ABSTRACT

Title of Document: THE MICRO-LANDSCAPE: MODULAR URBAN APARTMENT GARDENS

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This thesis proposes affordable and adaptable modular balcony and patio gardens as a way to mitigate the increasing alienation between urban apartment renters and the land. These modules would adapt the concept of a garden to the compact reality of urban densification with an aim towards mitigation of urban stresses and improved well-being of apartment renters. Large-scale implementation would have environmental benefits, including stormwater capture and treatment, pollution control and heat island effect mitigation. This thesis design also has the potential to encourage renters, garden supply retailers, landscape professionals, architects and developers to incorporate private gardens, on a more extensive basis, into the fabric of the urban built environment.

THE MICRO- LANDSCAPE: MODULAR, URBAN APARTMENT GARDENS

By

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Introduction: Smart Growth, Tactical Urbanism and Micro Design

More than half of the world's population lives in cities, a percentage rapidly increasing over time. Though the United States is often known for its characteristic suburban sprawl, urbanization and densification are increasing here as well. According to the 2007 economic census, 252 million Americans, or 84 percent, lived in metropolitan areas up from 78 percent in 1990, and less than 40 percent in 1900 (Landis 2009). The least dense, outer suburban counties—exurbs and emerging suburbs—registered extremely low growth rates in 2010-2011, continuing a downward trajectory established in the late 2000s. By contrast, Growth in cities and dense inner suburbs is increasing in a flip from trends dominant since the 1940s (Landis 2009). The nation's largest core cities grew by 17 percent between 1990 and 2007, adding 6.8 million new residents (Myers 2009).

From a conservation perspective, this is good news. Urban planners tout the ecological benefits of densification, which reduces greenfield development, sprawl and fossil fuel consumption, but also the social and economic benefits for people. Urban living is associated with greater wealth, better sanitation, nutrition, and overall health care (Florian Lederbogen 2011). It often means access to public transportation, walkable communities, and more retail options (Speck 2013, Washington State Department of Transportation 2014, Landis 2009).

While this may appear to be good news on an ecological and economic front, densification also has consequences for people living in urban environments. Densified areas are inherently less green, hotter, noiser and more polluted. In addition, the denser a development, the more disconnected its residents are from land and growing things.

While many elements of urban versus suburban life are hard to compare, a 1992 study indicated that density was a consistent factor that reduced satisfaction with the urban environment (Adams 1992). A study by Berry and Kozaryn showed more prevalent dissatisfaction with urban life in Anglo Saxon countries, which they theorize is a result of a cultural attachment to a rural ideal (Brian J.L. Berry a 2009). Urban life is associated with increased risk of chronic physical and psychological disorders (Florian Lederbogen 2011). Studies generally attribute this increased risk to the social stresses of urban life, but there are indications that the physical environment plays a role as well (Guite 2006, Delavelle 2005).

Densification has occurred hand in hand with a recent decline in home ownership, especially among the young (Collinson 2011, Myers 2009). Rental housing is the typical tenure choice for the young, the elderly, the disabled, people in highly mobile professional sectors, and low-wage working families, it is also likely to be an important alternative - at least in the short term - for many of the millions of families uprooted by the foreclosure crisis (Gervais 2011, Frey 2012, Frey, Brookings Institute 2011).

Dense rental housing is often far less planted than areas populated by homeowners (Gowen, Melnik 2013). Apartment renters are far less likely than homeowners to have access to private land, and less likely to lobby for public investment in public land. For those renters who do have access to private outdoor space, they are still less likely to invest in plantings. A 2013 study of the DC tree canopy showed residents of neighborhoods dominated by rental housing tended to have less disposable income, but also did not own the green spaces around their homes (Gowen, Melnik 2013). Few were willing to invest in trees they would not own. The study indicated residents were far more likely to support tree plantings if a foundation, or the city committed to caring for the trees (Gowen, Melnik 2013). This is for the same reason that they are unlikely to invest in expensive customized window treatments or furniture. A renter is unlikely to invest heavily in a space he or she sees as temporary and owned by someone else (Behe 2006).

For many renters, the lack of private land is part of the appeal of a rental. No land means no maintenance. For others, access to planting space would make urban life far more palatable. Multiple studies show a connection between horticulture and human mental and physical health especially with regard to stress related disorders (Sus Sola Corazon 2012, Derback 2004, Gonzalez 2010).

Generally, designers approach the problem of alienation from the land in urban settings by designing communal green spaces. The resulting parks, urban agriculture projects, community gardens and parklets are essential to urban life. However, these efforts do not provide urban renters with a private green space to call their own. Even community gardens, where people can rent private plots tend to be not truly private or adjacent to homes. They are also hard to come by.

However, many renters, even in high-density apartment buildings, do have outdoor spaces often in form of a balcony or patio. However, these spaces generally lack soil, and direct access to potable water. To plant a balcony or patio, the renter needs to purchase and transport soil, plants and water. This effort is both inconvenient and expensive. Even for the committed gardener willing to haul soil, pots, plants and water for a container garden, patios and balconies can be harsh and unforgiving environments.

This project aims to enable urban renters to have a small, affordable and successful garden of their own. This garden will enable urban renters susceptible to physical and psychological urban stresses find an outlet to release tension and reconnect with nature.

Though this project aims to create private rental green spaces, it takes inspiration from the work on the Tactical Urbanism movement's work on ad hoc temporary public green spaces. The movement advocates "parklets" in parking spots, sidewalks, medians and other unconventional public spaces. These are quick, often temporary, cheap projects that aim to make a small piece of hardscape more lively or enjoyable (Berg 2012).

In the prime example of this approach, San Francisco's "Pavement to Parks" program works to develop small temporary parks in unused public spaces. This effort is a public private partnership with the approval of the city Planning Department. This program is inspired by similar efforts in New York using protective barriers and moveable tables and chairs to create welcoming outdoor spaces. Parklets often consist of modular units that are portable and reusable in a new space. The units maximize the use of a small space allowing for seating and planting where little potential for either is immediately apparent (Parks 2014).

This portable and modular concept is adaptable to urban rental outdoor spaces. A parklet is a reduction of the concept of a public park to its barest essentials in an effort to fit in a small space. It is not a replacement for open space, but a symbolic representation that enables city residents to feel some of the benefits of open space on a micro level. A similar concept is useful for rental spaces. This project aims to reduce the concept of a private garden to its essentials- seating space and planting space- concepts that can be scaled down to fit on a balcony or patio.

The scaling down of urban life is a challenge for multiple design disciplines. As real estate values rise in urban centers, space is at a premium and designers are working to create solutions that make life in tiny spaces livable. In an extreme version of this phenomenon New York City commissioned the design of micro apartments (nArchitects n.d.). A variety of other companies have designed tiny portable homes that are intended to include all things needed by homeowners but at 250-750 square feet (Houses 2014, Homes 2014).

