximately 109,700 square feet of the building is dedicated to office space, consisting of enclosed offices, open workstations such as cubicles, and collaboration spaces. Based on the average of 180 square feet per person in a similar sized office space, the number of office workers occupying the building on an eight hour average five days per week is 610 persons. Assuming the building will have 40 visitors during business times, this increases our occupancy to 650 persons.

The building will also provide approximately 16,000 square feet of column-free space for recreational use. Connecting to this space will be 3 rooms of 200 square feet, each containing 2 showers and lockers, for a total of 6 showers and 600 square feet.

In addition to recreation and office space, the building will also dedicate 2,000 square feet to retail. There will be a 1,300 square foot cafe (most likely a commercial Starbucks) connected to a 700 square foot grab-and-go style food stand with goods produced offsite. The remaining 16,000 square feet will be reserved for a systems control room, on-site water treatment and storage, and energy storage. Thus, our total square footage of the building is 132,600 square feet.

[2] Based on one person per 180 square feet average from https://www.gsa.gov/cdnstatic/Workplace_Standards_Benchmark.pdf

4. Building Utility Demand

4.1. Baseline Industry Averages

4.1.1. Water

According to the US Environmental Protection Agency, water used in office buildings accounts for approximately 9 percent of the total water use in commercial and institutional facilities in the United States. The three largest uses of water in office buildings are restrooms, heating and cooling, and landscaping (domestic/restrooms: 37%, heating and cooling: 28%, landscaping: 22%, kitchen/dishwashing: 13%).[3] We have also included six showers in three separate locker room spaces, a cafe, and a food stand space that each require separate water demands.

Table 3 shows the calculated baseline industry average water demand for the building. Using data from the EPA and the Portfolio Manager Median of water used in office buildings of 13 gallons per employee per day, the baseline industry average for water consumption for the office spaces of comparable size was calculated as 7,930 gallons per day. For the 6 shower units, each used 15 times throughout the day for a total of 90 showers per day, an average of 1,440 gallons per day for shower usage was calculated. This approximation is based on the Home Water Works average american shower usage of 16 gallons per shower.[4] Moving on to retail space, the water usage for our Starbucks cafe was calculated as 31,200 gallons per month based on an average water use of 24 gallons per square foot per month[5]. The food stand will use an average of 0.5 gallons per square foot per day[6], for a total of 350 gallons per day.

Table 4.1.1: Baseline industry averages of water demand for similar-sized commercial buildings

Type of Space	Baseline Average Water Consumption	Average Total (including building operation hours)
Domestic/Restrooms	37% of office space demand	2947 gallons per day
Heating/Cooling	32% of office space demand	2230 gallons per day
Irrigation	22% of office space demand	1752 gallons per day

[3] Saving water in office buildings: https://www.epa.gov/sites/production/files/2017-01/documents/ws-commercial-factsheet-offices.pdf
[4] Showering to Savings: https://www.home-water-works.org/indoor-use/showers
[5] Starbucks Cuts Monthly Water Use to 24 Gallons Per SF: https://www.environmentalleader.com/2009/04/starbucks-cuts-monthly-water-use-to-24-gallons-per-sf/#:~:text=Starbucks%20Cuts%20Monthly%20Water%20Use%20to%2024%20Gallons%20Per%20SF&text=The%20latest%20report%20shows%20that,environmental%20stewardship%20and%20ethical%20sourcing
[6] Baseline Water Consumption Worksheet: https://files.nc.gov/ncdeq/Environmental%20Assistance%20and%20Customer%20Service/IAS%20Water%20Efficiency/Baseline%20Water%20Consumption%20Worksheet.pdf

Kitchen/Dishwashing	13% of office space demand	1036 gallons per day
Total Office Space (including the categories listed above)	13 gallons per employee per day	5,650 gallons per day
Showers	16 gallons per shower, 90 showers per day	1,025 gallons per day
Coffee/Cafe (Starbucks)	24 gallons per square foot per month	1,040 gallons per day
Food Stand	0.5 gallons per square foot per day	250 gallons per day
Total Baseline Building Demand		7,965 gallons per day 242,234 gallons per month 2,906,800 gallons per year

Note: Office, shower, and food stand space in operation for 260 days per year for 8 hours per day and Starbucks open 360 days per year for 14 hours per day.

4.1.2. Energy

According to the US Energy Information Administration (EIA), lighting is the largest single use of electricity in commercial buildings, followed by refrigeration, ventilation, and cooling. Space heating demand was the most overall energy use in commercial buildings in 2012. These will be the focus of what aspects in our building need to be addressed in order to meet the Living Building standards.

Based on this value and the structural requirements of the office portion of the project building, the energy consumption for an office space comparable to the project's would be around 2.51 million kWh annually.

The energy consumption of the project's retail space is based on the average restaurant's energy use per square footage, applied to the project's square footage allocation towards restaurant or cafe retail. Based on EIA data on buildings under the food sales category, a retail space comparable size to the project's would consume 0.31 million kWh annually.

For the exhibition portion of the building, the US EIA considers such space as under their "Public Assembly" category. Based on their annual energy consumption data from 2012, an exhibition space of comparable size to the project's would consume 0.40 million kWh annually.

Table 4.1.2: Industry averages of comparable sized buildings, by type of space:

Description	Value	Unit	Comments
Total industry average annual energy consumption	3.042359116	million kWh	

OFFICE	**2.514809563**	**million kWh**	
Annual energy consumption per square footage	22.79972405	kWh/sf	See footnote[7]
Project's office square footage	109700	sf	From Size and Occupancy
Project's shower square footage	600	sf	From Size and Occupancy
Industry consumption for office our size	2514809.563	kWh	
	2.514809563	million kWh	
FOOD SALES (no preparation in house)	**0.122659138**	**million kWh**	
Annual energy consumption per square footage	61.329569	kWh/sf	See footnote
Project's food sales square footage	2000	sf	From Size and Occupancy
Industry consumption for food sales our size	122659.138	kWh	
	0.122659138	million kWh	
EXHIBITION SPACE	**0.4048904153**	**million kWh**	
Annual energy consumption per square footage	25.30565096	kWh/sf	See footnote
Project's exhibition space square footage	16000	sf	From Size and Occupancy
Industry consumption for exhibition space our size	404890.4153	kWh	
	0.4048904153	million kWh	

4.2. Living Building Demand

The following are requirements of the project that are held in comparison with baseline and industry averages:

1. Must use 50% less water for the project’s other needs compared to a baseline regional building
2. Must achieve a 70% reduction in total net annual energy consumption compared to an equivalent building baseline
3. Must project a 20% reduction in the embodied carbon of primary materials compared to an equivalent baseline

[7] Calculated from total consumption from https://www.google.com/url?q=https://www.eia.gov/energyexplained/use-of-energy/commercial-buildings-in-depth.php&sa=D&source=editors&ust=1612495766343000&usg=AOvVaw2te8oZ8C6Dqt94wIRlyEi7 and total square footage from https://www.eia.gov/consumption/commercial/data/2012/bc/cfm/b1.php

4.2.1. Assumptions for Water[8] to meet LBC Demand

All projects must not use potable water for irrigation, and must use 50% less water for the project's other needs than a baseline regional new building of the same type. The maximum water demand limits are listed below in Table 5 by space type. They are calculated based on a 50% reduction from the baseline industry averages for water consumption determined in section 4.1.1.

Table 4.2.1.1: Maximum water demand for the LBC project

Type of Space	Maximum Demand for LBC Project
Domestic/Restrooms (Office)	1473 gallons per day
Heating/Cooling (Office)	1115 gallons per day
Irrigation (Office)	876 gallons per day
Kitchen/Dishwashing (Office)	518 gallons per day
Total Office Space Demand	2,825 gallons per day
Showers	513 gallons per day
Coffee/Cafe (Starbucks)	520 gallons per day
Food Stand	125 gallons per day
Total Demand for LBC Building	3,982 gallons per day 121,117 gallons per month 1,453,400 gallons per year

We will use several strategies to meet the 50% reduction from the baseline industry average, including management practices for water supply, on-site treatment and reuse. Specifically, our practices will include rainwater and stormwater harvesting, including strategies for potable and non-potable uses, greywater reclamation and reuse, and on-site wastewater treatment and reuse, including composting toilets.

According to the living building challenge, "one hundred percent of occupants' water use must come from captured precipitation or closed-loop water systems that account for downstream ecosystem impacts and that are appropriately purified without the use of chemicals" and "One hundred percent of storm water and building water discharge must be managed on-site to feed

[8] Water demand data obtained from https://www.energy.gov/eere/femp/federal-water-use-indices

the project's internal water demands or released onto adjacent sites for management through acceptable natural time-scale surface flow, groundwater recharge, agricultural use or adjacent building needs."

We will also use low-flow faucets, showerheads, appliances, and cleaning systems where applicable to reduce water consumption at the individual level.

4.2.2. Assumptions for Energy[9] to meet LBC Demand

The demand for this project must adhere to the Living Building guidelines on energy consumption on an annual basis. The maximum energy consumption based on requirement 3.A requires that the project have a 70% reduction in annual energy consumption as compared to an equivalent building. The maximum demand limit for this project is 0.96 million kWh annually and are listed below by space type.

Table 4.2.2.1 - Maximum goal energy demand for the project, by type of space

Description	Value	Unit	Comments
Annual Total Goal Consumption	0.967904347	million kWh	Sum of each space's annual consumption
OFFICE	**0.7544428689**	**million kWh**	
Industry consumption for office our size	2514809.563	kWh	
LBC Goal Consumption for office our size	754442.8689	kWh	Based on LBC 70% reduction from industry average
	0.7544428689	million kWh	
FOOD SALES	**0.0367977414**	**million kWh**	
Industry consumption for food sales our size	306647.845	kWh	
LBC Goal Consumption for food sales our size	36797.7414	kWh	Based on LBC 70% reduction from industry average
	0.0367977414	million kWh	
EXHIBITION SPACE	**0.1214671246**	**million kWh**	

[9] Energy data obtained from https://www.eia.gov/energyexplained/use-of-energy/commercial-buildings-in-depth.php

Industry consumption for exhibition space our size	404890.4153	kWh	
LBC Goal Consumption for exhibition space our size	121467.1246	kWh	Based on LBC 70% reduction from industry average
	0.1214671246	million kWh	

This project will follow the zero energy buildings standard as put forth by the US Department of Energy[10], in producing more energy than it consumes. Energy consumption and plans for reduction will focus on lighting and heating/cooling, as these are the primary consumption areas for commercial buildings. The following table shows the projected energy consumption for various building purposes, totalling 0.91 million kWh projected to be consumed annually, which is 0.05 million kWh less than the maximum allowance as calculated in the previous section.

Table 4.2.2.2 - Projected annual energy consumption, by usage

Description	**Value**	**Units**	**Comments**
ANNUAL DEMAND (based on annual usage)	**0.8984903665**	**million kWh/year**	
Lighting	**0.3672375479**	**million kWh**	
1 LED fixture	77.7	$	See footnote[11]
	2	ft	
	1	ft	
	2	sf	
	50	W/light	
Spacing criteria	1.5		Max industry standard
Ceiling height	9	ft	From Structural Requirements
Spacing distance	13.5	ft apart	SD = SC * Ceiling Height[12]
	13.5	ft apart lengthwise	
	14.5	ft apart width	
	195.75	sf in between 4	
	48.9375	sqft for 1 panel	
Total square footage of floor	131300	sf	
Total space required for LED panels	2683.014049	sf	

[10] Definition obtained from https://www.energy.gov/eere/buildings/downloads/common-definition-zero-energy-buildings
[11] Specifications from https://www.1000bulbs.com/product/218606/IRT-10264.html
[12] From Arranging Downlights for General Lighting (takethreelighting.com)

# of troffers	1341.507024	count	
Daylight	8	hours	9am - 5pm
Non daylight hours	11	hours	4am - 9am, 5 -11pm
Total hours of 100% capacity	15	hours	daylight hours, lights at 50% capacity
Annual hours used	5475	hours	
Energy consumed from lights	367237547.9	Wh	
	367237.5479	kWh	
Total energy consumption from lighting	**0.3672375479**	**million kWh**	
Office equipment	**0.04139926667**	**million kWh/year**	
Occupancy (office workers)	609	office persons	
Monitors	1219	monitors	Double monitors
	24	kWh/year	ASUS[13]
Energy use of monitors	29253.33333	kWh /year	
	0.02925333333	million kWh/year	
Computers	609	computers	
	19.2	kwh/year	ASUS[14]
	11701.33333	kWh	
	0.01170133333	million kWh/year	
Printers			
Building floors	5	floors	
Total printers	15	printers	3 each floor, 1 in middle and 2 at each end
	0.57	kWh/week/printer	See footnote[15]
	29.64	kWh/year/printer	
	444.6	kWh/year	
	0.0004446	million kWh/year	
Total energy consumption from office equipment	**0.04139926667**	**million kWh/year**	
Heating	**0.08753333333**	**million kWh/year**	

[13] From ENERGY STAR Most Efficient 2021 — Computer Monitors | EPA ENERGY STAR
[14] From ENERGY STAR Certified Computers | EPA ENERGY STAR
[15] From Brother - MFC-L5850DW

Energy consumption/sf	2	kWh/sf	See footnote[16]
Total sf of our building requiring heat	131300	sf	
	262600	kWh	
	0.2626	million kWh/year	
Total energy consumption from Heating	**0.08753333333**	**million kWh/year**	1/3 of the year requiring active heating
Ventilation	**0.2626**	**million kWh/year**	
Energy consumption/sf	2	kWh/sf	See footnote
Total sf of our building requiring ventilation	131300	sf	
	262600	kWh	
Total energy consumption from Heating	**0.2626**	**million kWh/year**	
Hot Water heating	**0.06565**	**million kWh/year**	
Energy consumption/sf	0.5	kWh/sf	See footnote
Total sf of our building requiring heat	131300	sf	Square footage includes shower space
	65650	kWh	
Total energy consumption from Heating	**0.06565**	**million kWh/year**	
Water treatment	**0.06409208467**	**million kWh**	
Energy Usage Intensity (low)	5	kBtu/GPD	See footnote[17]
	5000	btu/GPD	
	1.465355351	kWh/GPD	
Energy usage Intensity (high)	50	kBtu/GPD	
	50000	btu/GPD	
	14.65355351	kWh/GPD	
Water usage	15	gal/day per person	from Water Demand
Occupancy	650	persons	from Size and Occupancy

[16] From Benchmarking Commercial Building Energy Use Per Square Foot | Iota (iotacommunications.com)
[17] Values from Energy Use in Wastewater Treatment Plants (energystar.gov)

	7952.409835	GPD	
Energy Consumption (low)	11653.1063	kWh	
	0.0116531063	million kWh	
Energy Consumption (high)	116531.063	kWh	
	0.116531063	million kWh	
Energy Consumption (average)	**0.06409208467**	**million kWh**	
Emergency	**0.00997813396**	**million kWh**	
Lighting	0.007062260536	million kWh	1 week of annual consumption
Heating	0.001683333333	million kWh	1 week of annual consumption
Water treatment	0.00123254009	million kWh	1 week of annual consumption

In regards to lighting, the building will make the most of the natural sunlight it receives in Santa Monica, limiting lighting to only the hours before, after and around sunrise and sunset, during which occupancy should be at its lowest of the day. Dimmable ceiling lights will be used to minimize the duration in which lights are operating at full capacity. Total energy consumption from lighting will be 0.37 million kWh annually.

All office appliances will meet Energy Star certified monitors, computers, and imaging equipment[18]. As equipment becomes more energy efficient, a larger focus must be placed on plug load, or the energy being consumed while equipment is not in use, but still plugged in. All staff will be briefed on plug load best practices to minimize energy consumption such as unplugging their system when leaving for the day or shutting off when not in use[19]. Total energy consumption for computers, monitors, and printers will be 0.04 million kWh annually.

To combat energy consumption for air conditioning, the project will forgo a traditional A/C unit and instead have elements that naturally regulate the temperature of the building. Any hot air will be allowed to dissipate out of clerestory windows while cooler air enters at ground level. The windows on the South side of the building will have trellis structures to promote epiphyte growth that in summer block direct sunlight from heating the building and in the winter, allow direct sunlight to shine into the building[20]. There will be a heating system in place only for colder months, or ⅓ of the year. Total energy consumption from space heating will be 0.09 million kWh annually. 0.26 million kWh will be consumed for ventilation of the building.

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[18] Energy Star certified equipment listed at https://www.energystar.gov/ia/partners/publications/pubdocs/ENERGY%20STAR%20Office%20Equipment%20Brochure_508.pdf
[19] Best practice from https://newbuildings.org/resource/plug-load-best-practices-guide/
[20] Design from https://env.cpp.edu/rs/building-systems

Any water treatment processes will require energy as all water is treated onsite. The current projects take an average of the range of energy usage intensity given by Energy Star combined with the annual water demand based on occupancy. Once the exact treatment processes are chosen and designed, the calculations will be more exact. Total energy consumption designated for water treatment processes will be an average of 0.08 million kWh annually. Energy consumed to heat water will be 0.06 million kWh annually.

In accordance with the Living Building challenge, there must be enough energy reserved for emergencies for one week. Essential operations for energy include lighting, heating, and water treatment. Total energy consumption for emergency use is 0.01 million kWh annually.

5. Water

5.1. Water Quality Criteria

5.1.1. Drinking Water[21]

General drinking water regulations as defined by the Environmental Protection Agency. Please note that the list below *only* contains those chemicals that could be of a concern for an office environment that follows the Living Building Challenge guidelines.