This thesis aims to do the same for the private garden. The modular apartment garden is designed with a patio or balcony in mind, both structures relatively common in the urban apartment building, but often ignored as a potential green space. This garden will be tailored to suit a concrete patio or balcony. It will be modular and all-inclusive. It will include everything from growing medium to plants and will be adaptable to urban microclimates. The modules will be adaptable to multiple space sizes and shapes and will enable the urban renter to enjoy the benefits of a private garden on a small and affordable scale.

As such these modules will be:

- All-inclusive: They will contain plant materials, containers, a water source or solution, soil medium and a composting system. All parts and tools are included in a single "kit" or "set."
- Uniquely suited to tough urban conditions. All plant and physical materials are pre-selected to survive urban microclimates. This garden is not a canvas for experiments, but a tried and proven solution.
- Low maintenance – plants will be drought tolerant and growing medium will be chosen for water and nutrient retention.
- Able to collect and store rainwater- obviating the need for city water use
- Easily portable enough to move to a new location along with apartment furniture.
- Easy to take apart and reassemble
- Attractive but simple to maintain
- Affordable- for renters unwilling to invest heavily in a space they do not own.

Apartment renters, as individual customers, are rarely the focus of landscape architects, garden supply retailers or nurseries. This is for good reason. At best, most apartment renters think of their balconies as an extension of their indoor environment where a couple plants can be grown, like houseplants, in small containers to be watered with a watering can. Few individual renters have the means or dedication to approach a professional designer, or even do significant research on their own for a Do-It-Yourself (DIY) solution.

This thesis seeks to challenge the perception that urban outdoor rental spaces are not viable locations for gardens by designing a modular garden geared to the individual urban apartment renter. This garden will enable the urban renter to enjoy the benefits of private green space on a small and affordable scale. It will help make density more appealing by mitigating the alienation of urban renters from land and personal contact with growing things.

If implemented on a large scale modular apartment gardens will help capture stormwater, assist in first flush capture and reuse, control airborn pollutants and atmospheric deposition, capture carbon dioxide (CO2) and reduce the heat island effect. In addition, the modules will make urban density more appealing for apartment renters enabling smart growth initiatives meant to limit greenfield development, sprawl and fossil fuel consumption.

Chapter 1: Urban realities-Opportunities and Challenges:

Section 1: Demographics:

Ownership remains a sign of status for many Americans, but its position as the mark of prosperity is no longer as assured as it was twenty years ago. Especially among young urban professionals, shared and temporary access to goods such as cars, or videos is often preferable to ownership (Eckhardt 2012). The same is true of rental housing. Many young urban renters are willing to rent in relatively expensive city centers rather than buy in cheaper but less appealing suburbs. Meanwhile, baby boomers are also moving into denser areas (Butrica 2012). These demographics are putting immense pressure on the largest and most persistent group of urban renters- low-income families, who are spending increasing percentages of their earnings on rent (DiPasquale 2011, Collinson 2011).

These demographics indicate a large percentage of urban renters consider themselves transient, lack disposable income or both. Market research shows Renters, as a whole, are far less likely to invest in gardening products and supplies than homeowners (B.K. Behe 2009). They are also likely to make choices that favor immediate return rather than long-term investment. For instance, renters are more likely to buy annuals or perennials rather than bulbs, which they likely see as a long term investment less immediate rewards (Behe 2006). As a result, a garden solution for the urban renter must be affordable for the largest range of incomes and prioritize near term impact over long term potential.

This design is configured to respond to these demographics. It provides a garden that is affordable, and also portable. While the “ground” the modules sit on may belong to someone else, the modules themselves belong to the renter and are an investment that can be taken to a new apartment. A modular garden could be made in such a way as to be easy to take apart and put together again in a new location and rearranged to fit a different space. The modularity also allows for mass production and eventually for cheaper prices.

Section 2: Microclimate:

While densification is increasingly the urban environmental policy of choice, it has distinct environmental consequences that directly affect the plant palette of an urban renter. Dense areas produce heat islands as they store solar energy in the urban fabric during the day and release this energy into the atmosphere at night. The process of urbanization replaces the cooling effect of vegetated surfaces by imperviously engineered surfaces with different thermal properties. Furthermore, anthropogenic sources (e.g. central heating systems, air conditioning, transport, industrial processes) emit heat directly into the urban area, while buildings and infrastructure increase surface roughness that can reduce wind speeds, convective heat loss and evapotranspiration. Warm, still days reduce air quality because high temperatures and ultraviolet light stimulate the production of photochemical smog, ozone and other compounds from traffic and industrial emissions and plants (Glaeser 2011).

For an urban gardener this means that plants that would survive or even thrive in a suburban or exurban setting will wither in the summer heat of an urban area. The rental balcony or patio tends to be made of concrete and to be attached to a building that emits further heat. Often times the outdoor space available to a renter gets an overwhelming amount of sun during the day, with plants receiving not only direct sunlight but also sunlight reflected off of concrete surfaces. Other balconies and patios get no sun at all as tall building shadow them. These shady spaces still tend to be hotter than average and also tend to be dry. They would need plants that can withstand shade and dry conditions.

Section 3: Soil and Water

Patios are open to the sky and may get rainwater, but balconies do not. Unless the patio or balcony has a built in planter, neither contains soil. For most aspiring gardeners on a patio or balcony water is limited to what can be transported from a kitchen or bathroom sink with a watering can. Any design that will thrive must include a water collection and storage mechanism that is inexpensive and simple to operate. It will also require a plant palette that is drought tolerant. Without a connection to city water on the patio or balcony itself, water thirsty plants will require too much work to maintain for most renters.

The lack of city water on a balcony or patio offers an opportunity to develop ways to divert rainwater into a collection mechanism and then store and filter it in modular planters.

Growing medium for a small urban rental space is a challenge. It is not expensive, but in large amounts it can be hard to obtain in an urban setting. In addition, it tends to be heavy and make containers hard to move and handle. The goal for this project is to choose a growing medium that is appropriate to the plant choice but also relatively lightweight, and easy to handle. Most plants under consideration require soil that retains some water but is also well drained. So these characteristics are also requirements for growing medium.

Section 4: Retail Limitations:

Gardeners who remain interested in planting a patio or balcony also face limited access to garden retail stores. Few garden supply retailers are willing to establish stores in city centers. As a result, urban renters must order supplies online or go to the suburbs to buy them. Renters who choose to live in walkable communities because they do not have a car have very limited options (Behe 2006).

The modular system this project proposes is condusive to a one stop shop in an urban area that sells all parts, including plants and growing medium, in one place. This would enable renters to purchase the modules and pick up everything they need in a single car trip or to order delivery of the entire system as a unit. Renters would be able to pick up or receive all the materials for the modules in one day and put them together easily on the same day. There would be no need for repeat trips saving on both fuel, effort and expense.

Chapter 2:. Typology of Rental Outdoor Spaces

This typology is limited to small urban spaces potentially attached to a rental property and controlled by an individual renter (or family of renters). As a result, it does not include community garden plots or shared garden spaces. It also does not include communal green roofs and courtyards planted and managed by an apartment building's management.

To determine what kinds of outdoor spaces to include I did a review of literature on small garden spaces. The books I consulted were helpful in identifying the following types of outdoor spaces: (Beckett 1982, Miller 1983, Richardson 2012)

Balcony

- Opportunities: Shaded and controlled space which can often be quite large, balcony railing can also hold plants, microclimates created by balconies create interesting growing spaces, placing plants on a balcony creates a lovely frame for views from an apartment, less pests than plantings at ground level.

- Challenges: Most balconies do not have water access of their own. Lack of rainwater requires either constant hand watering or a rainwater collection system, balconies are often made of concrete and can get very hot despite a roof overhead, north facing balconies lack light much of the day.

- Solutions: Trellises for shade and additional growing space, rain collection mechanisms, stacked container systems, solar powered hydroponics

Entrances, Stair Landings and Steps

- Opportunities: Stairs provide interesting changes in elevation adding drama to an arrangement of container plants.

- Challenges: Space often very limited and often either very shady or very bright, have to ensure plants are not stepped on or stolen, shrubs or grasses can offer haven to rodents.

- Solutions: containers that are compact but sturdy enough to be hard to tip over or steal, keep plants off the ground to avoid rodents, use plants to frame stairs but ensure they don't take over and prove a tripping hazard, overhands and stair railings can be used to hang planters

Window Ledges

- Opportunities: Creative space usage, can be enough space to grow herbs or small perennials at a low budget

- Challenges: Securing a windowbox to a window can be difficult, access to a window box can also be a challenge if a window has screens, size of the window box is limited to reach of owner, plant palette is limited to things that grow in small containers.

- Solutions: Use planter that rests on the ledge instead of one that hangs, pick plants that need little to no maintenance if the screen is difficult to open.

Patios/Terraces

These spaces are rare for renters, but offer the most options. They are outdoor spaces that are paved or decked but not covered by a roof or obstructed by an overhead balcony. They can be at ground level or on a higher floor depending on building architecture.

- Opportunities: relatively large and often have plenty of sun, sheltered sunny space can offer warm microclimate in winter, if shady can offer the opposite in the summer, larger patios can accommodate both shady and sunny areas, or can be altered to do so, some patios have access to a water source and electricity, though many do not.

- Challenges: Paving can get very hot in summer sun and can cook plants. , dark north facing patio or a patio shaded by a tall building or tree can prove hard to protect against damp and mosquitoes, larger space means more planting space but also more empty space to fill which raises price of plant materials and containers.

- Solutions: find planters that are large but inexpensive and plant selections that are well suited to their microclimate and spread out quickly to fill planters, try to cover as much surface area as possible to reduce heat island effect, use shade structures to reduce glare where possible as well as outdoor rugs or even turf where possible.

While all of these spaces could prove viable as growing spaces, this thesis focuses on two typologies- the balcony and patio- the most common outdoor apartment spaces and the most viable for a garden. The final design is presented in four sample designs. Two are for a balcony- they have the same layout but one is in full sun and the other is in part shade. The other two are for a patio in full sun and part shade.

Chapter 3: Design Precedents

Section 1: Modular Parklets

Some parklets feature modular components, in particular, benches that contain planters or planters that can be rearranged to form rooms in a small space. The idea that these items of furniture can be rearranged in a new space to form a new parklet is applicable to the modular apartment garden. Rebar, a San Francisco design firm showcases a variety of innovative designs intended to create temporary settings through modular forms. Particularly intriguing is a nomadic grove for a museum in San Francisco. The trees in the grove are in moveable planters whose position in the "grove" changes on a regular basis. (Rebar 2014) This thesis aims to use similar ideas, but on a scale that is affordable and manageable for the individual apartment renter.

Section 2: IKEA

IKEA furniture has become immensely popular among apartment renters because it is cheap, stylish and easy to assemble, take apart and either move to a new apartment or throw out. The company's stated mission is to provide well designed home furnishing products that are affordable to as many people as possible (IKEA 2013). IKEAs products are practical and produced on the assumption that most customers have a limited budget for limited spaces. IKEA design emphasizes color and aesthetic appeal. Products generally lean towards a minimalist approach, stripped of extra luxury perks, but retaining a stylish appearance. They are also flat-packed for relatively easy transportation and construction at home. Construction directions include no words but use clear and easy to understand images instead (IKEA 2013).

This is not to say that the products are high quality. Few people purchase IKEA products based on durability. IKEA is a store for people willing to pay less for a product that satisfies a temporary need. For the renter, this is a perfect model. IKEA does not create heirloom furniture; it creates short-term low cost solutions. While this thesis aims to create modules that are durable enough to withstand a few seasons of wear and tear, it does not aim to create something permanent. The modules are intended as the building blocks of a temporary, inexpensive garden. They are ideally mass-produced and not meant to last a lifetime, but merely the length of a lease or two.

IKEA's flat packing of furniture also means that an individual can furnish an entire apartment in one shipment or carload of boxes. For the modular garden to succeed it needs to adopt a similar concept. Many urban renters do not have cars and will need to rent one to pick up large items or rely on deliveries. As such, the entirety of a modular garden needs to be able to fit, in unassembled form, into a single delivery truck or rented pick up truck. Otherwise, it will not be practical. This must include plants, growing medium, containers and rain collection mechanism parts

Section 3: The Symbolic Garden

Gardens, in the American vernacular, evoke flower beds, lawns and a sense of lush luxury. For the apartment dweller, this lushness can be nearly impossible to mimic. The apartment garden is limited to what can grow in planters with limited root space. Lack of access to plentiful water is also a limiting factor.

The goal then, is not to replicate the American garden in miniature, but to create a planted aesthetic that brings an apartment dweller in close contact with nature on a symbolic level. The Japanese dry garden is a good precedent for this idea. It invites the viewer to imagine a larger world of water and mountains while containing neither. To do so relies more on arrangements of stones than actual plants (Nakagawara 2004).

A design solution that works for an outdoor rental space will also rely heavily on principles of minimalism- evoking as much as possible through simple lines and structure. Peter Walker in his discussion of minimalist garden design defines minimalism as the examination of the abstract and the essential and as a way to see beyond the "object" that is designed to the larger landscape**.** Minimalist design, as he frames it, is proposed as a solution to modern problems of waste and excess. Walker perceives minimalism as a way to reconnect with nature through symbolism as well as contrast (Walker 2006). A garden can utilize minimalist forms to evoke the natural in a constrained space.

An outdoor space on a patio, balcony or entryway frames the renter's view of the outside world. It can compliment what is outdoors or obscure it, but it provides a lens through which a concrete slab of outdoor space becomes a work of art. Generally, urban balconies and patios have little that is ornamental about them. They tend towards a modernist functionality and could benefit, aesthetically from an addition of simple color, new materials, and the softening that plant materials can provide.