Table 5.1.1.1: National Primary Drinking Water Regulations

Relevant National Primary Drinking Water Regulations		
Contaminant	MCL1 or TT2 (mg/L)	PHG3 (mg/L)
Antimony	0.006	0.006
Arsenic	0.01	0
Asbestos	7 million fibers/L	7 MFL
Benzo(a)pyrene (PAHs)	0.0002	0
Bromate	0.01	0
Cadmium	0.005	0.005
Chloramines	MRDL4 = 4.0	MRDLG5 = 4.0
Chlorine	MRDL4 = 4.0	MRDLG5 = 4.0
Chlorine dioxide	MRDL4 = 0.8	MRDLG5 = 0.8
Chlorite	1	0.8
Copper	TT; Action Level = 1.3	1.3
Cryptosporidium	TT	0
Fecal Coliform and E. Coli	MCL	0

[21] National Primary Drinking Water Regulations: https://www.epa.gov/sites/production/files/2016-06/documents/npwdr_complete_table.pdf

Fluoride	4	4
Giardia lamblia	TT	0
Haloacetic Acid (HAA5)	0.06	-
Lead	TT; Action Level = 0.015	0
Legionella	TT	0
Nitrate	10	10
Nitrite	1	1
Total Coliforms (TC)	5%	0
Total Trihalomethanes (TTHMs)	0.08	0
Turbidity	TT	-
Vinyl chloride	0.002	0

Table 5.1.1.2: National Secondary Drinking Water Regulations

Relevant National Secondary Drinking Water Regulations	
Contaminant	Secondary Maximum Contaminant Level
Aluminum	0.05 - 0.2 mg/L
Chloride	250 mg/L
Color	15 (COLOR UNITS)
Copper	1.0 mg/L
Corrosivity	Noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mgL
Manganese	0.05 mg/L
Odor	3 Threshold odor number
pH	6.5 - 8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids (TDS)	500 mg/L
Zinc	5 mg/L

Table 5.1.1.3: References for Table 2.1.

1MCL	*Maximum Contaminant Level*
2TT	*Treatment Technique*
3PHG	*Public Health Goal*
4MRDL	*Maximum Residual Disinfection Level*
5MRDL	*Maximum Residual Disinfection Level Goal*

The following table presents the microbial integrity requirements:[22]

Table 5.1.1.4: Log Removal/Inactivation through Filtration and Disinfection Required Under the 1989 SWTR.

Log Removal/Inactivation through Filtration and Disinfection Required Under the 1989 SWTR			
Process	Log Removal requirements		
	Giardia Cyst	Viruses	Cryptosporidium
Total log removal/inactivation required	**3**	**4**	**2**
Treatment	Inactivation and/or removal	Inactivation and/or removal	Removal

For Cryptosporidium, 2.0 log removal will be achieved by the filters, and thus there are no CT calculations involved since disinfection is not required.

Disinfection, in order to achieve 4-log removal for virus, has the following CT requirements:

Table 5.1.1.5: Log requirements for virus[23].

CT Values for a 4 -log Inactivation of Viruses by Free Chlorine		
Temperature (C)	CT for a 4- log Inactivation of Viruses (mg/L-minutes)	
	pH = 6 - 9	pH = 10
0.5	12	90
5	8	60
10	6	45
15	4	30
20	3	22
25	2	15

[22] Disinfection Profiling and Benchmarking: https://www.epa.gov/sites/production/files/2020-06/documents/disprof_bench_3rules_final_508.pdf
[23] Disinfection: CT and Microbial Log Inactivation Calculations: https://www.saskatoonhealthregion.ca/locations_services/Services/Health-Inspection/Documents/WaterQuality/Log_Inactivation_Brochure_2009.pdf

Table 5.1.1.6. Log CT ($CT_{99.9}$) Values for Giardia Cysts by free chlorine[24]

Chlorine Conc. (mg/L)	Temperature <= 0.5°C							Temperature = 5°C							Temperature = 10°C						
	pH							pH							pH						
	<=6.0	6.5	7	7.5	8	8.5	9	<=6.0	6.5	7	7.5	8	8.5	9	<=6.0	6.5	7	7.5	8	8.5	9
<=0.4	137	163	195	237	277	329	390	97	117	139	166	198	236	279	73	88	104	125	149	177	209
0.6	141	168	200	239	286	342	407	100	120	143	171	204	244	291	75	90	107	128	153	183	218
0.8	145	172	205	246	295	354	422	103	122	146	175	210	252	301	78	92	110	131	158	189	226
1.0	148	176	210	253	304	365	437	105	125	149	179	216	260	312	79	94	112	134	162	195	234
1.2	152	180	215	259	313	376	451	107	127	152	183	221	267	320	80	95	114	137	166	200	240
1.4	155	184	221	266	321	387	464	109	130	155	187	227	274	329	82	98	116	140	170	206	247
1.6	157	189	226	273	329	397	477	111	132	158	192	232	281	337	83	99	119	144	174	211	253
1.8	162	193	231	279	338	407	489	114	135	162	196	238	287	345	86	101	122	147	179	215	259
2.0	165	197	236	286	346	417	500	116	138	165	200	243	294	353	87	104	124	150	182	221	265
2.2	169	201	242	297	353	426	511	118	140	169	204	248	300	361	89	105	127	153	186	225	271
2.4	172	205	247	298	361	435	522	120	143	172	209	253	306	368	90	107	129	157	190	230	276
2.6	175	209	252	304	368	444	533	122	146	175	213	258	312	375	92	110	131	160	194	234	281
2.8	178	213	257	310	375	452	543	124	148	178	217	263	318	382	93	111	134	163	197	239	287
3.0	181	217	261	316	382	460	552	126	151	182	221	268	324	389	95	113	137	166	201	243	292

Chlorine Conc. (mg/L)	Temperature = 15°C							Temperature = 20°C							Temperature = 25°C						
	pH							pH							pH						
	<=6.0	6.5	7	7.5	8	8.5	9	<=6.0	6.5	7	7.5	8	8.5	9	<=6.0	6.5	7	7.5	8	8.5	9
<=0.4	49	59	70	83	99	118	140	36	44	52	62	74	89	105	24	29	35	42	50	59	70
0.6	50	60	72	86	102	122	146	38	45	54	64	77	92	109	25	30	36	43	51	61	73
0.8	52	61	73	88	105	126	151	39	46	55	66	79	95	113	26	31	37	44	53	63	75
1.0	53	63	75	90	108	130	156	39	47	56	67	81	98	117	26	31	37	45	54	65	78
1.2	54	64	76	92	111	134	160	40	48	57	69	83	100	120	27	32	38	46	55	67	80
1.4	55	65	78	94	114	137	165	41	49	58	70	85	103	123	27	33	39	47	57	69	82
1.6	56	66	79	96	116	141	169	42	50	59	72	87	105	126	28	33	40	48	58	70	84
1.8	57	68	81	98	119	144	173	43	51	61	74	89	108	129	29	34	41	49	60	72	86
2.0	58	69	83	100	122	147	177	44	52	62	75	91	110	132	29	35	41	50	61	74	88
2.2	59	70	85	102	124	150	181	44	53	63	77	93	113	135	30	35	42	51	62	75	90
2.4	60	72	86	105	127	153	184	45	54	65	78	95	115	138	30	36	43	52	63	77	92
2.6	61	73	88	107	129	156	188	46	55	66	80	97	117	141	31	37	44	53	65	78	94
2.8	62	74	89	109	132	159	191	47	56	67	81	99	119	143	31	37	45	54	66	80	96
3.0	63	76	91	111	134	162	195	47	57	68	83	101	122	146	32	38	46	55	67	81	97

[24] See Note 22.

5.1.2. Recycled Water (Greywater)[25]

Recycle regulations as set forth by California Water Boards through Title 22[26]:

Table 5.1.2.1: Water Quality Standards for Various Water Recycling Sites.

Water Quality Standards for Various Water Recycling Sites (non-potable)		
Water Type	Parameter	Quality Criteria
Disinfected Tertiary (recycled water that has been oxidized, filtered and disinfected)	Total Coliform	1. Median concentration must not exceed 2.2 MPN/100 mL using the last 7 days analyses were completed 2. Must not exceed 23 MPN/100 mL in more than one sample in any 30 day period 3.Must not exceed 240 MPN/100 mL at any time
	Turbidity for Filtration Using Natural Undisturbed Soils or a Filter Bed	1. Must not exceed average turbidity of 2 NTU within a 24-hour period 2. Must not exceed 5 NTU more than 5 percent of the time within a 24-hour period 3. Must not exceed 10 NTU at any time
	Turbidity for Filtration Using Microfiltration, Ultrafiltration, Nanofiltration or Reverse Osmosis	1. Must not exceed 0.2 NTU more than 5 percent of the time within a 24-hour period 2. Must not exceed 0.5 NTU at any time
Disinfected Secondary - 2.2 (recycled water that has been oxidized and disinfected)	Total Coliform	1. Median concentration must not exceed 2.2 MPN/100 mL using the last 7 days analyses were completed 2. Must not exceed 23 MPN/100 mL in more than one sample in any 30 day period
Disinfected Secondary – 23 (recycled water that has been oxidized and disinfected)	Total Coliform	1. Median concentration must not exceed 2.3 MPN/100 mL using the last 7 days analyses were completed 2. Must not exceed 240 MPN/100 mL in more than one sample in any 30 day period

[25] National Primary Drinking Water Regulations: https://www.epa.gov/sites/production/files/2016-06/documents/npwdr_complete_table.pdf
[26] APPENDIX D: TITLE 22 REQUIREMENTS: https://www.napasan.com/DocumentCenter/View/276/Appendix-D-Title-22-Requirements-PDF

Un-disinfected Secondary (recycled water that has been oxidized but not disinfected)	-	-

Table 5.1.2.2: Water Quality Allowable Non-potable usage[27].

Permitted Non-Potable Uses				
	Treatment Level			
Use	Disinfected Tertiary	Disinfected Secondary - 2.2	Disinfected Secondary - 23	Un-disinfected Secondary
Agriculture				
Food crops, including all edible root crops, where the recycled water comes into contact with the edible portion of the crop	X			
Food crops where the edible portion is produced above ground and not contacted by the recycled water	X	X		
Any nonedible vegetation where access is controlled so that the irrigated area cannot be used as recreation areas	X	X	X	
Urban Irrigation				
Residential landscaping	X			
Other Uses				
Flushing toilets and urinals	X			
Cleaning roads, sidewalks and outdoor work areas	X			

[27] See note 25.

5.1.3. Rainwater[28]

Rainwater regulations as set forth by the Environmental Protection Agency:

Table 5.1.3.1: Rainwater Water Quality Guidelines.

Minimum Water Quality Guidelines and Treatment Options for Stormwater Reuse	
USE	Minimum Water Quality Standards
Potable Indoor Use	Total Coliforms = 0
	Fecal Coliforms = 0
	Protozoa Cyst = 0
	Viruses = 0
	Turbidity < 1 NTU
Non-potable Indoor Use	Total coliforms < 500 cfu per 100 ml
	Fecal coliforms < 100 cfu per 100 ml

Table 5.1.3.2 Rainwater Water Suggested Treatment[29].

	Suggested treatment
Potable Indoor Use	1. Pre-filtration – first flush diverter 2. Cartridge filtration – 3 micron sediment filter followed by 3 micron activated carbon filter 3. Disinfection – chlorine residual of 0.2 ppm or UV disinfection
Non-potable Indoor Use	1. Pre-filtration – first flush diverter 2. Cartridge filtration – 5 micron sediment filter 3. Disinfection – chlorination with household bleach or UV disinfection

Compliance Assurance:

1. Annual water quality monitoring is highly recommended.
2. Regular system inspection and maintenance to replace spent/worn out components such as UV-lamps and filters.
3. Cross-contamination should be avoided by strictly coding the piping system and preventing the infiltration of grey water into the system. Backflow prevention measures are necessary.

[28] Municipal Handbook Rainwater Harvesting Policies: https://www.epa.gov/sites/production/files/2015-10/documents/gi_munichandbook_harvesting.pdf
[29] See Note 27.

5.1.4. Groundwater[30]

Groundwater rule as set forth by the Environmental Protection Agency[31]:

Table 5.1.4.1: Groundwater Rule requirements

GWR Requirement
Provide 4-log virus treatment for all groundwater sources or meet the triggered source water microbial monitoring requirements.
Correct source fecal contamination within 120 days of notification
Correct significant deficiencies identified by the State within 120 days of notification.

Compliance Assurance:

- Regularly monitor the source on a state-specified schedule that could last for an extended period (e.g. 12 months).
- A Hydrogeologic Sensitivity Assessment (HSA) might be conducted to determine if the source of groundwater comes from a sensitive hydrogeologic setting.
- If the water sample has fecal indicator-positive, five additional samples should be taken within 24 hours of the being notified. The GWR requires corrective action in case that any of these samples also test positive. The GWR also requires that the public is notified accordingly.
- Residual disinfectant should provide 4-log removal (99.99% disinfection). Sampling should occur daily at peak flow or another time specified by the State. If the residual level follows below the specified amount, sampling should be taken every 15 minutes until the levels are restored to normal values.
- Certain information will be reported to consumers (i.e. fecal indicator, failure to correct deficiency, etc.), certain information will be reported to the state (i.e. failure to meet treatment requirements, completion of corrective action, etc.), and certain information must be kept filed (i.e. documation of any corrective action taken, documentation of meeting state-specified criteria).

[30] National Primary Drinking Water Regulations: https://www.epa.gov/sites/production/files/2016-06/documents/npwdr_complete_table.pdf
[31] Compliance Timetable for Systems Serving Fewer than 10,000 People: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=60000K72.txt

5.1.5. Surface Water (Stormwater)[32]

For surface water, according to the SWTR, along the IESWTR and LT1ESWTR, the following requirements regarding Giardia Cyst, Viruses, and Cryptosporidium should be met when the listed below technologies are employed[33]:

Table 5.1.5.1: Surface water treatment requirements.

Log Removal/Inactivation through Filtration and Disinfection Required Under the 1989 SWTR		
	Log Removal requirements	
Process	Giardia Cyst	Viruses
Conventional sedimentation/filtration credit	2.50	2.00
Disinfection inactivation required	0.50	2.00
Direct filtration credit	2.00	1.00
Disinfection inactivation required	1.00	3.00
Slow sand filtration credit	2.00	2.00
Disinfection inactivation required	1.00	2.00
Diatomaceous earth credit	2.00	1.00
Disinfection inactivation required	1.00	3.00
No filtration	0.00	0.00
Disinfection inactivation required	3.00	4.00

Disinfection:

- Disinfection residual concentration at the point of entry cannot be lower than 0.2 mg/L for more than 4 hours.
- Disinfectant concentration must undergo continuous monitoring and the lowest value should be recorded daily.
- Grab sampling should be conducted at least once a day, unless the residual concentration falls below 0.2 mg/L. Then grab sampling should be conducted every 4 hours until the concentration reaches the required levels.
- In case of failing to comply with the concentration requirements, the EPA should be notified immediately.
- The residual disinfection concentration in the distribution system cannot be undetectable or have an HPC of more than 500 mg/L in more than 5% of the samples in one month for a period of 2 consecutive months.

[32] National Primary Drinking Water Regulations: https://www.epa.gov/sites/production/files/2016-06/documents/npwdr_complete_table.pdf
[33] SWTR FACT SHEET - EPA Region 8: https://www.epa.gov/sites/production/files/documents/SWTR_Fact_Sheet.pdf

Compliance Assurance:

1. Daily log sheets and daily/weekly contact time calculations should be kept on file for a period of at least 5 years.
2. Turbidity monitoring results should be kept for at least 3 years.
3. Disinfection profiling and benchmarking should be kept indefinitely.
4. Monthly SWRT reports should be submitted monthly to the EPA Region 8 office.

5.2. Supply

An office building needs to satisfy a varied demand for water, as described earlier in the document (section 4.1). According to the Living Building challenge, this water needs to fulfil a closed-loop system, where no potable water might be used for non-potable activities, and no chemicals can be used to treat water. However, a connection to the main water line can be performed provided that the recycled/collected water is not enough to satisfy demand.

Regarding water supply, there are four main points of focus:

1. Water from rainwater: capture, treatment, storage, and distribution
2. Greywater treatment and resupply
3. Groundwater from well
4. Water connection to the municipal supply line

The first three points will influence the amount of water that can be supplied without having to rely on an external connection, with the two first options being the most likely. Point four will determine whether the building will require a physical connection to the main water supply line.