Section 4: Existing Products

FIGURE I: LECHUZA PLANTER

While there are few modular systems that are all inclusive- there are a variety of planting systems that offer precedents for this project. Interest in vertical gardening has spurred production of various containers for vertical planting many of which are useful for small outdoor spaces (Woolypocket.com n.d., florafelt, Vertical Garden Solutions, Apartment Therapy, Digginfood.com, Nestinstyle.com, WilliamsandSonoma.com, Mini Garden, Australian Design Review).

Urbillis sells high-end hip solutions in bright colors for a variety of patio and balcony settings.   These include planters, wall planting systems and patio planters. They are cute and stylish and easy to assemble but expensive and often more attractive than productive (Urbilis 2013). Lechuza planters- are far less expensive, lightweight, self-watering and attractive. They come in many colors and sizes and have a recommended substrate and optional coasters for portability (Lechuza 2013). Woolypockets sells a variety of products made of felt of plastic that are inexpensive and easily portable when emptied of soil. They also tend to be modular, easy to use and relatively productive (Woolypocket.com 2014).

However, the felt options are less attractive with long-term outdoor use.. Some companies sell planters with attached trellis provide a vertical and horizontal option in one (Room Dividers 2013).

Green roof manufacturers are designing modular green roof blocks that enable relatively inexpensive vegetative cover for large hardscape spaces. Some even come pre-planted with hardy succulents (Greenroofblocks.com 2014).

A variety of planting containers are “self watering” which essentially means they include a water reservoir at the bottom that gradually allows water to wick through the plant roots and into the plants. This allows for better water storage and less frequent watering (Lachuza 2013). Balcony railing planters or window boxes can also be constructed with similar reservoirs so long as they are exposed to rainwater (Lachuza 2013, Greenbo 2013, Greendiary 2013).

For a balcony that is completely protected from rainfall, a gutter can be attached to the exterior of the railing that will collect rainwater and direct it into a rain barrel for use on the balcony. A website called Collective Psyche shows an example that is more functional than attractive, but a modular and attractive version could be constructed (Collective Psyche 2013).

Hydroponics offer much potential, especially since they don’t require a regular water source. Once filled they function mostly on their own and are easy to empty out and then move to a new location. However, hydroponic systems also have some serious drawbacks. They require a power source which most balconies lack. Any hydroponic system would need to be solar powered, easy to care for, and also attractive. Many of the currently available systems are far more functional than aesthetically pleasing. An exception is an indoor system designed by Danielle Trofe, which remains bulky but is attractive. A solar powered and less costly version would have potential for a balcony. (Hickman 2012, Danielle Trofe Design 2013)

These products are helpful in imagining what the modular garden would look like. The challenge for this thesis, is to take these ideas a step further by including plants, soil medium, containers and a water collection and delivery system all in one.

Chapter 4: Plants

A review of literature on container gardens yielded some key tenets for this project in terms of plant selection.

- Thrillers, fillers and spillers: Most designers for container gardens emphasize the need for three types of plants in each container- thrillers, fillers and spillers (Richardson 2012) Thrillers are tall focal plants, fillers compliment that plant and fill gaps and spillers soften the edge of the planter by spilling down its side.
- Plants need to be tough enough to survive the urban microclimate but not so tough as to be invasive.
- Plants that would succeed on a green roof will do well on an urban patio or balcony. Criteria for these plants include: shallow roots, heat, cold, sun, wind, drought tolerance, insect and disease resistance. These plants require minimal nutrients and maintenance. Herbaceous perennials are the most traditional in appearance but the hardest to select for these criteria. Hardy succulents are the workhorses of greenroofs and have much potential for this project. These plants have unsurpassed ability to survive drought and are often evergreen. Good selections can survive on very little water and often can be colorful and varied. Grasses also have potential if they can survive in relatively shallow medium.
- Native plants can be useful if they are sufficiently tough, but a patio or balcony in an urban setting is not a native environment for any plant as it

is almost entirely isolated from the spectrum of taxa that make up any native plant community (Snodgrass 2006).

- Plugs are often the best starting system for soilless medium. Nursery containers contain nursery medium that is highly organic and unsuitable for transplant into largely inorganic medium. Plugs are easily packed and shipped in boxes and can survive several days en route. They are less expensive and sized to easily fit in smaller containers. However, they are smaller and take longer to establish maturity than nursery plants (Snodgrass 2006).
- Low investment, but high yield. Planting on a tiny scale in a harsh concrete environment is time consuming, difficult and expensive. For example, while many projects aimed at growing plants on a balcony or patio emphasize vegetables, few edible plants will significantly contribute to a renter's diet without a disproportionate investment of time, resources and water. In addition, vegetables are generally annuals and require renewed planting every year and a barren winter garden. By contrast, perennial herbs need little water, are attractive for multiple growing seasons and sometimes evergreen, and can easily produce enough to obviate the need to purchase herbs from a grocery store.

Chapter 5: Growing Medium

The goal for this project is to choose a growing medium that is appropriate to the plant choice but also relatively lightweight, and easy to handle. Most plants under consideration require soil that retains some water but is also well drained. So these characteristics are also requirements for growing medium.

Succulents, herbs, and perennials tend to prefer media that is courser in texture containing more bark, perlite or sand. This thesis will require a growing medium similar to one for a green roof- which is normally 75-90% inorganic and contains a combination of expanded clay, expanded shale, pumice or crushed clay tiles with vermiculite or perlite and organic compost. The mix contains no soil as soil contains silt and will block drainage components. The medium should also be ph neutral (Snodgrass 2006).

Filler at the bottom of a container can take up space, reduce weight and improve drainage and water retention. It can be made from crushed aluminum cans, plastic milk jugs, and non-biodegradable "packing peanuts." This material fills the bottom one third of a container. The filler takes up space while allowing water to pass through and further space for roots to grow (Extension 2013).

Section 1: Potential Medium Components

Long fiber sphagnum moss: is simply dried sphagnum, the source plant for sphagnum peat moss. It is very lightweight, provides excellent aeration to plant roots and holds up to 20 times it's weight in water, which significantly reduces watering frequency. Since it contains very little nutrient value, it is best to use with a complete and balanced plant food (progressivegardening.org 2013).

Perlite is a unique volcanic mineral that expands from four to twenty times its original volume when it is quickly heated to a temperature of approximately 1600-1700 degrees F. When expanded, each granular, snow-white particle of perlite is sterile with a neutral pH and contains many tiny, closed cells or bubbles. The surface of each particle is covered with tiny cavities providing a large surface area. These surfaces hold moisture and nutrients and make them available to plant roots. In addition, because of the physical shape of each particle, air passages are formed which provide optimum aeration and drainage. Because perlite is sterile, it is free of disease, seeds, and insects. Perlite has been used for many years throughout the world for soil conditioning and as a component of growing mixes with materials such as peat moss or bark. Extensive studies have shown that the unique capillary action of perlite makes it a superior growing media for hydroponic cultures. However, it does not absorb or hold water and so it is usually included in a mix to improve drainage or increase aeration. Perlite is lightweight (6 to 8 lb/ft3), chemically inert, pH neutral, sterile and odorless (progressivegardening.org 2013, Evans 2014).

Vermiculite: This mineral is similar to perlite in that it also expands to many times its original volume when heated. It differs in that it increases the retention of nutrients and water, while perlite is more useful for increasing aeration. is a member of the phyllosilicate group of minerals, resembling mica in appearance. Horticultural grade vermiculite improves soil aeration while retaining the moisture and nutrients necessary to feed roots, cuttings, and seeds for faster growth. Like perlite, horticultural vermiculite is permanent, clean, odorless, nontoxic and sterile. It will not deteriorate, turn moldy or rot. The pH of vermiculite is essentially neutral (7.0-9.5) but owing to the presence of associated carbonate compounds, the reaction is normally alkaline. Vermiculite possesses cation exchange properties and can hold and make ammonium, potassium, calcium and magnesium available to the growing plant. As part of a growing medium mix it helps promote faster root growth, and gives quick anchorage to young roots by retaining air, plant food and moisture and releasing them as needed. It is also very light and easy to handle (progressivegardening.org 2013). The pH of vermiculite will vary depending on where it is mined. Most U.S. sources are neutral to slightly alkaline, whereas vermiculite from Africa can be quite alkaline (pH = 9). Vermiculite is used exten- sively in the greenhouse industry as a component of mixes or in propagation. It is usually sold in four size grades: #1 is the coarsest and #4 the smallest. The finer grades are used extensively for seed germina- tion or to topdress seed flats. Expanded vermiculite should not be pressed or compacted, especially when wet, as this will destroy the desirable physical properties (Evans 2013).

Peat: Peat is the base for many soilless mixes, which are often composed primarily of shredded peat moss with vermiculite and perlite added to increase porosity. Peat is usually included in a mix to increase the water-holding capacity but decrease weight. Peats used in horticulture are usually classified into three types: moss peat, and reed-sedge.

- *Moss peat,* more often called peat moss, is the most common form used in the industry and is derived mostly from sphagnum moss. Peat moss is the least decomposed form of the peat types, is typically light tan to brown in color, lightweight (6.5 lbs/yd3), high in moisture-holding capacity and very acid (pH 3.8 to 4.3). A significant problem with peat moss is "wetting up." Peat moss is inherently hydrophobic (repels water). To address this situation, some suppliers offer a product with a wetting agent already included. Peat moss is typically sold in compressed bales that expand 50% to 100% when properly fluffed. Most recipes call for peat moss on a volume basis.
- *Sphagnum moss* is the young residue or live portion of the plant. It is commonly used for plant shipment, propagation or to line hanging baskets.
- *Reed-Sedge:* is formed principally from reeds, sedges, marsh grasses, cattails and other associated swamp plants and is widely used in Florida. Peat humus is usually derived from reed-sedge or hypnummoss peat and represents an advanced stage of decomposition. This type of peat is usually dark brown to black and has a low moisture-retention capacity (Evans 2013).

Peat is used as the base for soilless mixes that generally cost more than inferior potting soils, but offer many advantages. Peat is relatively light weight, clean to handle and mixes that include it are ready to use right out of the bag. Recent improvements in these soilless mixes include the inclusion of biofungicides, natural bacteria that greatly reduce the incidence of fungal disease. Soilless mixes need regular fertilizer as they do not have much organic material and are generally not recommended for cacti and succulents because they retain too much water for too long (progressivegardening.org 2013).

Mycorrhizae: a root bio-stimulant that increases the number of extremely fine feeder roots a plant utilizes to take in nutrients, which produces larger fruit, vegetable, and flower yields, faster growth, and significantly reduces transplant shock.

Cocopeat: A byproduct of coconut fibers, cocopeat is produced from entirely renewable organic resources. It increases water use efficiency, superior air capacity, and works well with both organic and inorganic plant nutrients. It is consistent and uniform in texture and is now available in fine and coarser, more fibrous consistencies. It is a completely homogenous material composed of millions of capillary micro-sponges, that absorb and hold up to eight times their own weight in water. The average dry bulk density is 4 lbs/ft3. Coir peat generally contains significant amounts of phosphorus (6 to 60 ppm) and potassium (170 to 600 ppm) and can hold up to nine times its weight in water. Since coir contains more lignin and less cellulose than peat, it is more resistant to microbial breakdown and, therefore, may shrink less. Coir is easier to re-wet after drying than peat moss. The natural pH is generally between 5.5 and 6.5 combined with a 30 to 70 percent air to water ratio that assures coir will hold and release nutrients in solution over extended periods with reduced watering. Coir peat comes from a wide variety of countries and is processed in many different ways. Growers have to examine each type to assess its total soluble salts, sodium and chloride levels (progressivegardening.org 2013, Evans 2013).

Stonewool/Rockwool: The raw material for stonewool, also commonly known as rockwool, is basalt rocks and chalk. These are melted at 1600 C°. The lava is then blown into a spinning chamber, which pulls the lava into fibers, much like 'cotton candy'. The fibers are packed together into a mat and from this mat are cut various sized growing slabs, blocks, and the new mini-cubes (right) that are ideally suited for container gardening applications.

FIGURE II: ROCKWOOL

When the cubes are wetted, they stack on top of each other leaving airspace in between the cubes. Each cube has six surfaces from which excess water can drain. As a result, even if you overwater, the stonewool cubes do not get water logged. Stonewool growing cubes have an excellent air to water ratio that averages 50% water to 50% air for unparralleled oxygenation to the root system. Special advantages are achieved by mixing the cubes in with LECA fired clay pellets. The stonewool cubes will help spread the water in the container as well as keeping a water buffer in between irrigation cycles. Stonewool container cubes weigh approximately a mere 1/10 of the weight of a bag of ordinary potting soil by volume. As with most soil-free growing media, a complete and balanced plant food is recommended for optimum results (progressivegardening.org 2013, Evans 2013).

Expanded Clay Pebbles: These are made from clay formed into pellets and fired in rotary kilns at 1200°C. This causes the clay to expand, like popcorn, become porous, and completely sterile. They are light in weight, do not compact, and are completely reusable. They also possess the qualities of being completely inert, and pH neutral. The pebbles drain freely and do not hold any excessive water, which is why they provide good oxygen levels around the roots and why they are particularly suited for flood and drain soil-free plant growing systems. They are used extensively for greenhouse rose cultivation and embraced by orchid growers. In drip irrigation systems the pellets can be mixed with a medium with better capillary action, such as coco peat, so that the nutrients are more evenly dissipated. As with most soil-free growing media, a complete and balanced plant food is recommended for optimum results (progressivegardening.org 2013).