5.2.1. Rainwater

In general, rainwater would be one of the most important methods to consider when contemplating a closed-loop water supply system. However, the climate in Southern California, namely in Santa Monica, is not the most convenient to develop a stormwater collection system. This is the rainfall pattern in the region:

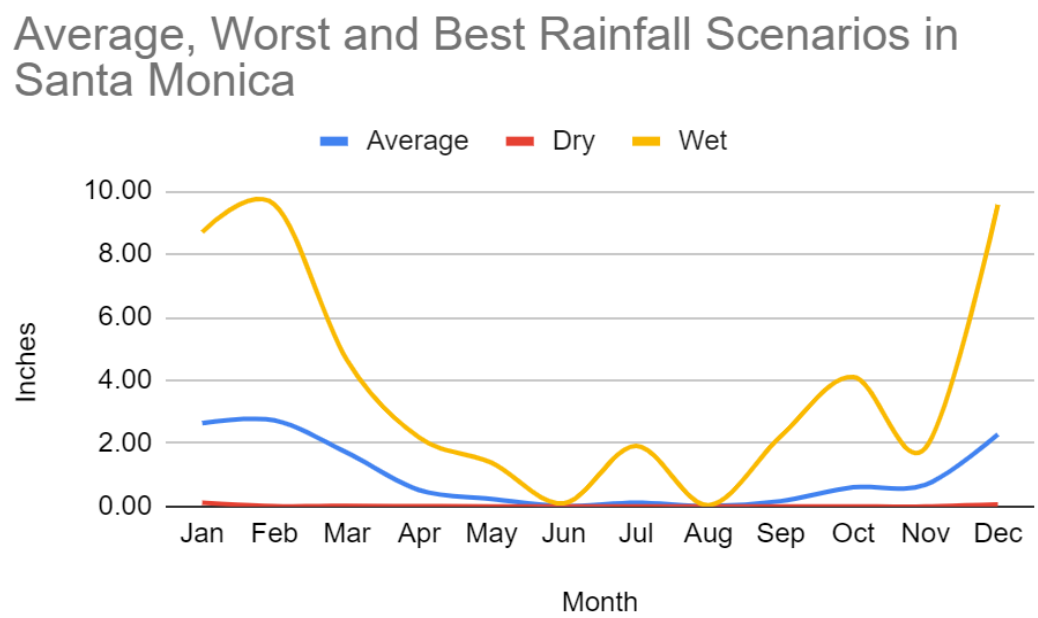

Figure 5.2.1.1: Rainfall data from the Western Regional Climate Center.

In order to develop such a system given the scarcity in rainfall, it is necessary to optimize the collection and storage of rainfall in order to supply the building with as much water as possible. To do so, it is crucial to maximize water storage and both collection and distribution efficiency.

The rainwater harvesting technology consists of three main components: the collection system, a storage tank, and the treatment system. The design of the tank will determine the time the water can be stored to avoid stagnation and prevent it from becoming unusable, while the rooftop catchment area and collection system will optimize the gathering of rainwater, and the pump along with the piping and treatment systems will influence the efficiency in distribution. The amount of rainwater captured daily will have a value of (roughly) 8,800 gal/day in the best case scenario during the most rain-abundant month (February). The following table illustrates this case, along with the average and dry scenarios:

Table 5.2.1.2: Rainwater capture with 45,525 sqft. of catchment area. For total monthly values multiply each individual value by the number of days in that month (i.e July(wet) = (1,757.56) * (31 days) = 54,484.6 gallons per month)

Total Monthly Rainwater Capture (gal) - Daily values			
Month	Average	Dry	Wet
Jan	2417	110	7964
Feb	2767	10	9709
Mar	1565	18	4257
Apr	492	9	2072
May	220	0	1272

Jun	9	0	95
Jul	110	0	1758
Aug	9	0	37
Sep	161	0	2109
Oct	558	0	3762
Nov	653	0	1759
Dec	2096	64	8760

All in all, there is *not enough water* - even with the most optimal outlook given the rain conditions - to satisfy a closed-loop water system year round. Considering there are 620 workers who use around 12.5 gallons of water per day each, that would mean that the office at least required 9,300 gallons of water per day; calculations show that the most that can be captured through a rainwater catchment system is 9700 gallons roughly, in the most rainy month. However, the remaining months would be water-scarce. This estimate does not include any water that would be used by any activity other than worker's needs and wellbeing (i.e. outdoors amenities, retail facilities, etc.).

5.2.2. Greywater

Another crucial approach to tackle closed loop water supply systems is grey water and wastewater treatment and resupply. Wastewater from toilet flushing can be redirected towards a composting system. Given toilets that flush at 0.125 GPF, and considering an average of 2.5 flushes/person/day, then a total of 0.3125 gallons a day per person would be employed for toilet composting/recycling. This system is preferred because of the difficulty in recycling toilet water, and the additional benefits of composting, namely nutrients-rich products that can be used as fertilizers. This can be complemented with a urine-diverting mechanism to separate solid waste from liquid waste. The composting system consists of a composting chamber, a ventilation system, and the pertinent piping system.

Water from showers and faucets can be recirculated more easily for further re-use. This can be achieved by the implementation of a filtration/disinfection system constructed on-site. This water, however, is not for potable reuse. Calculated estimates indicate that in-office faucet usage is 6.5 gal/person/day, while shower usage is 8 gal/person/day. These figures will be greater due to the water usage in non-office settings, which were calculated to be around 12 gallons/square foot per month for retail space and 0.25 gallons/square foot per day for food stand space.

5.2.3. Groundwater

At a depth of 50 feet[34], the groundwater table can be also employed as a water resource. This system would consist of a submerged pump and well casing/screens to prevent sediment filtration. A pressurized tank confined underground would then be employed to collect the water, then it would then undergo proper filtration so it could be used for drinking purposes.

Even though theoretically the source is unlimited at small scale, it would be beneficial to minimize the utilization of a groundwater aquifer since underground water recharge is an extremely slow process compared to superficial water recharge (i.e. rivers, lakes, etc).

5.2.4. Municipal Line

Given the scarcity of water supply in the region, and provided that it will be impossible to satisfy the water demand considering the upper water consumption threshold per person per day, it will be crucial to have a connection line to supply water from a central water treatment facility. This supply will complement the well water and the rainwater. This will have seasonal variations since the amount required will depend on the total rainfall and the amount of workers present at any given period, along with the total water withdrawn from the private well.

5.3. Process Flows

5.3.1. Overall Process Flow

The treatment processes will vary based on source of water. The primary source of water will be rainwater collected on site, treated, and stored for use. When rainwater does not meet current demand, groundwater will be used to supplement after being treated. From there, potable water will be used for various purposes in the building and become grey water. Grey water will be used for composting toilets and irrigation purposes and directed to the percolation basin and later groundwater aquifer for indirect reuse. All storage basins are suited to store water for a week’s worth of demand.

[34] Well depth provided by Gregg Drilling: http://www.greggdrilling.com/wp-content/uploads/2017/10/Southern-California-Groundwater-Depth-Table.pdf

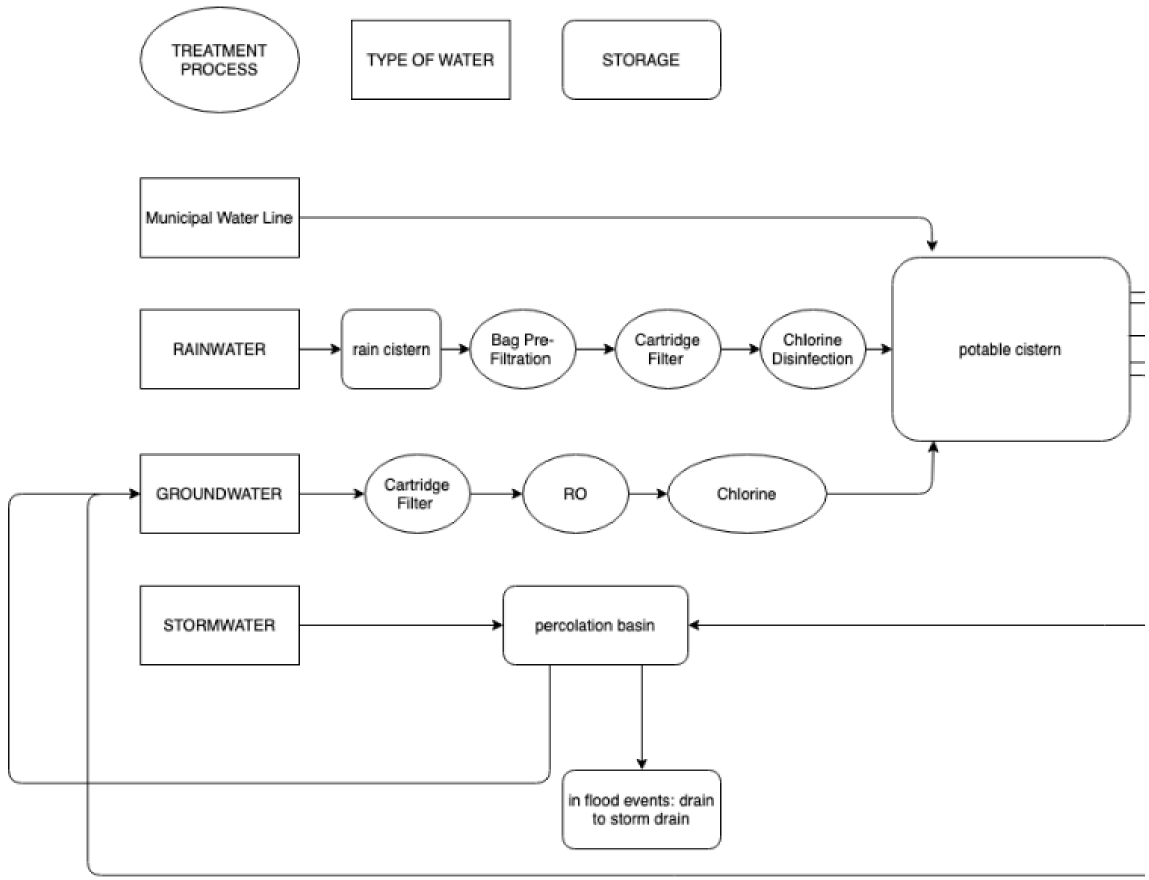

Figure 5.3.1.1: Overall Process Flow Diagram, upstream of potable cistern

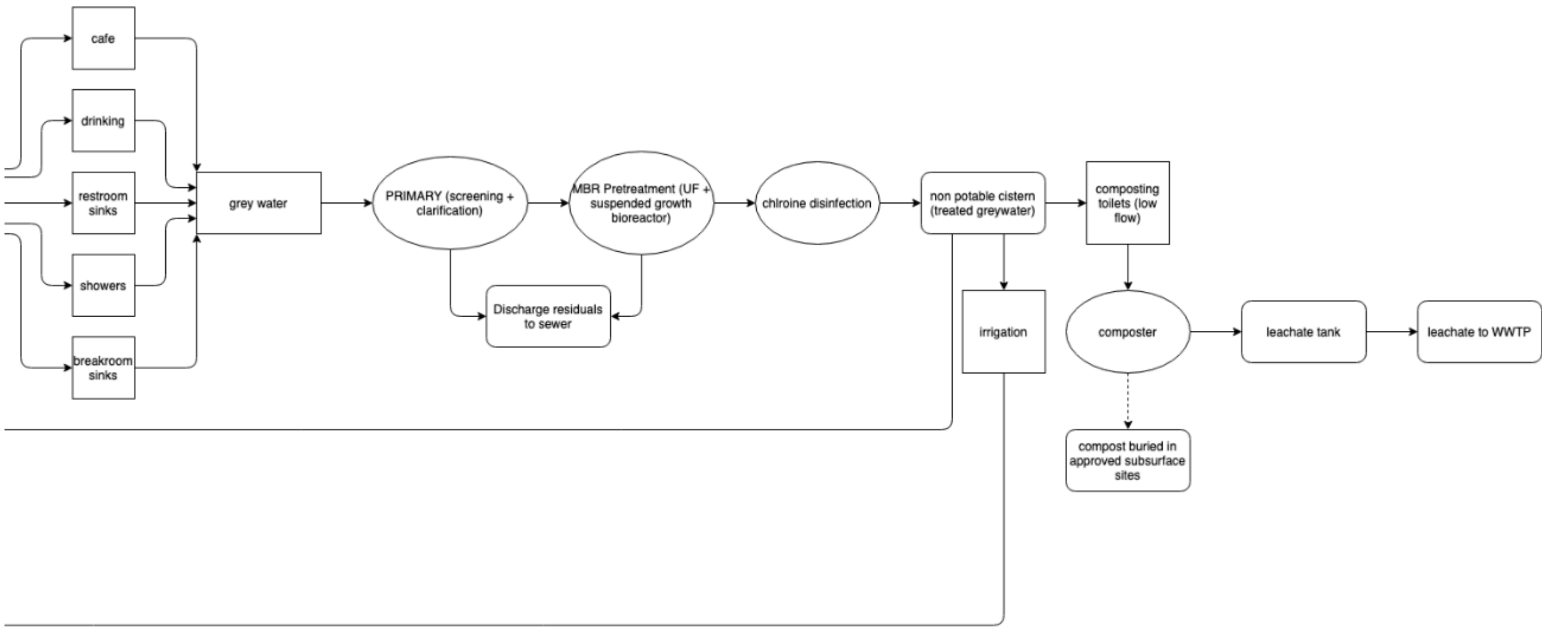

Figure 5.3.1.2: Overall Process Flow Diagram, after points of use

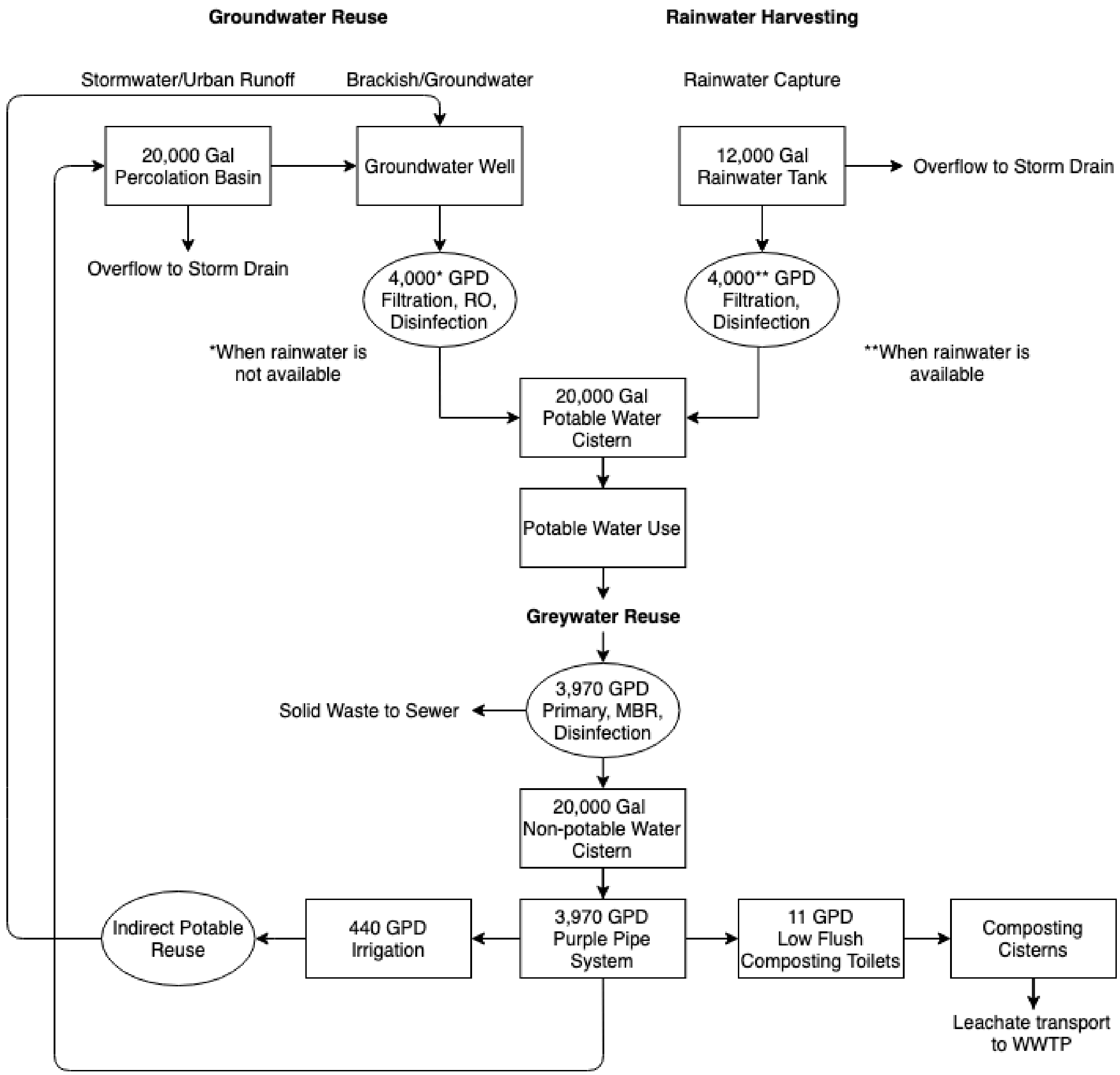

Figure 5.3.1.3: Conceptual Process Flow Diagram

5.3.2. Rainwater Treatment

Rainwater will be treated according to current regulatory requirements for potable water use. After collection, rainwater will go through cartridge filtration and then disinfection with chlorine and sodium hydroxide. Chlorine is added to have a residual once water is stored in a potable cistern, and sodium hydroxide is added to raise the natural pH of rainwater. When rainwater levels are low and unable to provide constant flow to the disinfection tank, this change will be measured by a flowmeter and will direct a valve to divert remaining rainwater to the percolation basin. This is done so that the volume in the disinfection tank does not change, and the concentration of disinfectants will stay constant.

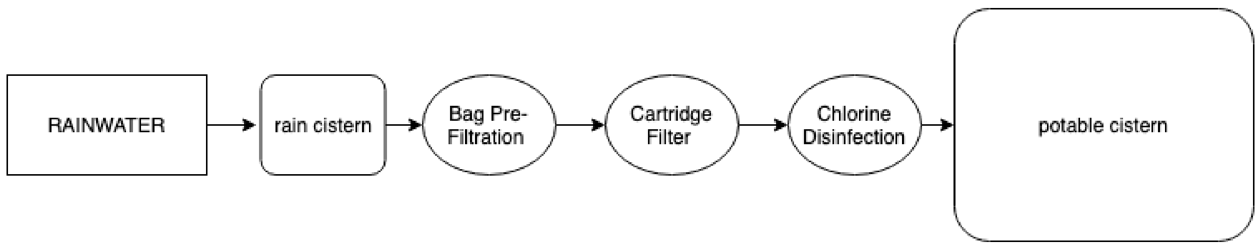

Figure 5.3.2.1: Process Flow Diagram for Rainwater Treatment

The process and instrumentation diagram for the rainwater treatment is shown below, as well as sectional views of the treatment equipment.