Silica stone: Predominantly silicon dioxide, the stones slowly release silica to the plant, which is important for cell growth. It does not break down like other media, and can used to successfully cultivate plants from seedling to specimen. Pores in the media do not clog over time and the stone is capable of absorbing up to 150% of its own weight in water and slowly release it to the plant as required. Silica stone can be used as a beneficial supplement to expanded clay, rockwool, coco peat, and other mediums depending on the application. As an example, silica stone used as a supplement with coco helps to reduce the common problem of compaction and increases moisture retention. When lining the bottom of a pot with silica stone, the silica stone acts as a reserve reservoir so plants can get the extra moisture they need in the later stages of growth. Silica stone can also be applied as a top dressing (progressivegardening.org 2013).

Softwood bark: Bark is the primary component (80% to 100% by volume) in most outdoor container nursery mixes. For many years, bark was viewed as a forest waste product, but today the availability for container use is limited in some markets due to alternative demands (e.g., landscape mulch, fuel) and reduced timber production.

Pine bark is preferred over hardwood bark since it resists decomposition and contains fewer leachable organic acids. Pine bark is usually stripped from the trees, milled and then screened into various sizes. A good potting medium usually consists of 70% to 80% (by volume) of the particles in the 1/42- to 3/8- inch range with the remaining particles less than 1/42 inch. Bark is described as either fresh, aged or composted. Many growers use fresh bark but typically add 1 lb N/yd3 to compensate for the potential nitrogen draft that occurs in the pot. Composting bark typically takes 5 to 7 weeks. Aging is a cheaper process, but aged bark has less humus and a greater nitrogen draw-down in the container than composted bark (Evans 2013).

Hardwood bark: The chemical properties of hardwood bark are significantly different from pine bark. The pH of fresh hardwood bark is usually less acid (pH 5 to 5.5) than peat moss or pine bark. Composted bark may be rather alkaline (pH = 7 to 8.5). Hardwood bark typically contains toxic compounds and, for this reason, should be composted before use.

Rice hulls: Parboiled rice hulls (PRH) are produced by steaming and drying rice hulls after the milling process, which results in a product that is free of viable weed and/or rice seed. Despite being an organic compound, rice hulls consist mainly of lignin, cutin and insoluble silica, providing a slow breakdown of particles and therefore making them an appropriate substrate. A number of researchers have demonstrated that PRH is a suit- able alternative to perlite in greenhouse substrates. The pH of composted rice and parboiled rice hulls ranges from 5.7 to 6.2, and 6.2 to 6.5, respectively. Fresh rice hulls are light in weight (bulk density 6 to 7 lbs/ft3) and useful to increase drainage and aeration. Fully composted rice hulls will hold more water than unprocessed hulls.

Cotton Gin Trash: Composted gin trash can increase the water- and nutrient-holding (CEC = 200 meq/100 gm) properties of media and has a pH of 5.5 to 6.0. High soluble salts can be a concern, but this can be reduced quickly through leaching with water. Media becomes less productive though if it contains > 50% gin trash (Evans 2013).

Chapter 6: Container Materials

Materials used in this thesis design solution need to be lightweight so as to be easily moved by the transient gardener during a move, or if the building requires containers be moved for maintenance. In addition, containers need to survive harsh weather conditions and protect plants from heat and cold extremes. Lastly, materials must be relatively inexpensive but durable.

Section 1: Materials

Wood: Wood is easy to cut and assemble and lends itself readily to home construction. It also functions as a good insulator and can be relatively lightweight. If treated correctly, it is likely to last for a long period of time, or at least, long enough for the duration of home rental. Ideally planters should be constructed of rot resistance hardwoods- oak, teak and cedar. Treatment should exclude creosote which is harmful to plants (Richardson 2012, Kenneth A. Beckett 1983).

Metal: Galvanized or rubber coated metal can be attractive, light and modern looking. It will not crack in winter but it can cook plants in summer. It offers very little insulation for roots (Richardson 2012).

Glazed ceramics: Ceramics are heavier than wood or metal but impervious and resilient. They are also more expensive and do not stand up to rough handling, but they can be very attractive and are good insulators (Kenneth A. Beckett 1983).

Plastics: Heavy duty plastic can be shaped and textured to resemble all sorts of finishes and adopt bold fluid shapes. Plastic can be lightweight and durable if it is formulated to resist chemical reactions to UV rays which break down plastic and make it brittle (Kenneth A. Beckett 1983).

Fiberglass: This material is strong, durables and lightweight. It can be more colorfast than plastic and made to look like other materials. However, fiberglass tends to be more expensive than plastic and rough handling can cause fraying of fibers (Timber Press 2013, Kenneth A. Beckett 1983).

Hypertufa: This substance is an anthropic rock made from various aggregates bonded together using Portland cement. It is a manufactured substitute for natural tufa, which is a slowly precipitated limestone rock. Like tufa, it is very porous and favorable for plant growth. It is lighter than terracotta or concrete and can withstand harsh winters down to −30 °C (−22 °F). It is generally made of 1 part cement to 3 parts aggregate- the aggregate is typically 4 parts sphagnum to 5 parts perlite. To increase structural strength and longevity, polymer fibers, liquid acrylic,[2] and fiberglass[3] may be incorporated into the mixture, along with various grades of sand, pebbles, and crushed rock which add to the final object's overall strength and stone-like appearance though they increase its weight. It can also be dyed to resemble natural rock. (Wikipedia 2013).

Fabric: Multiple manufacturers make fabric planters made of felt. These planters are lightweight, inexpensive and especially good for aeration of roots. When produced in pocket form they can be attached to walls and enable vertical gardening (Woolypocket.com 2013).

Section 2: Construction

Drainage

Various techniques for container drainage are common in the current market. This section reviews some of them.

Porous Materials: Clay or terra cotta materials soak up water as do wire baskets lined with absorbent material and peat pots. Porous material will lose water faster than non-porous materials. Containers can be lined with plastic to make the pot resistant to water loss, but porous materials are also more susceptible to freezing and cracking in winter.

Crocking: Fine gauge mesh is placed over drainage holes to prevent pests from coming in and the bottom of a container is covered with broken crockery of flat stones. 1 cm of granulated fine sphagnum peat then stops particles from washing down into the crocking. Alternatively one can use pulverized bark. Growing medium is then added on top of this layer (Kenneth A. Beckett 1983).

Self Watering Planters: Containers can be constructed with a reservoir at the bottom and a system to enable watering into this reservoir instead of into the soil medium itself. Porous material over the reservoir allows plant roots to wick water from the reservoir. This enables more occasional watering and better regulation of water use. Lechuza manufactures planters like this at reasonable prices that are lightweight and meant for either indoor or outdoor use. Planters meant for outdoor use have a reservoir meant to capture rainwater that percolates through the soil medium into the reservoir, reducing the need for additional water.

Indoor planters are intended for hand watering once every few weeks. There are other manufacturers that make similar products (Lachuza 2013).

Temperature Control: Metal containers allow for the greatest temperature fluctuations as do small pots. Dark pots absorb the most heat. In metal containers temperatures fluctuate more than non-metal ones. Pots can be insulated with foam or other types of waterproof insulation to reduce this problem (Extension 2013).

Container Size: The size of the container should accommodate the roots of the plants when fully grown. Most plants need to be repotted in larger pots as their roots grow (Wilson* 2013).

Section 3: Water Collection and Drainage

Rental outdoor spaces often lack an independent source of water. As a result any successful solution will require a water collection mechanism.

A. **Containers with water storage:**

This is an option for open air patios. Containers can be constructed with a reservoir at the bottom and a system to enable watering into this reservoir instead of into the soil medium itself. (Lachuza 2013) Balcony railing planters or window boxes can also be constructed with similar reservoirs so long as they are exposed to rainwater (Lachuza 2013, Greenbo 2013, Greendiary 2013).

B. Gutter and Rain Barrel:

For a balcony that is completely protected from rainfall, a gutter can be attached to the exterior of the railing that will collect rainwater and direct it into a rain barrel for use on the balcony. A website called Collective Psyche shows an example that is more functional than attractive, but a modular and attractive version could be constructed (Collective Psyche 2013).

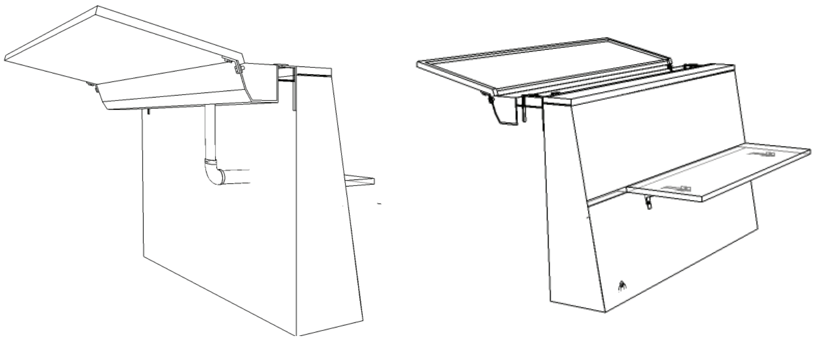
FIGURE III: GUTTER RAIN CATCHMENT ON BALCONY

C. **Solar Powered collection and purification:**

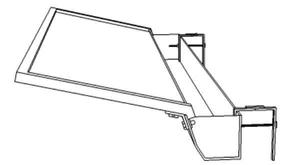
A collection mechanism is constructed to funnel water into a cistern through a solar powered pump that filters the water (Duke 2002). This system would require exposure to sun and rain water. It could be useful on an open-air patio or if the collection mechanism could be mounted to the outside of a balcony railing.

Chapter 7: The Design

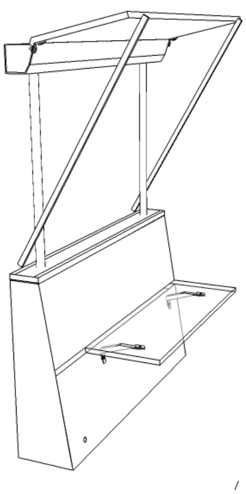
The final design for this project is modular, self-watering and easily flatpacked for delivery or shipping. It leans heavily on concepts developed by green roof technology. Growing medium is soilless, lightweight and also relatively shallow influencing a choice of plants tested and tried on green roofs.   These choices allow for easier installation and greater resilience in dry conditions. The design includes modules for planters, seating, water collection and storage as well as a table with a built in planter for patio settings. The modules are adaptable to multiple settings and designed to create the maximum effect with a minimum of material. They are also designed with a view towards architectural structure creating not only growing space but also outdoor living space.



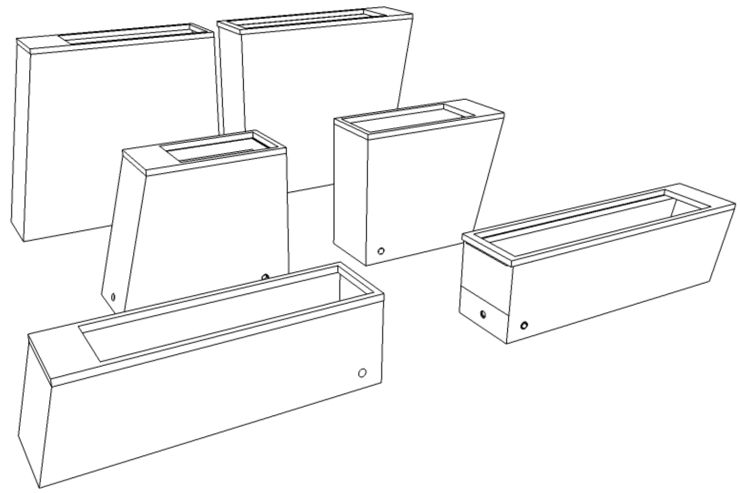
Bench/Rain Barrel with Rain Catchment Panel, Gutter



Gutter and Rain Catchment Panel



Bench/Rain Barrel with Rain Catchment Panel Configured as sun shade



Planters

The Modular Garden:
Main Parts

1) Rain Barrel/Bench- includes rain storage bladder and connector pipe to planters

2) Rain collection panel/sunshade- can be configured as a rain collection panel for a gutter attached to a balcony railing or as a sunshade for a bench on a patio

3) Gutter

4) Pipes- from gutter to bladder

5) Planters with shelf, made to contain wicking baskets for water, water tray, drainage layer, growing medium and plants

6) Table with embedded planter

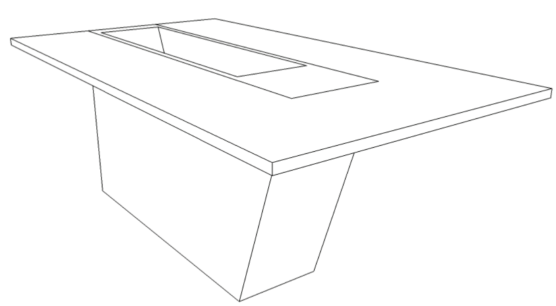


Table with embedded planter

Section 1: Bench/Rain Collection and Storage System

The modules are designed to attach to a rain catchment and storage system. This system is centered around a rain storage module that doubles as the back of a