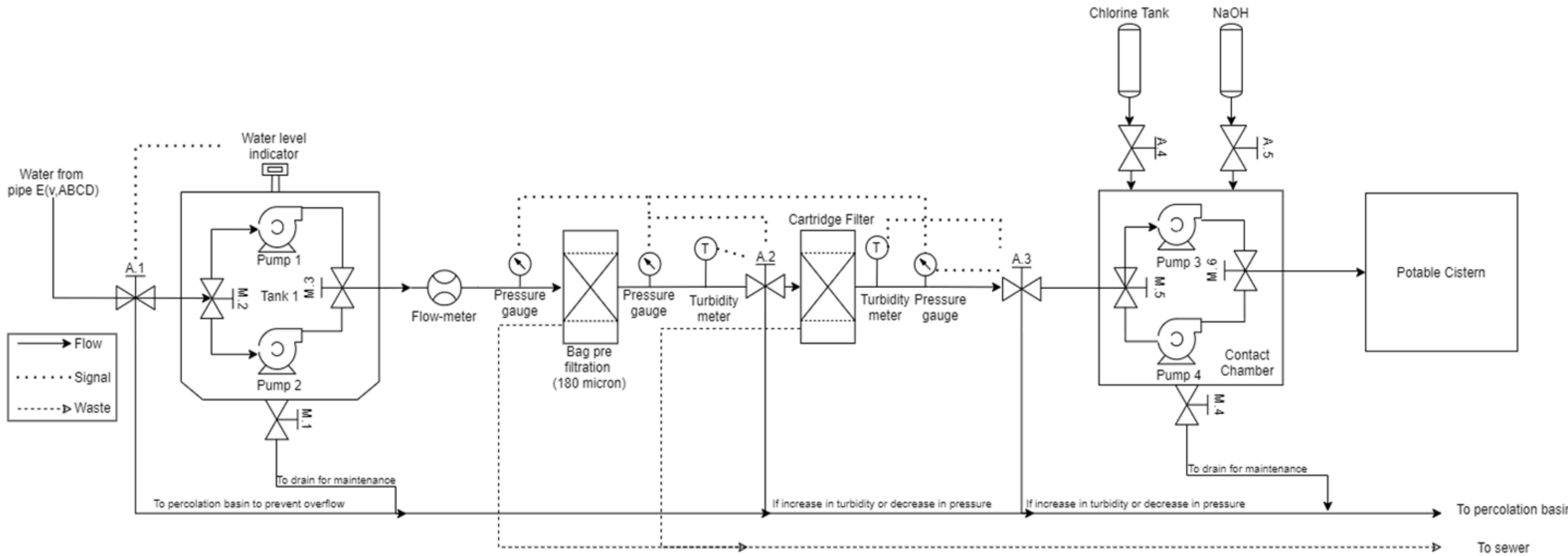

Figure 5.3.2.2: Process and Instrumentation Diagram for Rainwater Treatment

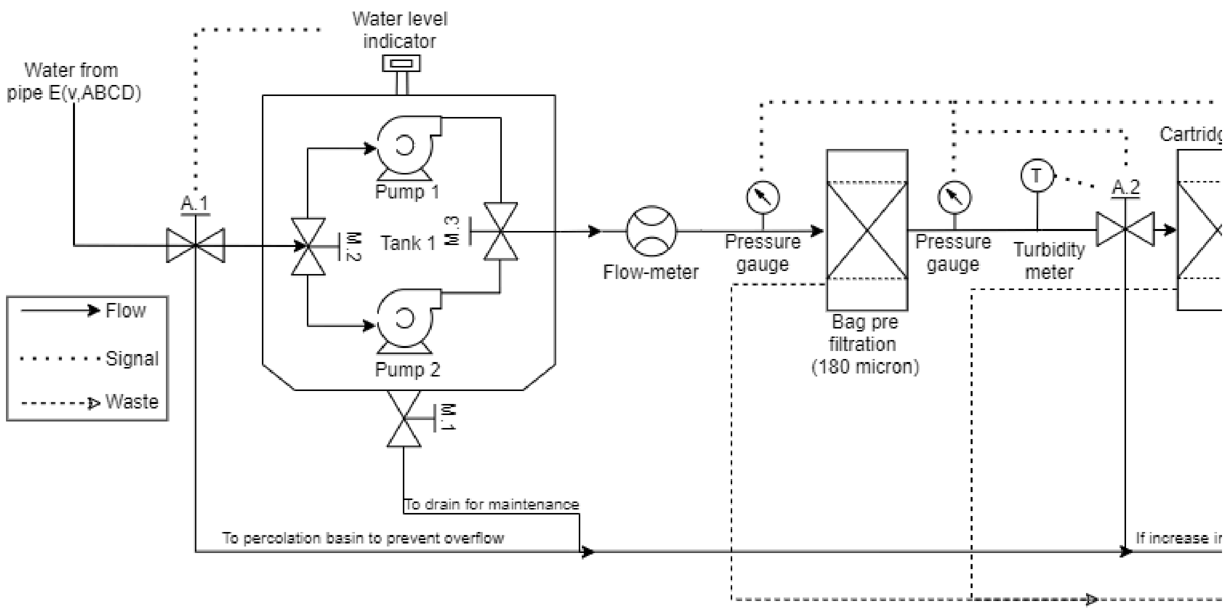

Figure 5.3.2.3: Process and Instrumentation Diagram for Rainwater Treatment - Upstream

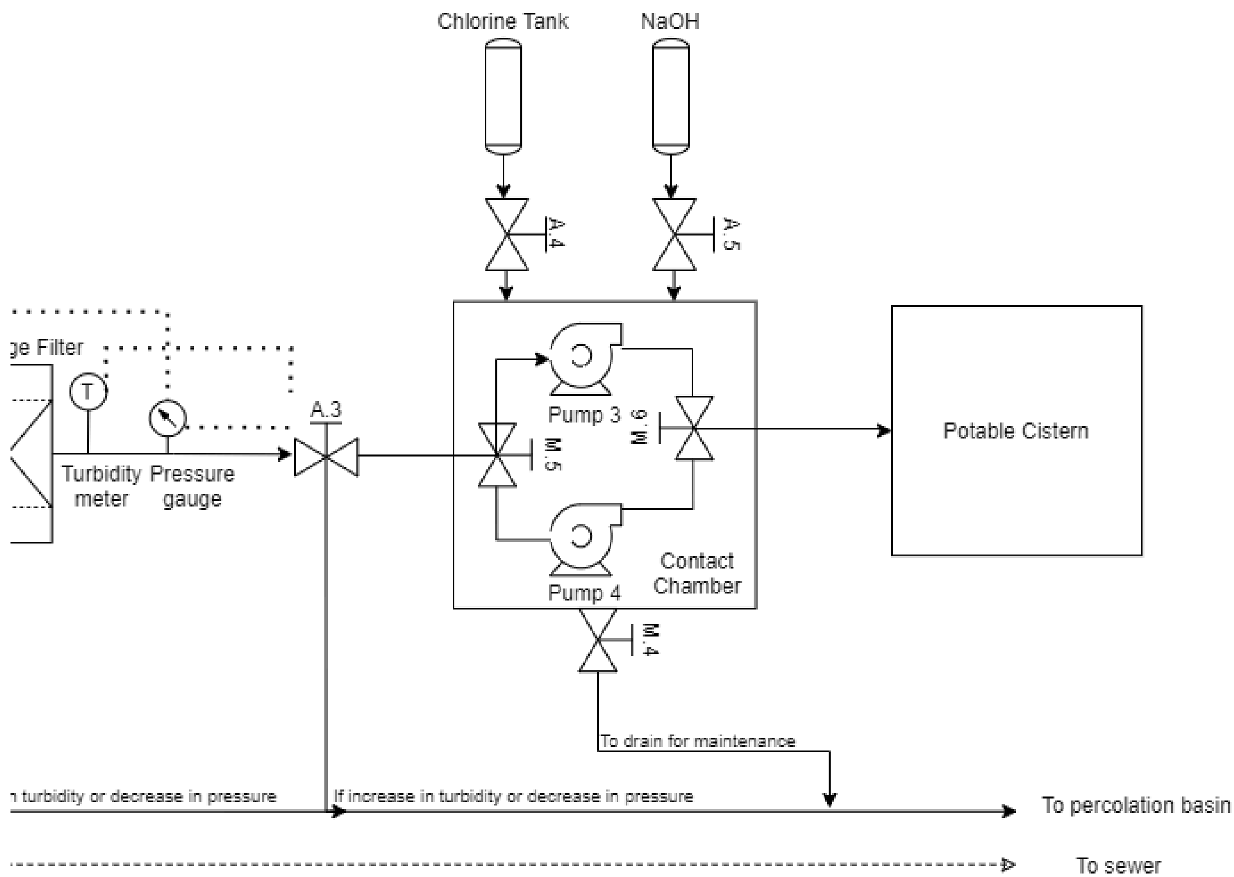

Figure 5.3.2.4: Process and Instrumentation Diagram for Rainwater Treatment - Downstream

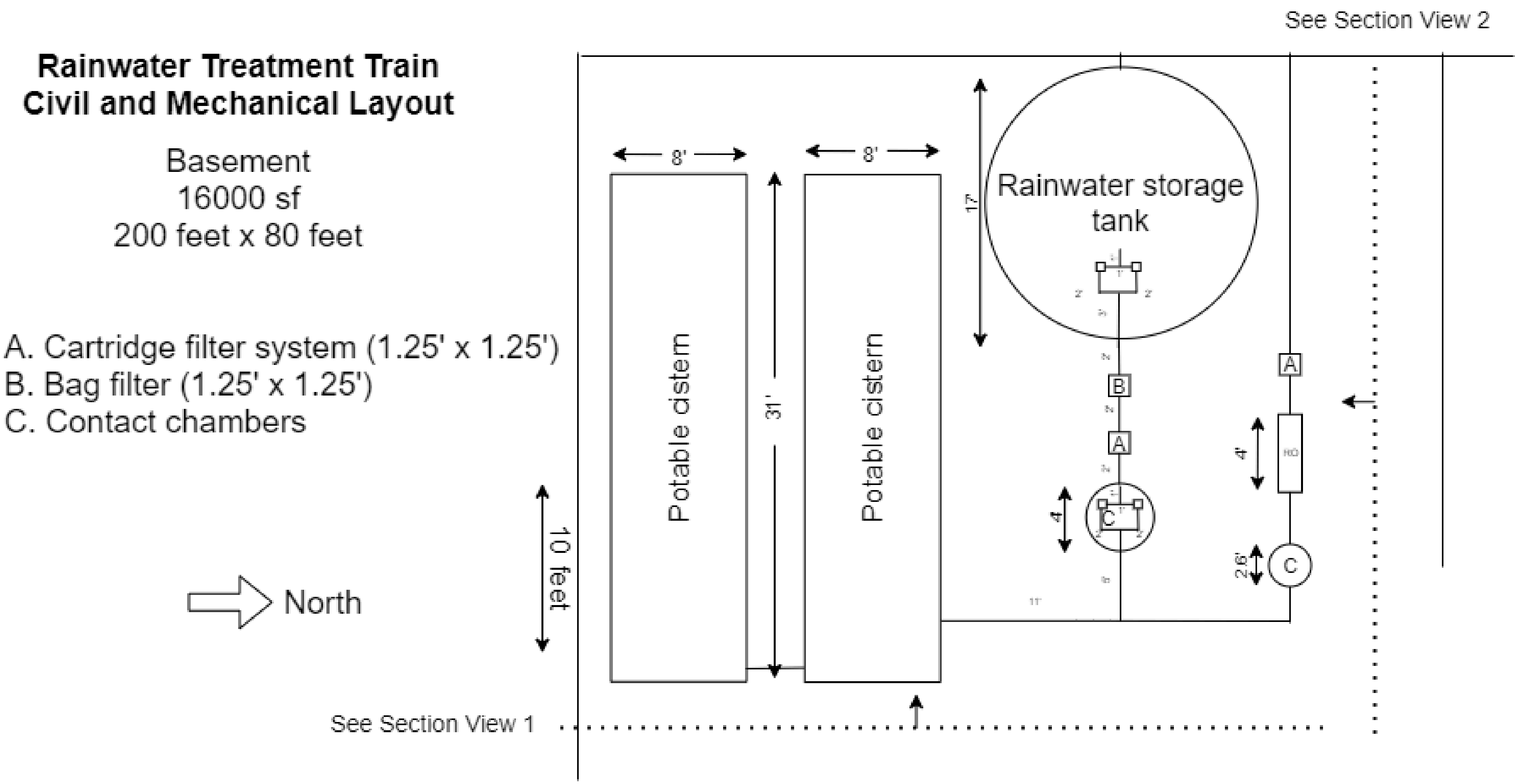

Figure 5.3.2.5: Close up civil and mechanical layout for rainwater treatment train

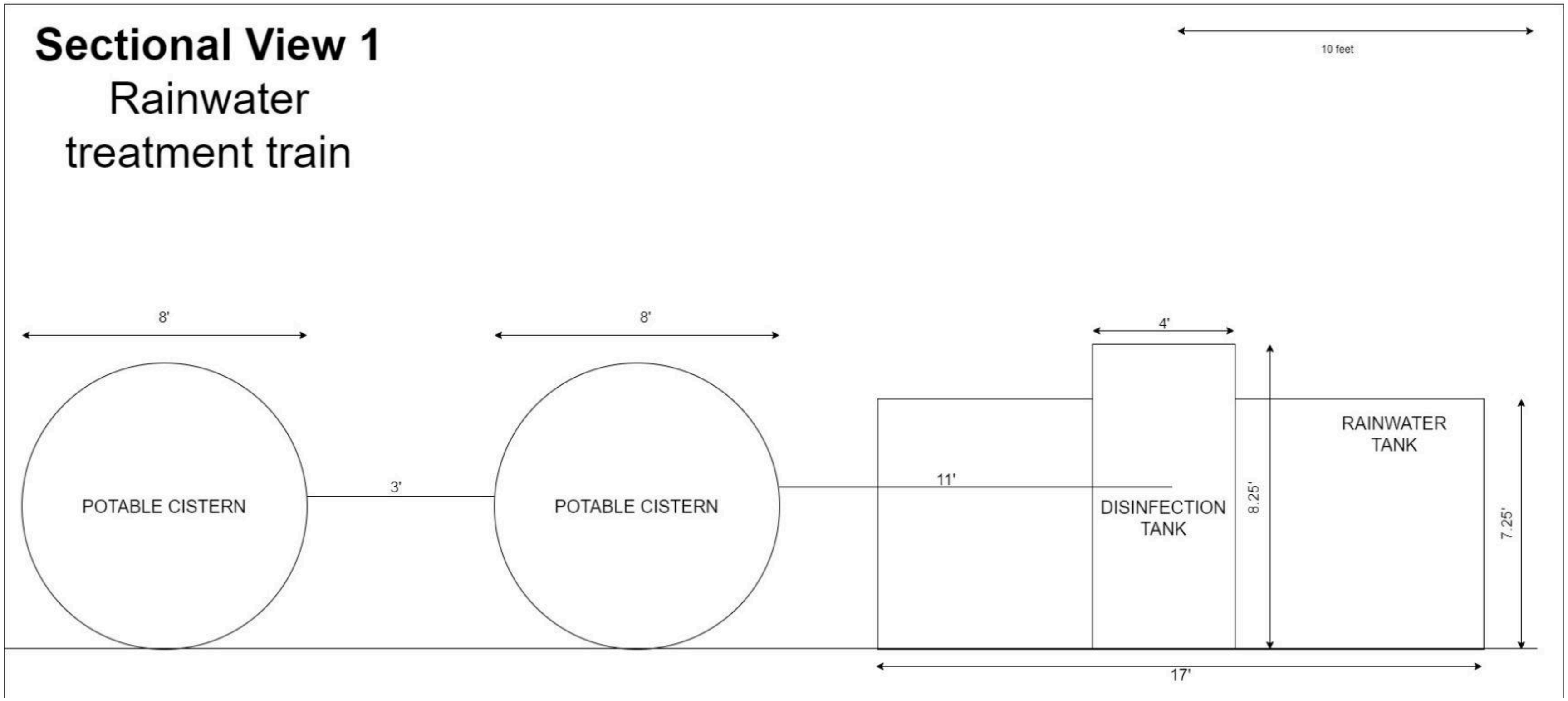

Figure 5.3.2.6: Sectional view of rainwater treatment train, west

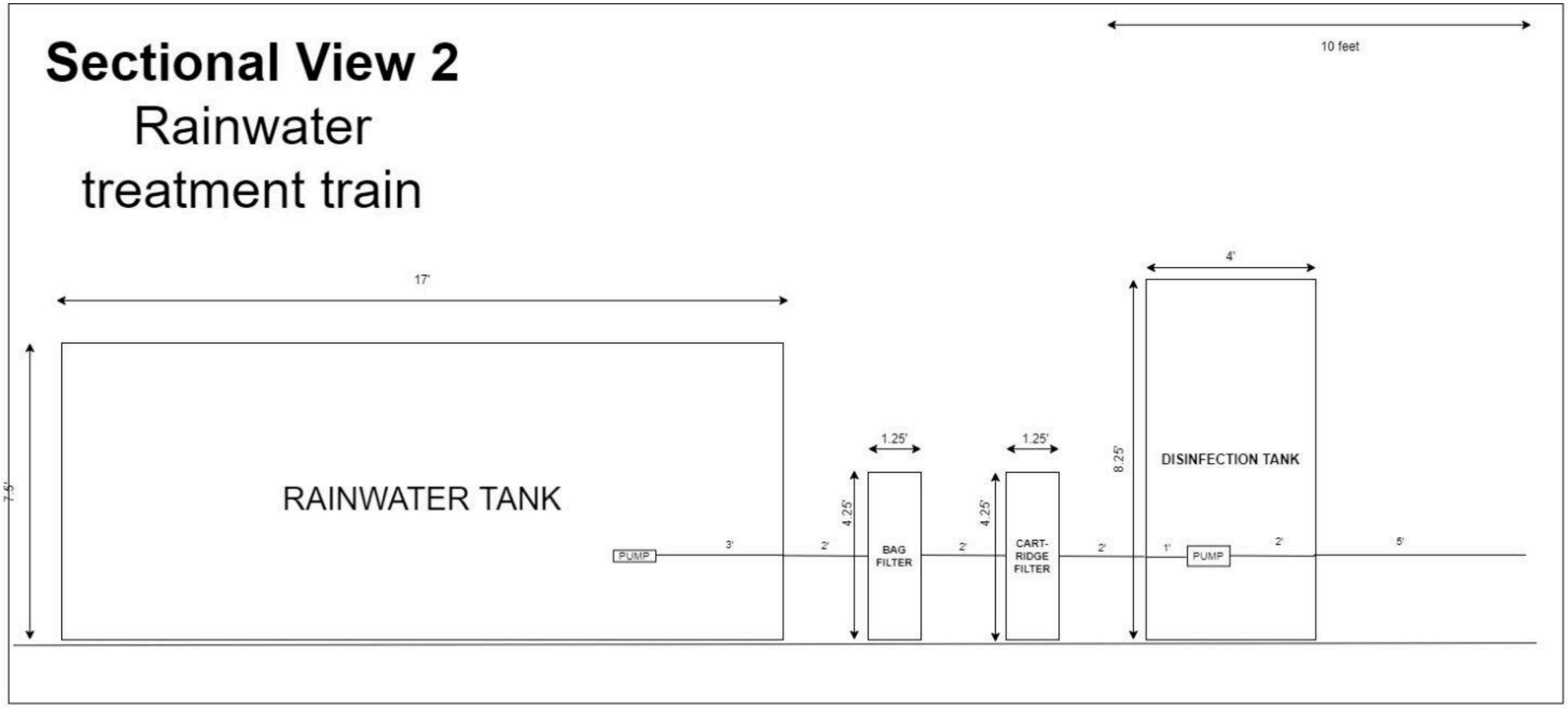

Figure 5.3.2.7: Sectional view of rainwater treatment train, south

These are the design criteria for the rainwater treatment train:

Table 5.3.2.1 - General rainwater parameters for wet season (max possible flow)

	Rainwater Capture Design Criteria - Wet season (Max flow) - Basement components			
	Parameter	Units	Value	Comments
General	Max flow	gpd	9,709	Max flow from calculated table.
	Average flow	gpm	5 gpm	Average flow as calculated from disinfection.
	Flow meter	number	1	To check if the required flow is being pumped through the filters.
	Power	-	N/A	
	Containment tank[35]	number	1	One containment tank that can undergo maintenance during dry months. Low risk of failure. Extra 3,000 gallons for redundancy in case there is an extreme rainfall event (note that values are monthly averages).
	Volume	gal	12,000	
	D	ft	204	
	H	ft	95	
	Automatic Motor Valve	number	5	Functions explained in P&iD diagram (A.1 - A.3). Valves A.4 and A.5. are for chemical delivery.
	Power	Power	N/A	
	Mechanic Valve	number	6	Two mechanically operated valves for pump service.
	Power	Power	--	
	Pressure gauge	number	3	To measure pressure drop for the filters.
	Power	Power	N/A	
	Turbidity-meter	number	2	To measure turbidity between the filters.
	Power	Power	N/A	
	Water Level Indicator	number	1	Will signal A.1 and A.2 if water level exceeds 11,900 gallons to discharge water into the percolation basin stream.
	Power	Power	N/A	

[35] Equipment specification sheet can be found in Equipment List

Table 5.3.2.2 - Filtration rainwater parameters for wet season (max possible flow)

	Rainwater Capture Design Criteria - Wet season (Max flow) - Basement components			
	Parameter	Units	Value	Comments
Filtration	Type	type	Bag filter	Pre-filtration. 99% filtration for 5 gpm.
	Maelstrom Rainwater Filter[36]			
	Number	number	1	
	Average flow	gpm	5	
	Size	-	-	
	Width	inch	19.9	
	Height	inch	15.4	
	Pore size	micron	180	
	Throughput	%	96 - 99	
	Pressure drop	psid	20	
	Replacement	months	12	
	Type	type	Filter Cartridge	Certified cartridges by the Title 22 California Code of Regulation for log-removal, Title 21 of the U.S. Code of Federal Regulations for materials, and NSF - 61 certificated.
	Harmsco Cartridge (LT2 Filter) - HC/40-LT2[37]			
	Number	number	1	
	Flow	gpm	5	
	Pressure drop	psid	30	
	Size	-	-	
	Outer diameter	inch	7.75	
	Inner diameter	inch	2.75	
	Height	inch	9.62	
	Pore size	micron	0.35	
	Throughput	%	99	
	Replacement	months	12	
	Log removal	type	Conventional + Cartridge	
	Giardia	log	2.5	

[36] Equipment specification sheet can be found in Equipment List
[37] Equipment specification sheet can be found in Equipment List

	Virus	log	0	
	Crypto	log	2	
	MUNI-40 MP[38]			-
	Number	number	1	
	Floor space	in^2	225	
	Height	inch	19.5	
	Service Height	inch	35	

Table 5.3.2.3. - Pumping rainwater parameters for wet season (max possible flow)

	Rainwater Capture Design Criteria - Wet season (Max flow) - Basement components			
	Parameter	Units	Value	Comments
Pumping	5SQ05-180 (200-240VAC, 77 psi @ 5 GPM)[39]			
	Number	number	2	Two pairs of pumps for redundancy in case of failure.
	P.1. and P.2	location	-	Inside tank 1
	5SQ05-140 (200-240VAC, 60 psi @ 5 GPM)[40]			
	Number	number	2	Two pairs of pumps for redundancy in case of failure.
	P.3. and P.4	location	-	Inside contact chamber
	Type	-	submerged pump	
	Head	ft	140	Attached in spec sheet
	Design Capacity	gpm	5	As calculated from disinfection requirements.
	Power	hp	0.5	Attached in spec sheet
	Size	-	-	
	H	in	30.4	
	D	in	2.9	

[38] Equipment specification sheet can be found in Equipment List
[39] Equipment specification sheet can be found in Equipment List
[40] Equipment specification sheet can be found in Equipment List

Table 5.3.2.4. - Disinfection rainwater parameters for wet season (max possible flow). The chemical concentration is calculated based on 7 days of storage, with a steady flow of roughly 5 gpm. The total volume required should be distributed equivalently throughout the week (7 days).

	Rainwater Capture Design Criteria - Wet season (Max flow) - Basement components			
	Parameter	Units	Value	Comments
Disinfection	Chlorine tank	number	1	
	Volume	gal	0.5	See calculations table in appendix. 7 day storage. NaOCl 13% solution.
	Concentration feed	mg/L	1.5	Typical range 1 ~ 2 mg/L
	Sodium Hydroxide tank	number	1	
	Volume	gal	0.8	See calculations table in appendix. 7 day storage. NaOH 12% solution.
	Concentration feed	ph	7.5	Required to raise the pH of rainwater (5.5) for disinfection.
	Contact Chamber	-	-	Changed pH to 7.5, only had to increase tank to 700 gal but everything else stayed the same
	700 Gallon Dura-Cast Vertical Water Tank[41]			
	Number	number	1	
	Volume	gal	700	Required volume to operate at 5 gpm.
	H	inches	99.28	
	D	inches	47	
	Baffling Capacity	factor	0.5	Average baffling capacity.
	Inactivation	-	-	
	Virus (ph = 6.5, 20C)	log	> 2.00	
	Giardia (ph = 6.5, 20C)	log	0.5	
	HRT (τ) w/buffering	min	139	Calculated
	Flow	gpm	5	Calculated

[41] Equipment specification sheet can be found in Equipment List

This is the hydraulic profile:

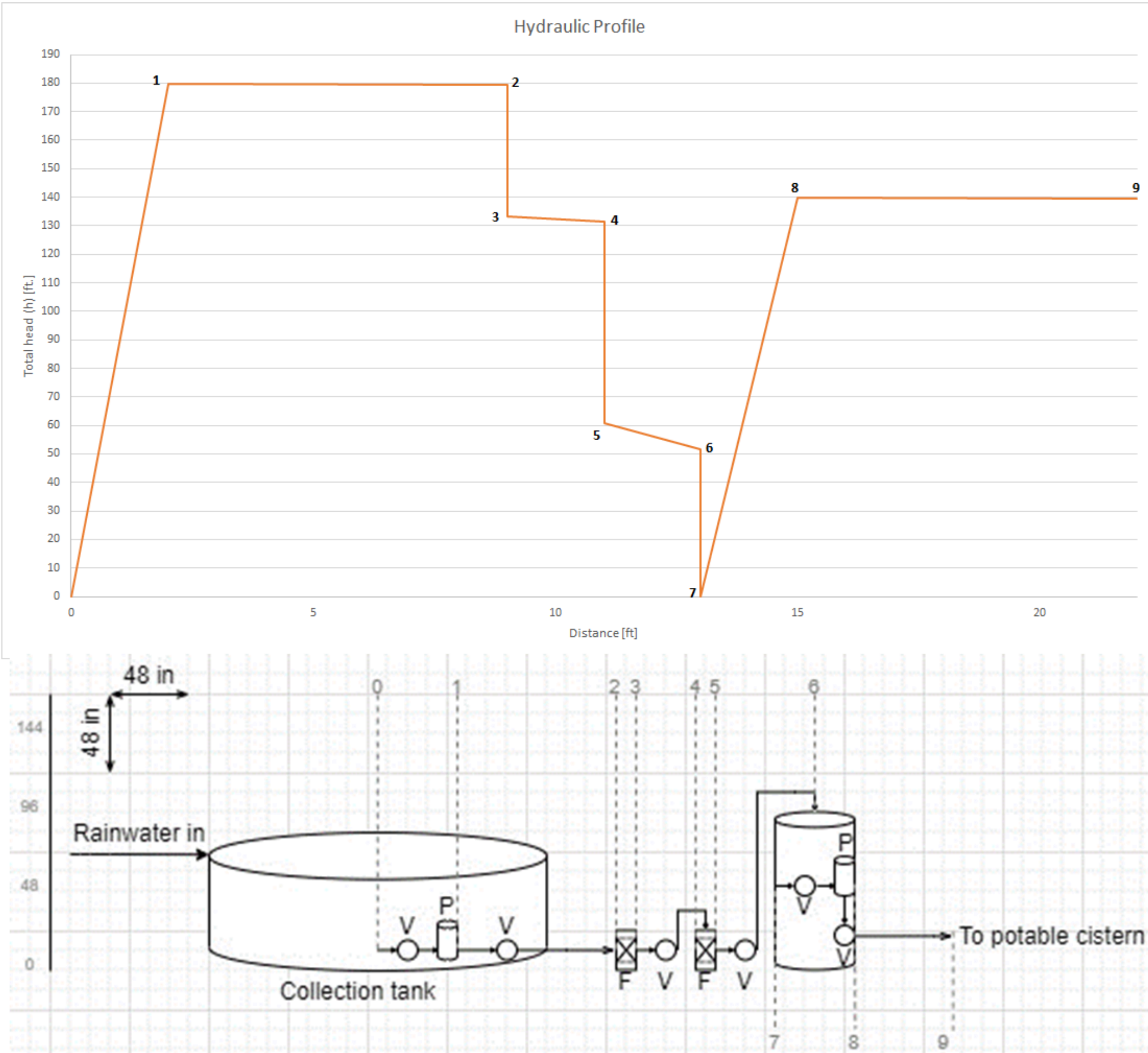

Figure 5.3.2.8: Hydraulic profile rainwater treatment

As it can be observed from this graph, the first jump provides 180 ft. of head with a submerged pump (5SQ05-180 (200-240VAC, 77 psi @ 5 GPM)). This head will be enough to filter water through bot clean and dirty filters. The second pump provides a max head of 140 ft. (5SQ05-140 (200-240VAC, 60 psi @ 5 GPM)). Both pumps are submerged within the tanks.

This is the flow balance:

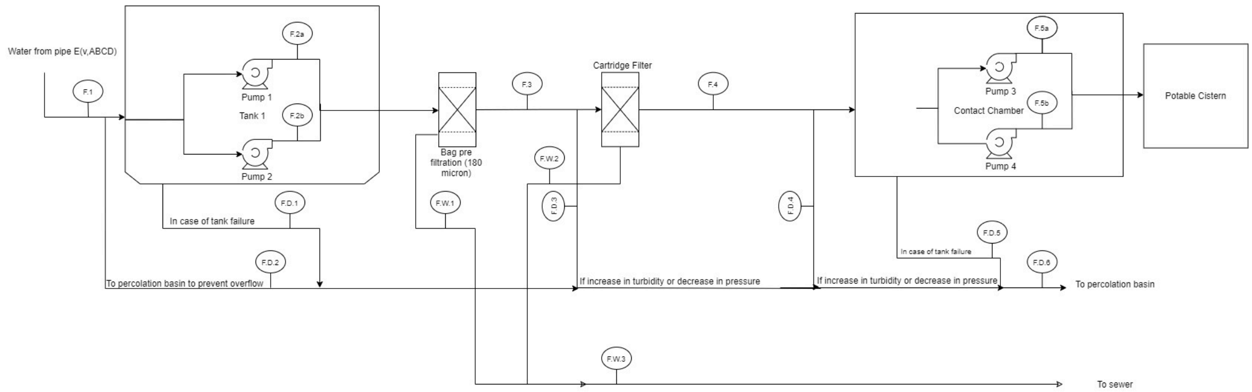

Figure 5.3.2.9: Flow balance - full diagram

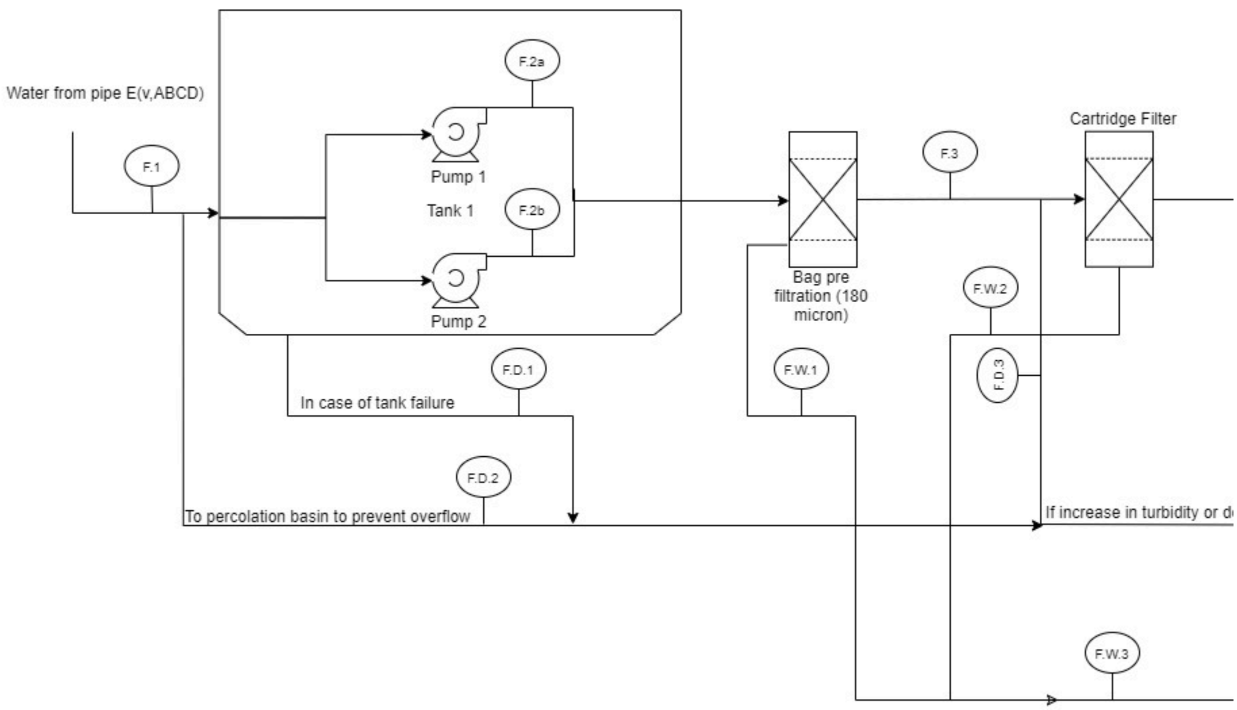

Figure 5.3.2.10: Flow balance - upstream segment

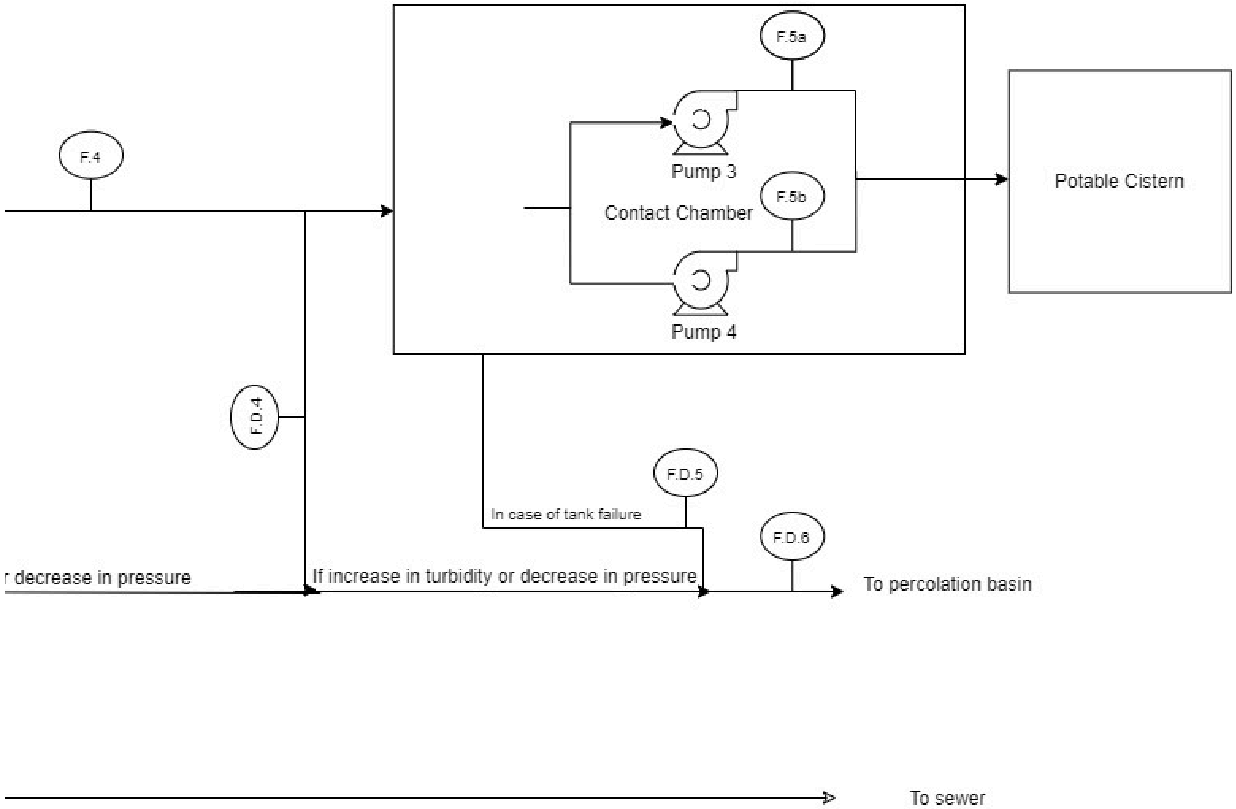

Figure 5.3.2.11: Flow balance - downstream segment

Table 5.3.2.5 - Primary flow - segment balance. Note that rainwater coming in is less than water leaving the first tank. This is because water is temporarily stored within the tank.

Primary flow								
Flow #	Units	F1	F.2a	F.2b	F.3	F.4	F.5a	F.5b
		Rainwater inflow	Tank 1 effluent -Pump 1	Tank 1 effluent -Pump 2	Bag filter effluent	Cartridge filter effluent	Contact chamber effluent - Pump 3	Contact chamber effluent - Pump 4
Flow	gpm	6.742361	5	5	4.95	4.9005	4.9	4.9
Comments		From design table	Pumps 1 and 2 will work one at a time (i.e. 5 gpm flow and not 10 gpm flow)		99% efficient	99% efficient	-	-

Table 5.3.2.6. - Diverted flow - segment balance.

Diverted flow							
Flow #	Units	F.D.1	F.D.2	F.D.3	F.D.4	F.D.5	F.D.6
		Tank 1 effluent (overflow)	Tank 1 effluent (Failure)	Bag filter effluent (failure)	Cartridge filter effluent (failure)	Contact chamber effluent (failure)	Max to percolation basin
Flow	gpm	6.742361	0.589399	4.95	4.9005	0.4111733	6.742361
Comments		max flow from rain being diverted	For a 2" pipe (no pump - gravity flow)	all bag filter flow being diverted	all cartridge filter flow being diverted	For a 2" pipe (no pump - gravity flow)	max possible flow

Table 5.3.2.7 - Waste flow - segment balance.

Waste flow				
Flow #	Units	F.W.1	F.W.2	F.W.3
		Waste effluent from bag filter	Waste effluent from cartridge filter	Combined sewer flow
Flow	gpm	0.05	0.0495	0.0995
Comments		-	-	-

5.3.2.1. Rainwater Treatment Controls

Rainwater treatment equipment will be controlled as follows:

a. *Rainwater Tank Valve*

The rainwater tank valve will be controlled manually at the variable frequency drive (VFD) or remotely from the control center. The operator will have the ability to open the valve in case the tank experiences a failure or if the tank is approaching maximum capacity. If opened, the valve will direct rainwater from the tank to the percolation basin.

b. *Rainwater Tank Pump*

The rainwater tank pump is a variable speed pump that can be controlled manually at the variable frequency drive (VFD) or remotely from the control center. The operator will have the ability to start or stop the pump and control the pump speed. This will allow the operator to choose the speed at which rainwater is treated and when it should be treated.

c. Prefiltration to Cartridge Filter Valve

The Prefiltration to Cartridge Filter Valve will only operate when the rainwater tank pump is placed in bypass. When the rainwater tank pump is placed in bypass, the Prefiltration to Cartridge Filter Valve will be started, and the valve will allow pre-filtered rainwater to flow through the cartridge filter system. The valve will also open during the pump shutdown to alleviate potential surge pressures.

d. Cartridge Filter to Contact Chamber Valve

The Cartridge Filter to Contact Chamber Valve will only operate when the rainwater tank pump is placed in bypass. When the rainwater tank pump is placed in bypass, the Cartridge Filter to Contact Chamber Valve will be opened, and the valve will allow filtered rainwater to flow into the contact chamber. The valve will also open during the pump shutdown to alleviate potential surge pressures.

e. Chlorine Tank and NaOH Valve

The chlorine tank and NaOH valve will only open when the rainwater tank pump is placed in bypass, but can be controlled manually at the variable frequency drive (VFD) or remotely from the control center when increased disinfection is required. The valves are set on a timer dependent on the flow produced by the rainwater tank pump so that disinfection is controlled by water flow.

f. Contact Chamber to Potable Cistern Valve

The contact tank valve will be controlled manually at the variable frequency drive (VFD) or remotely from the control center, but will automatically open with rainwater pump activation. The operator will have the ability to close the valve in case the potable cistern experiences a failure or if the tank is approaching maximum capacity. If closed, the valve will hold treated rainwater in the contact chamber until the pump can be reversed to remove all water from the treatment system.

5.3.3. Groundwater Treatment

Groundwater will be treated using reverse osmosis to treat Giardia and other potential viruses. It will pass through cartridge filters prior in order to protect the RO membranes. Then, it will also go through chlorine disinfection before it is stored in the potable cistern.

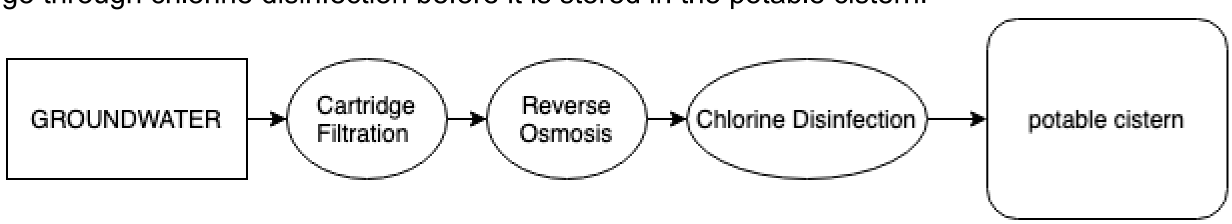

Figure 5.3.3: Groundwater Treatment Flow

Since only one cartridge and one reverse osmosis vessel is required, calculations were performed to match treatment duration times.

Table 5.3.3 Groundwater Design Criteria

CARTRIDGE FILTERS			
	Quantity	Unit	Comments
Cartridges purchased	1	cartridge	MUNI 40 MP (Harmsco LT2 Filter)[42]
Each cartridge capacity	14	gpm	Operating under max (30gpm) to match the RO duration
	20160	gpd	
Each cartridge size	37.5	ft2	
Avg system flux	537.6	gallons/ft-day	
	0.3733333333	gpm/ft^2	Calculated
Max flux rate	0.8	gpm/ft^2	From cutsheet
Recovery rate	1	Reflects 100%	Adsorption capacity is unaffected
	0		
Total system capacity	20160	gpd	
Actual inflow	3981.9178082	gpd	
Proportion of actual/capacity	0.1975157643		
Duration for actual flow to be filtered	4.740378343	hours	

REVERSE OSMOSIS			
Vessels purchased	1	vessel	MRO 4 LP Series[43]
Elements per vessel	5	elements/vessel	Specifically the MRO 5400-4-LP
Total number of elements	5	elements	
Design gpm	3.8	gpm	
RO Feed	5.0-5.8	gpm	From cutsheet
RO Reject	1.2-2.0	gpm	
Each element capacity	5400	gpd	From cutsheet
Operating pressure	125	psi	From cutsheet
Recovery Rate	0.75	Reflects 75 %	65%-75%, From cutsheet

42 Equipment specification sheet can be found in Equipment List
43 Equipment specification sheet can be found in Equipment List

Waste flow per element	1350	gpd	
Permeate flow per element	4050	gpd	
Waste flow, total	6750	gpd	
Permeate flow, total, or Total treatable capacity	20250	gpd	
Actual inflow	3981.917808	gpd	
Proportion of actual/capacity	0.1966379165		
Duration for actual flow to be treated	4.719309995	hours	

Chlorine			
Virus			
Target log removal	4		From regulations
Log removal from cartridge	0		
Log removal from RO	1		
Log removal required form chlorine disinfection	3		
pH of groundwater site sample	7.35		
Total Detention Time	4.5	minutes	
Temperature	20	Celsius	
Concentration of chlorine at peak flow	1	mg/L	
C	1	mg/L chlorine	Target chlorine residual to be maintained
CT99.99 for virus @ ph = 7.35, 20C	3		
CT99.9 for giardia @ pH = 7.35, 20C	63.79453587		
Virus CT calc	2.25		Correction factor for 3 log

			instead of a 4 log removal
Virus T	2.25		
Baffling factor	0.5	Average	
Virus Total Detention Time	4.5	minutes	
Assumed volume	100	gal	100 gallon tank[44]
height	37	in	
diameter	31	in	
Flow	22.22222222	gpm	
Concentration desired	1.5	mg/L	
Duration	7	days	
Percent of Sodium Hypochlorite in stock	13.40%		
Flow	3981.917808	gpd	Groundwater flow
	0.003981917808	mgd	
Loading conversion	8.34	lb/d = 1mg/L * mgd	
Chemical weight	10	lb/d	
Gallons required	0.2602213003	gallons	Amount of 13.4% solution Sodium Hypochlorite required annually

5.3.4. Greywater Treatment

Potable water will be used in the building, specifically the cafe, sinks, showers, urinals, and for drinking fountains. Used water is then considered grey water and goes through primary treatment consisting of screening and clarification to remove turbidity and solid contaminants, then a membrane bioreactor to remove organic matter, and chlorine disinfection to prevent microbial and bacterial growth. This grey water contains low amounts of organics so there is little impact on design criteria. This treated greywater will be directed towards a non-potable cistern to be used for irrigation and a small amount for composting toilets. The irrigation system will be connected to the percolation basin for groundwater recharge. After infiltration, greywater will be allowed to naturally infiltrate into the groundwater table and then be pumped out using the groundwater well for future treatment. This indirect potable reuse system is necessary to

[44] See equipment list for exact equipment

meet the Living Building Challenge requirements of a closed loop system involving recycled water.

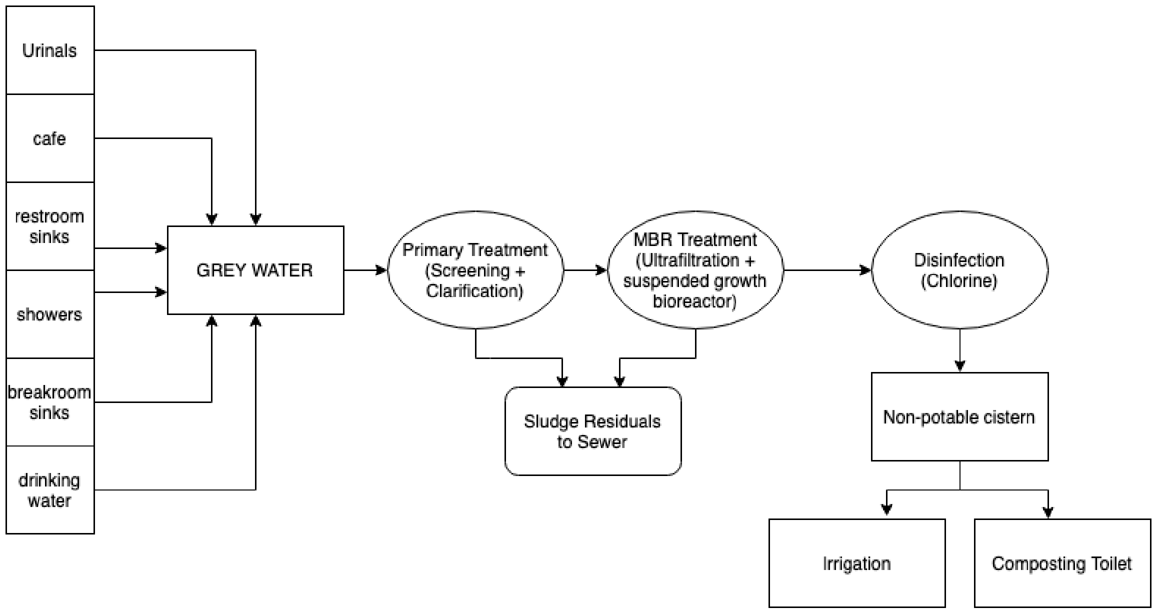

Figure 5.3.4: Greywater Treatment Flow

Table 5.3.4: Greywater Design Criteria

BIOREACTOR			
Volume	500	gal	500 gallon tank[45]
length	73.375	in	
width	62.656	in	
height	94.063	in	
HRT	181.3377272	min	HRT >> SRT (low organic loading)
	3.022295453	hour	~3 hour HRT
MEMBRANE			
Model	500S		Zeeweed 500S[46]
Pore diameters	0.04	microns	
Membrane surface area	300	sf	
Height	70.1	in	

[45] See equipment list for exact equipment
[46] Equipment specification sheet can be found in Equipment List

Diameter	8.5	in	
Configuration	Single Module Cassette		
Typical flow range	2-4	gpm	From cutsheet
Max Inlet Pressure	55	kPa	
Operating pH	5.0 - 9.5		
Chosen operating flow	4	gpm	
Actual inflow	2.75728613	gpm	
Proportion of actual/capacity	0.6893215325		
Treatment Duration	16.54371678	hours	
DISINFECTION			
Concentration desired	1.5	mg/L	
Duration	7	days	
Percent of Sodium Hypochlorite in stock	13.40%		
Flow	3970.492027	gpd	Greywater flow
	0.003970492027	mgd	
Loading conversion	8.34	lb/d = 1mg/L * mgd	
Chemical weight	10	lb/d	
Gallons required	0.259474617	gallons of 13.4% solution Sodium Hypochlorite required	

6. Energy

6.1. Supply

6.1.1. Solar panels and solar batteries

As Santa Monica receives a lot of sunlight throughout the year, solar power is a viable source of renewable energy for the building. According to weather statistics, shown in Table 6.1.1.2, the minimum average hours of sunshine in Santa Monica is 7, which occurs in January and December[47]. Taking this value, along with a low estimate of energy production per solar panel,

[47] Weather data: https://www.climatestotravel.com/climate/united-states/santa-monica

leads to an average of 1.75 kWh per day at minimum[48]. From Section 4.2.2, the building will require approximately 900,000 kWh annually. Using these values, summarized on Table 6.1.1.1, we can estimate that at least 203 solar panels will be required for the property to power the building for 24 hours, assuming all excess energy produced during the day is stored to be used for the night. Since this is the worst case scenario for energy production in the building, we can assume the building will produce more energy in other months to meet the 105% supply requirement of the living building challenge.

If we assume each solar panel will take up 20 ft^2 of space, we can estimate that 4060 ft^2 of the property will need to be dedicated to solar panels. This fits well within the property limits, and could also easily be placed on the roof of the building.

As implied earlier, the building will still need power during the hours the sun doesn't shine, meaning solar batteries will also be necessary to store excess energy. In addition to building up an excess of energy for days where there is no sunlight, as well as nighttime, there should be enough batteries to supply at least a week's worth of energy demand. While this reserve could be built over time, it is probably best to increase the number of solar panels to have a more stable supply. If Tesla Powerpack batteries, which can store 232 kWh of electricity[49], were to be used, approximately 45 would be necessary to hold a week's worth of energy supply. The Tesla Powerpack is an integrated battery system designed for utility & business energy storage.

There may still be times where Santa Monica is overcast for over a week, meaning there would not be enough energy to power the building during these times. Therefore, other sources of energy, and especially renewable energy, must be explored and integrated into the system as well.

Table 6.1.1.1: Projected annual solar energy supply and storage, including space required

Solar Power		**Units**
Size per solar panel	20	sq ft
Energy Production (low) (kWh)	0.25	kWh
Energy Production (high) (kWh)	0.4	kWh
Goal Demand	898,490	kWh
Goal Demand (hourly)	102.5673516	kWh
Worst case supply	1.75	kWh
# of panels to meet hourly demand	59	
24h multiplier	3.428571429	
# of panels to meet demand for 24h	203	

[48] Solar panel data: https://news.energysage.com/what-is-the-power-output-of-a-solar-panel/
[49] Energy storage data: https://www.tesla.com/powerpack

Necessary space	4060	ft
Tesla Powerpack	232	kWh
Week's worth of demand	10256.74158	kWh
# of batteries needed	45	

Table 6.1.1.2: Daily Average Hours of Sunshine in Santa Monica, CA

Month	Avg. Hours of Sunshine	Average Energy (low) (kWh)	Average Energy (high) (kWh)
Jan	7	1.75	2.8
Feb	8	2	3.2
Mar	9	2.25	3.6
Apr	10	2.5	4
May	10	2.5	4
Jun	10	2.5	4
Jul	12	3	4.8
Aug	12	3	4.8
Sep	10	2.5	4
Oct	9	2.25	3.6
Nov	8	2	3.2
Dec	7	1.75	2.8

6.1.2. Wind Turbines

While solar panels are the most practical renewable energy source, coastal Santa Monica has enough wind to make a small-scale wind turbine on the property a feasible option. Wind turbines are more efficient the larger they're built, however, this turbine would need to be able to fit on the limited property. The largest "residential" size wind turbines can produce up to 20 kWh per day[50], which would offset a small amount of the daily requirements, and provide some additional storage. In addition, on days where Santa Monica is overcast but still windy, it can provide some energy for the complex. We recommend against exploring this option unless there is ample space on the property to put a wind turbine large enough to provide at least 1 hour's worth of demand in a day.

[50] Wind turbine data: https://www.energy.gov/energysaver/installing-and-maintaining-small-wind-electric-system

6.1.3. Biogas from composting/solid waste: feasibility analysis

By the restrictions of the Living Building Challenge, no new buildings are allowed to use combustion of *any* material for energy, which unfortunately includes biogas. Reuse of waste products will be discussed in Section 7.

6.1.4. Energy connection to power grid

As there may be days where the energy provided by the renewable sources to power the building due to poor weather, the building needs to be connected to the main power grid to complement the renewable sources. In order to meet the 105% annual energy production criteria, there must be enough of the renewable sources for there to be days where production far exceeds demand from the building, to offset days where the system underperforms.

6.2. Process Flow

The Living Building energy system is designed so that the building's annual energy demand of about 900,000 kWh can be satisfied via solar energy. Photovoltaic solar panel arrays will supply the building and Tesla Powerpack system with energy. The electrical line flows from the panels to the charge controller where it is either sent to storage or the inverter for distribution to the building. The Powerpack system discharges the energy based on excess building demand and will charge to a maximum level of 10,260 kWh, which will satisfy the building's energy needs for at least 1 week. If the solar array system is damaged or disabled, or the batteries are depleted at a time without sunlight, the building will take energy from the municipal electricity grid.

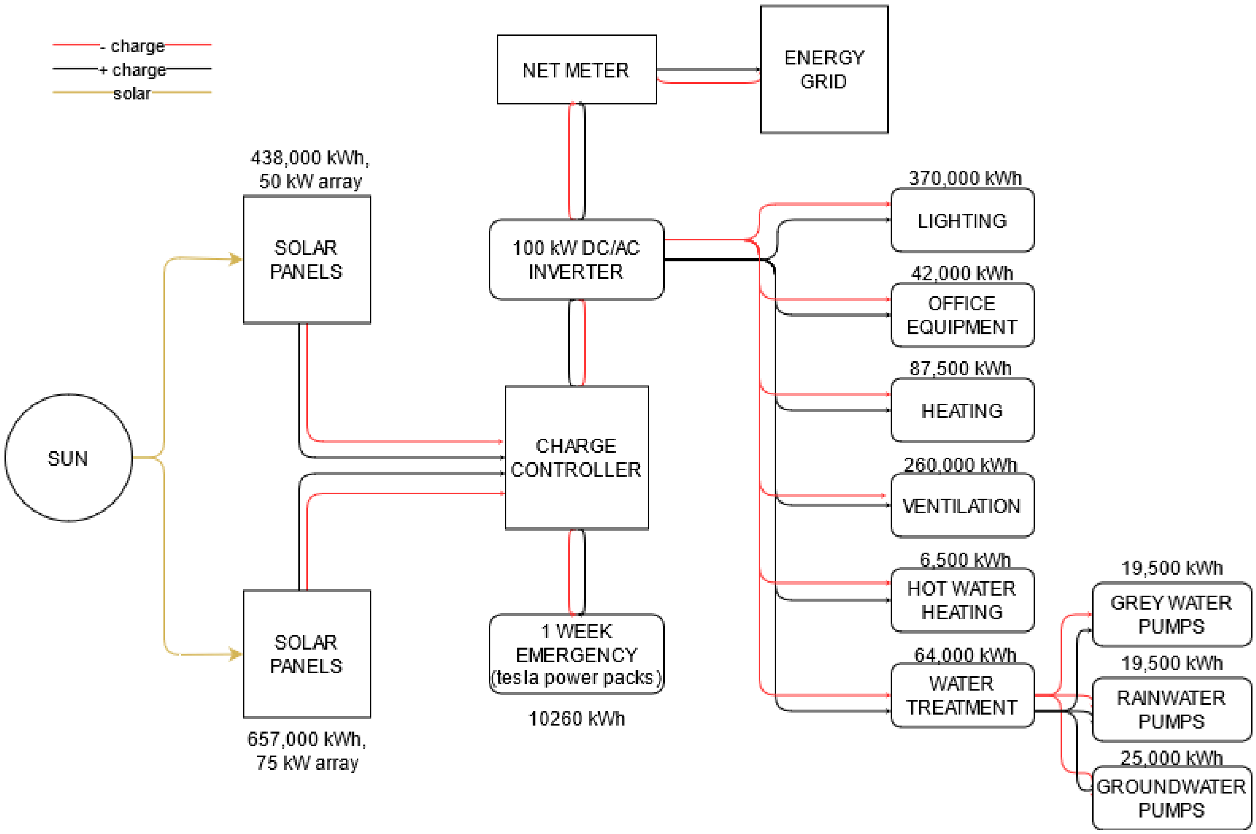

Figure 6.2.1 - Energy Load Diagram

Energy for the three water distribution systems was calculated based on calculated reverse osmosis pump energy requirements, and our estimations for the total amount of energy the entire water treatment system would require, as summarized in Table 6.2.1. Given the required pressure and estimated flow through the reverse osmosis system used in groundwater treatment, we calculated that reverse osmosis would require about 5825 kWh annually. Subtracting this from the estimated total energy required and dividing by 3 (assuming the same number of pumps & other powered components of each treatment train), each section would require about 19,392 kWh per year, and adding back RO requirements to groundwater gives it 25,217 kWh per year. Values were rounded for the energy load diagram shown above.

Table 6.2.1: Water treatment energy calculations

	Value	Units
RO Pressure	550	psi
Groundwater flow	4000	gpd
Groundwater flow	2.777777778	gpm
RO energy	0.8913522624	hp
RO energy	5824.962565	kwh
Total energy	64000	kwh

Energy minus RO	58175.03744	kwh
Energy per section	19391.67915	kwh
Groundwater energy	25216.64171	kwh

7. Civil & Mechanical Arrangement

This section shows the civil and mechanical arrangement of the MJSM treatment designs. The rooftop view and basement view are shown below. A closer view of the main basement is also shown as it houses all treatment equipment. A closer view of the rainwater treatment system can be found in Section 5.3.2.

The rooftop features the two 50 W solar arrays, positioned to be above the rest of the electrical system located in the basement. Outside the building are the percolation basin and the garden. This is detailed in Figure 7.1

Figure 7.3 includes the location of treatment equipment, a control room, all the electrical equipment (including the solar batteries, charge controller, and charge inverter), a storage room, a maintenance staff room, and a recycling center for the sorting of recyclable materials used in the building.

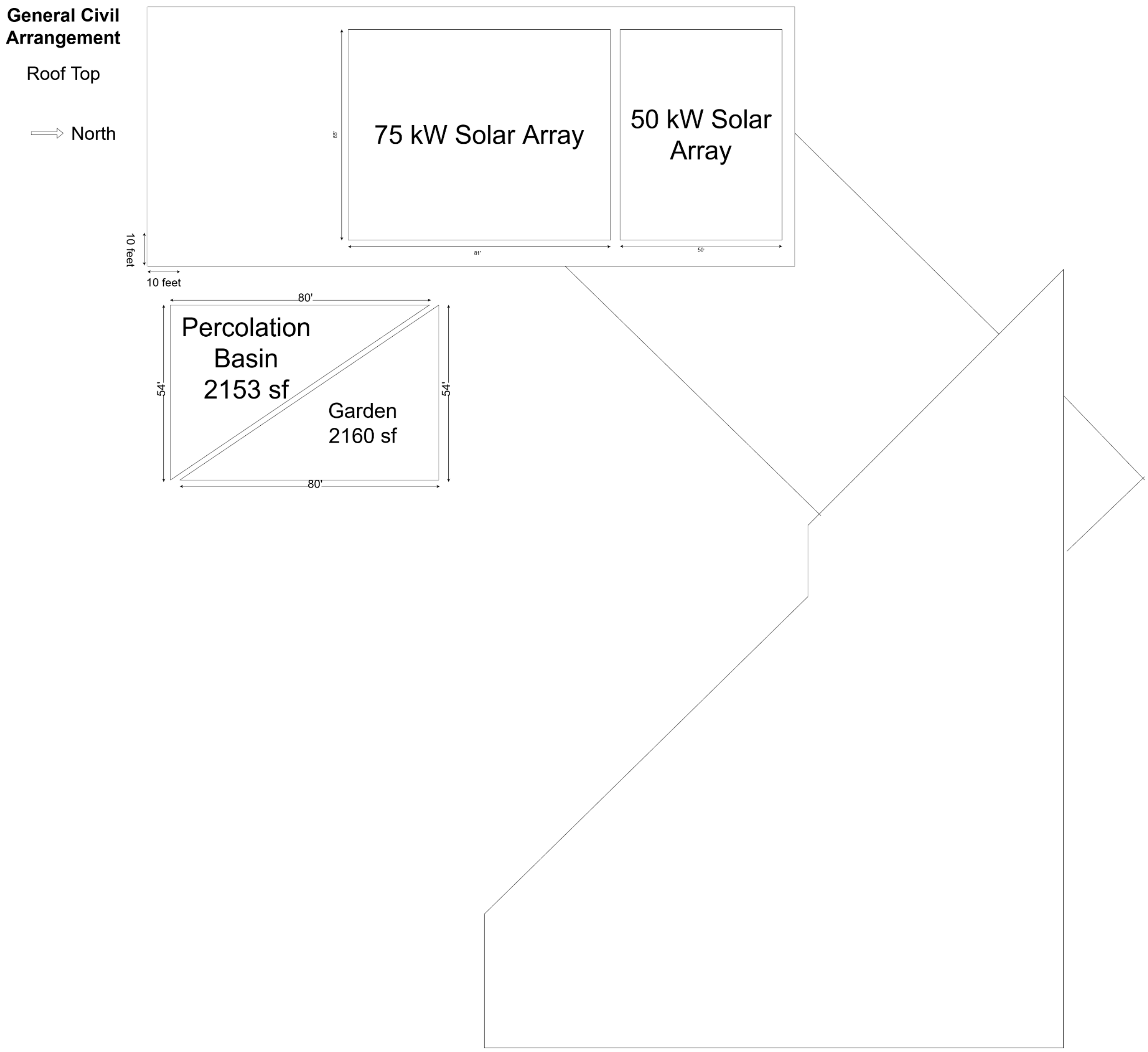

Figure 7.1 General Civil Arrangement: Rooftop view

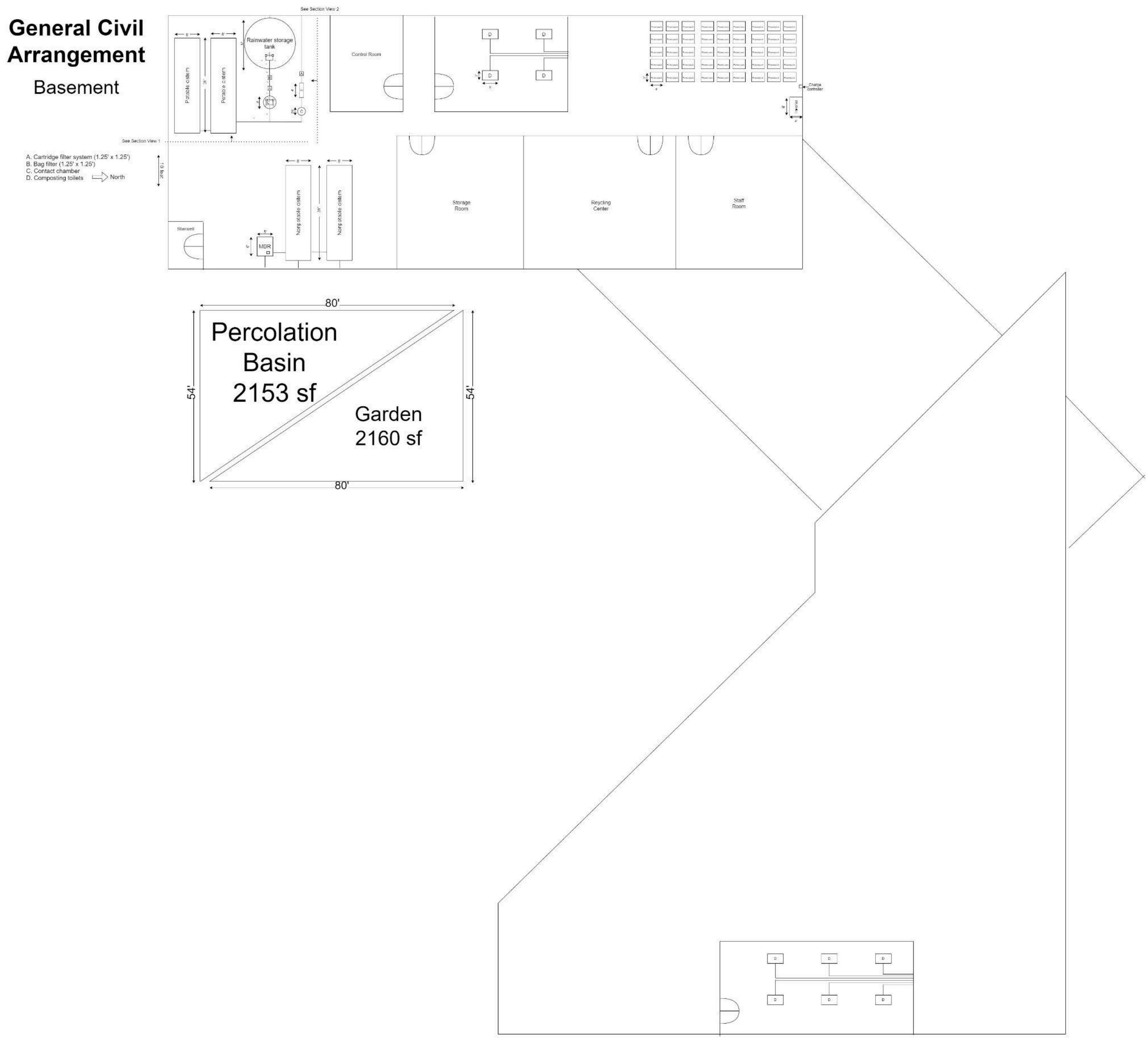

Figure 7.2 General Civil Arrangement: Basement view

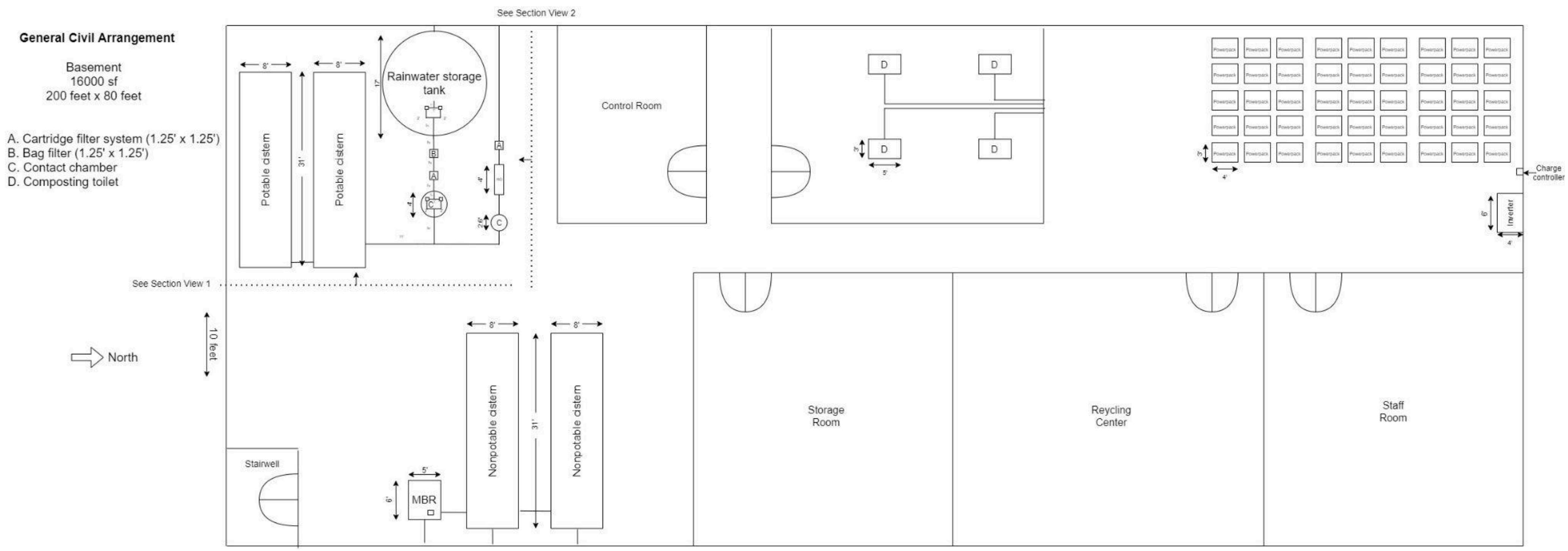

Figure 7.3: General Civil Arrangement: Lower basement view

8. Waste

The intent of this imperative is to integrate waste reduction into all phases of projects and to encourage imaginative reuse of salvaged "waste" materials.

All food waste from the onsite garden and kitchens that can be composted will be composted on site. As they are exposed to open air, aerobic composters do not release methane. However, the composter must be kept away from areas where people may work or pass by frequently, to prevent odors from disturbing those in the plot of land or anyone in the surrounding area. The goal for meeting the living building challenge is a 100% diversion rate for soil and biomass.

Recycling bins will be available in the building, and additionally all trash should further be screened and separated into recyclable elements and non-recyclable waste. A 99% diversion rate is required for paper and cardboard. Some trash must go to the landfill, but there will be a dedicated facility on the property for sorting recyclables as effectively and efficiently as possible.

Wastewater (and rainwater) will be treated onsite for non-potable reuse and direct potable reuse[51]. Grey water (clothes washers, bathtubs, showers, bathroom sinks), and black water (toilets, kitchens) can be treated on-site and used for irrigation of the onsite garden and other plants located onsite, or cycled back into the system as toilet water. Potable reuse is not authorized by state water reclamation requirements for recycled water use, but it is allowed for irrigation[52].

9. Cost and Recommendations

9.1. Project Cost

Assuming baseline water and energy consumption, and importing all water and energy from the Santa Monica grid, the total annual cost for water & electricity would be $621,989 over the course of 30 years. Based on maximum water flow, the water capital facility fee is 16,858. The annual water commodity cost, based on a cost of $1100 per acre-feet for water imported and $500 per acre-feet for water distribution, totals to $14,273 in year 1. The wastewater capital facility fee is $435,131, based on the size of the office building and a cost of $3,391.51 per 1000 sq. ft. The wastewater commodity cost is $17,641.65 based on a rate of $4.54 per hundred cubic feet. This data is summarized in Table 9.1.1.

Table 9.1.1 - Baseline Cost

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[51]Onsite Non-Potable Water Reuse Research: https://www.epa.gov/water-research/onsite-non-potable-water-reuse-research

[52]State water reclamation requirements for recycled water use: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/requirements.html

Peak water flow	112.8210046
Water Capital Facility Fee[53]	16,858
Annual Imported Water Purchase	9812.705807
Annual Water Distribution	4460.320821
Annual rate increase (import)	1.07
Annual rate increase (distribution)	1.03
Wastewater Capital Facility Fee	435,131
Wastewater Commodity Cost	17641.65
Wastewater rate increase	1.08
Electricity Cost[54]	356868.7243
Total Cost (30 years)	18659675.09
Annual Cost	621989.17

In order to calculate the cost of the Living Building Treatment System in comparison to the baseline cost, we need to calculate the capital cost, operating cost, water production cost, and inflation/interest rate over time. To calculate the capital cost, we first need the building cost, specifically the basement where the water treatment equipment will be located, and the cost of all the water and electrical equipment. These values combined give us the facility cost. The construction cost can in turn be estimated from the facility/equipment costs. By multiplying the equipment cost by 0.4, we get the installation cost. By multiplying the facility cost by 5%, we get both the civil site work/yard piping and general requirements costs. By multiplying the facility cost by 0.25, we get the electrical & instrumentation cost. Adding these four values to the facility cost gives the construction cost. The contingency cost is 30% of the construction cost, and the engineering/admin cost is 15% of the construction cost. This data is summarized in Tables 9.1.2 and 9.1.3, along with the pricing estimates of the equipment.

Table 9.1.2 - Capital Cost - Water

Item Description	Item Category	Number of item	Item units	Cost per unit	Total cost
Building slab/foundation	A	592.59259	cubic yard	600	355555.554
Building walls	A	466.66667	cubic yard	900	420000.003
Treatment Structures Cost	A				775555.557
Storage tanks	B	72000	gal	2.5	180000
Pumps	B	12	hp	800	9600
Cartridge filters	B	8		150	1200

[53] Water & Wastewater Capital Facility Fees in Santa Monica: https://www.santamonica.gov/press/2020/11/24/council-sets-new-water-and-wastewater-capital-facility-fees

[54] Electricity Cost in Santa Monica: https://www.electricitylocal.com/states/california/santa-monica/

Chlorine tank	B	1	gal	75	75
NaOH tank	B	1	gal	75	75
Reverse osmosis	B	0.0288	mgd of permeate	1,000,000	28800
Membrane filter	B	1	modules (6 gpm)	3,000	3000
Equipment Cost	B				222750
Facility Cost	C				998305.56
Equipment Installation	D	222750	Category B	0.4	89100
Civil site work/yard piping	E	998305.56	Category C	0.05	49915.278
General Requirements	F	998305.56	Category C	0.05	49915.278
Electrical & Instrumentation	G	222750	Category B	0.25	55687.5
Construction Cost	H				1242923.62
Contingency	I	1242923.62	Category H	0.3	372877.086
Engineering + Admin	J	1242923.62	Category H	0.15	186438.543
Total Cost	K				1802239.25

Table 9.1.3 - Capital Cost - Energy

Item Description	Item Category	Number of item	Item units	Cost per unit	Total cost
Solar panels	B	2	50 Kw grid	69,703	139405
Solar batteries	B	10257	kWh	539	5528523
Charge controller	B	1		1532	1532
Inverter	B	1	100 Kw inverter	28267	28267
Facility Cost	C				5697727
Equipment Installation	D	5697727	Category B	0.4	2279090.8
General Requirements	F	5697727	Category C	0.05	284886.35
Electrical & Instrumentation	G	5697727	Category B	0.25	1424431.75
Construction Cost	H				9686135.9
Contingency	I	9686135.9	Category H	0.3	2905840.77
Engineering + Admin	J	9686135.9	Category H	0.15	1452920.385
Total Cost	K				14044897.06

The operating cost is calculated from the energy usage (which is negligible due to electricity being generated in the facility), maintenance cost (5% of equipment cost), consumables (5% of equipment cost), filter replacement, chemical refilling, and labor, which is all summarized in Tables 9.1.4 & 9.1.5.

Table 9.1.4 - Operations/Maintenance Cost - Water

Item Description	**Item Category**	**Number**	**Replacement frequency (years)**	**Cost**	**Cost per year**
Maintenance Cost		222750		0.05	11137.5
Consumables		222750		0.05	11137.5
MF membrane replacement	Filters	1	5	3000	600
MF membrane cleaning	Filters	1	0.083	1000	12048.19277
RO membrane replacement	Filters	1	8	400	50
RO membrane cleaning	Filters	1	0.5	500	1000
Chlorine replacement	Chemicals	1	0.083	2.5	30.12048193
NaOH replacement	Chemicals	1	0.083	10	120.4819277
Staff		3	1	80000	240000
Total Cost	L				276123.8

Table 9.1.5 - Operations/Maintenance Cost - Energy

Item Description	**Item Category**	**Number**	**Replacement frequency**	**Cost**	**Cost per year**
Maintenance Cost		5697727		0.05	284886.35
Total Cost	L				284886.35

Finally, we are able to calculate the total annual cost of the living building system during its life cycle. With an annual inflation rate of 2%, and an annual interest rate of 0.25%, we can estimate that the total cost of the living building system will be $1,550,525 annually over 30 years, taking into account a 2.23% yearly cost increase, as summarized in Table 9.1.6 & Table 9.1.7. We can also calculate unit water production cost: 62 cents per gallon of water, or $204,493 per acre-foot of water. Unit energy production cost is $1.18 per kWh. Also included on the tables are baseline water, wastewater, and energy calculations, as referenced in Table 9.1.1.

Table 9.1.6 - Life Cycle Analysis - Water

	Capital Cost	**O+M Cost**	**Total Cost**	**Baseline Water**	**Baseline Wastewater**
Base cost	1802239.25			16858	435131
1	60074.64	276123.8	336198.44	14272.96	17641.65
2	61516.43	282350.39	343866.82	15093.6552	19052.982
3	62992.82	288717.39	351710.21	15966.4467	20577.22056

4	64504.65	295227.97	359732.62	16894.82068	22223.3982
5	66052.76	301885.36	367938.12	17882.50252	24001.27006
6	67638.03	308692.87	376330.9	18933.47342	25921.37167
7	69261.34	315653.89	384915.23	20051.98815	27995.0814
8	70923.61	322771.89	393695.5	21242.59406	30234.68791
9	72625.78	330050.4	402676.18	22510.15139	32653.46294
10	74368.8	337493.04	411861.84	23859.85501	35265.73998
11	76153.65	345103.51	421257.16	25297.25766	38086.99918
12	77981.34	352885.59	430866.93	26828.29489	41133.95911
13	79852.89	360843.16	440696.05	28459.3116	44424.67584
14	81769.36	368980.17	450749.53	30197.09056	47978.64991
15	83731.82	377300.67	461032.49	32048.88286	51816.9419
16	85741.38	385808.8	471550.18	34022.44051	55962.29725
17	87799.17	394508.79	482307.96	36126.05126	60439.28103
18	89906.35	403404.96	493311.31	38368.57596	65274.42352
19	92064.1	412501.74	504565.84	40759.48843	70496.3774
20	94273.64	421803.65	516077.29	43308.91813	76136.08759
21	96536.21	431315.32	527851.53	46027.69588	82226.9746
22	98853.08	441041.48	539894.56	48927.40267	88805.13256
23	101225.55	450986.97	552212.52	52020.42198	95909.54317
24	103654.96	461156.73	564811.69	55319.99568	103582.3066
25	106142.68	471555.81	577698.49	58840.28386	111868.8912
26	108690.1	482189.39	590879.49	62596.42887	120818.4024
27	111298.66	493062.76	604361.42	66604.62378	130483.8746
28	113969.83	504181.33	618151.16	70882.18569	140922.5846
29	116705.11	515550.62	632255.73	75447.63407	152196.3914
30	119506.03	527176.29	646682.32	80320.7747	164372.1027
Total Cost			14256139.51	1155970.206	2433633.761
Annual Cost			475204.65	38532.34	81121.13
Unit Production ($/gal)			0.6275656318	0.002120277048	0.004463763946
Unit Production ($/AF)			204492.85	690.89	1454.52

Table 9.1.7 - Life Cycle Analysis - Energy

	Capital Cost	O+M Cost	Total Cost	Baseline Energy

Base Cost	14044897.06			
1	468163.24	284886.35	753049.59	356868.7243
2	479399.16	291310.54	770709.7	364916.114
3	490904.74	297879.59	788784.33	373144.9724
4	502686.45	304596.77	807283.22	381559.3915
5	514750.92	311465.43	826216.35	390163.5558
6	527104.94	318488.98	845593.92	398961.744
7	539755.46	325670.91	865426.37	407958.3313
8	552709.59	333014.79	885724.38	417157.7917
9	565974.62	340524.27	906498.89	426564.6999
10	579558.01	348203.09	927761.1	436183.7339
11	593467.4	356055.07	949522.47	446019.6771
12	607710.62	364084.11	971794.73	456077.4208
13	622295.67	372294.21	994589.88	466361.9666
14	637230.77	380689.44	1017920.21	476878.429
15	652524.31	389273.99	1041798.3	487632.0376
16	668184.89	398052.12	1066237.01	498628.14
17	684221.33	407028.2	1091249.53	509872.2046
18	700642.64	416206.69	1116849.33	521369.8228
19	717458.06	425592.15	1143050.21	533126.7123
20	734677.05	435189.25	1169866.3	545148.7196
21	752309.3	445002.77	1197312.07	557441.8233
22	770364.72	455037.58	1225402.3	570012.1364
23	788853.47	465298.68	1254152.15	582865.9101
24	807785.95	475791.17	1283577.12	596009.5363
25	827172.81	486520.26	1313693.07	609449.5514
26	847024.96	497491.29	1344516.25	623192.6388
27	867353.56	508709.72	1376063.28	637245.6328
28	888170.05	520181.12	1408351.17	651615.5218
29	909486.13	531911.2	1441397.33	666309.4518
30	931313.8	543905.8	1475219.6	681334.7299
Total Cost			32259610.16	15070071.12
Annual Cost			1075320.34	502335.7
Unit Production ($/kWh)			1.177456998	0.1651138741

We also took into account return on investment from excess water or energy produced by the system. Our current design produces low return on investment for both processes, with an estimated $3937 return from water sales and a mere $88.98 from energy production annually. This data is calculated and summarized in Table 9.1.8, based on supply and demand estimates, and market rates for water and energy.

Table 9.1.8 - Return on Investment

	Water	Units	Energy	Units
Production	8000	gpd	1095000	kWh
Demand	2912.380952	gpd	898490.3665	kWh
Excess Supply	5087.619048	gpd	196509.6335	kWh
Yearly Supply	5.698865286	AF/year	538.3825575	kWh/year
Cost per unit	690.89	$/AF	0.1651138741	$/kWh
Annual Return on Investment	3937.29	$/year	88.8944298	$/year

Taking into account this return on investment, the annual cost of the Living Building Challenge system is slightly reduced to $1,546,499 annually.

9.2. Equipment List

Compiled in Table 9.2.1 is a list of major equipment required for the water & energy systems included in the living building challenge project.

Table 9.2.1 - Major equipment list

Category	Item	Number	Link
Energy	Trina Solar Panel Grid (50 kW, 75 kW)	2	Trina 50 kW Solar Panel Grid
Energy	Tesla Powerpack	45	Tesla Powerpack
Energy	Morningstar TriStar Charge Controller	1	TriStar Charge Controller
Energy	Solectria 100KW Inverter	1	Solectria 100 kW Inverter
Water	Potable Cistern	2	Tank depot cistern
Water	Cartridge Filter	2	MUNI 40 MP (Harmsco LT2 Filter)
Water	Chlorine/NaOH storage tank	2	100 Gallon Plastic Water Storage Tank
Water	Pump	12	Centrifugal 5 GPM pump
Water	Water level indicator	3	Aquatel d110 Tank Level Monitor
Water	Flow meter	3	Vortex Shedding Medium
Water	Pressure gauge	9	100 PSI Water Pressure Gauge
Water	Turbidity meter	6	Endress Hauser Liquiline CM442

Rainwater	750 gallon rainwater storage tank	1	Rainwater Storage Tank
Rainwater	Bag Filter	1	Maelstrom Rainwater Filter
Groundwater	RO Filter	2	S-240-Spiral-System.pdf (vsep.com)
Grey water	Composting Toilet	10	Centrex 3000 Air Flow Composting Toilet
Grey water	Non-potable cistern	2	Tank depot non-potable tank
Grey water	Wastewater filter	1	500 gal capacity bioreactor
Grey water	UF Membrane (MBR filter)	1	ZeeWeed 500S Module

9.3. Project Alternatives Analysis

The client has several options in how they wish to approach this project by the triple bottom line framework. By pursuing baseline industry standards, the cost will be lowest, however the project will be more detrimental to the environment and have few positive social effects. By pursuing a Living Building Challenge certification, the project will have a net positive effect on the environment, employees, and surrounding community, but will also be expensive both in purchasing necessary technologies and developing the project to meet all LBC guidelines.

The other option is to pick and choose aspects of the Living Building Challenge to follow, to maximize environmental and societal benefits without spending beyond a budget limit. The difference between around $600,000 for the baseline scenario and approximately 1.5 million for the living building challenge is quite a large gap, and upon first glance it would seem that choosing the baseline is the obvious choice. However, much of the cost of the living building challenge comes from the one week requirement for energy storage, and the expensive batteries that come with it. The batteries total to over 5 million dollars in overhead cost, which in turn makes all the other values in the calculation much larger. Therefore, meeting the majority of requirements for the living building challenge becomes more feasible if the number of batteries used in the final design is scaled back.

9.4. Project Recommendation

It is at the discretion of the client to ultimately decide which scenario is the better option, but our team supports pursuing most of the living building challenge requirements, while scaling back on the number of solar batteries to be included in the system if overhead cost is a major concern. The water treatment system included in design is more expensive than simply purchasing water from the city, but our design will provide better quality water that also comes from recycled/renewable sources. The solar panel system with a smaller number of batteries will have an even greater positive effect on the environment and local society, as excess energy that cannot be stored can be provided back to the community. We believe that the benefits to the environment of pursuing the living building challenge are immense, and will positively impact the local community.

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11. Appendix

See attached documents for design calculations.