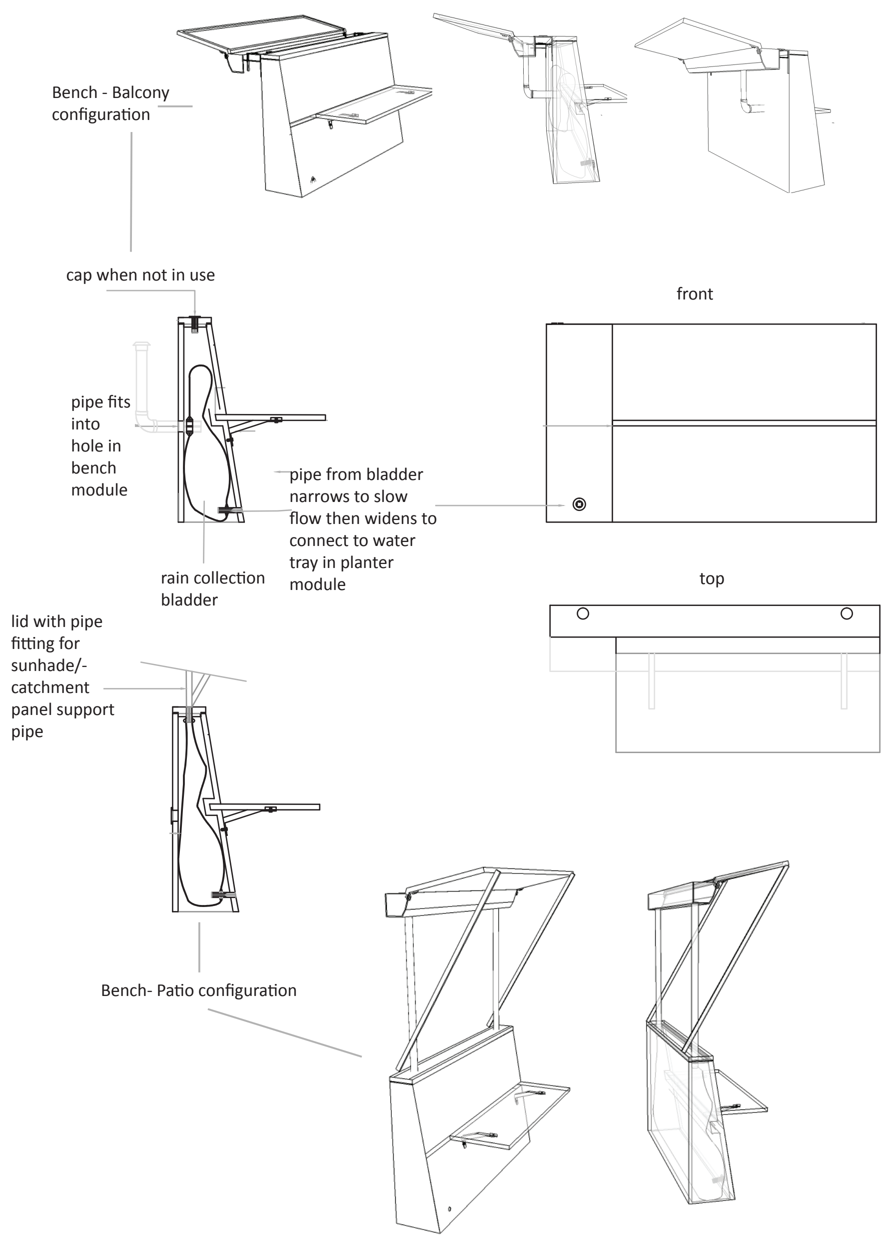
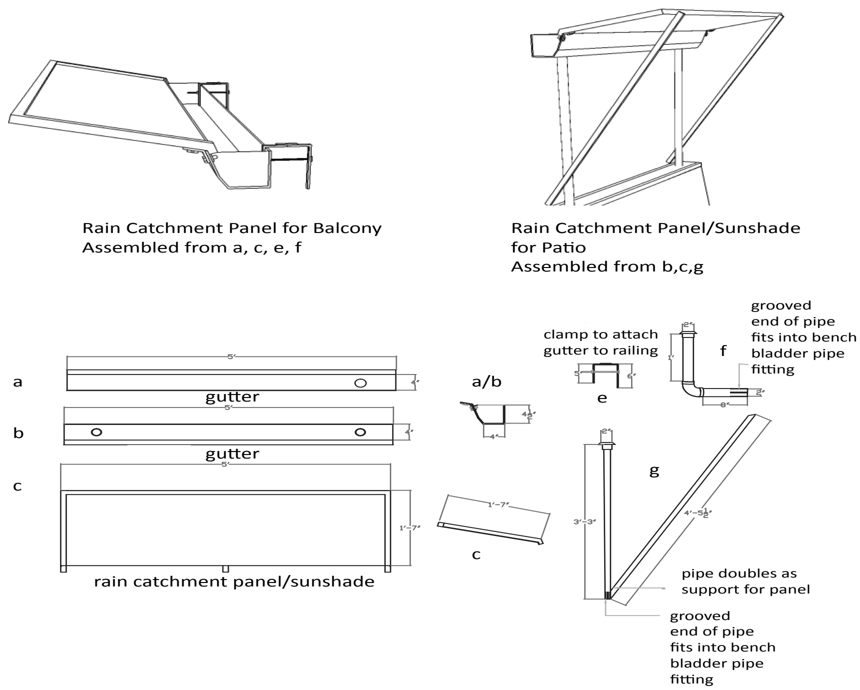


FIGURE IV: BENCH COMPONENTS

bench. This module is a 3' tall structure that has a shelf for seating. It collects water through pipes connected to 1.5'x5' rain collection panels. Rain that falls on the panels drains into a gutter.

FIGURE V: RAIN COLLECTION COMPONENTS



This gutter can be configured to hang on a balcony railing using brackets. In this configuration, multiple gutter modules are

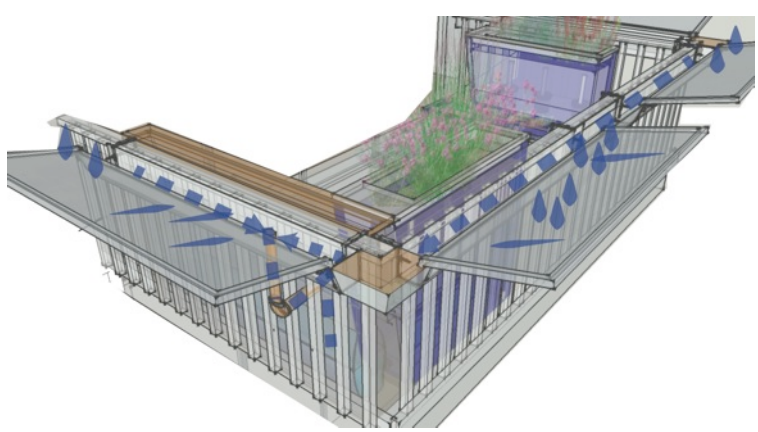


FIGURE VI: BALCONY WATER FLOW FROM GUTTERS

connected to multiple rain collection panels all of whom drain into a pipe that directs water into a singular bladder. (see Figure VII)

Both the gutter and the rain collection panel are made of corrosion resistant aluminum sheeting, a lightweight option that is easy to weld and form and is a good choice for situations that require contact with water. It also provides a nice contrast to the compressed agricultural fiber panels.

On a patio, where a railing is not available, the rain collection panel doubles as a sunshade for the benches. It drains into a gutter module which connects to pipes that double as supports for the rain shade. These pipes then drain into the bladder in the bench hollow. (See Figures IX)

In either configuration, the bladder connects to planter modules through a connector pipe with a slow release valve that empties into the planter's water collection tray. (See Figure VIII)

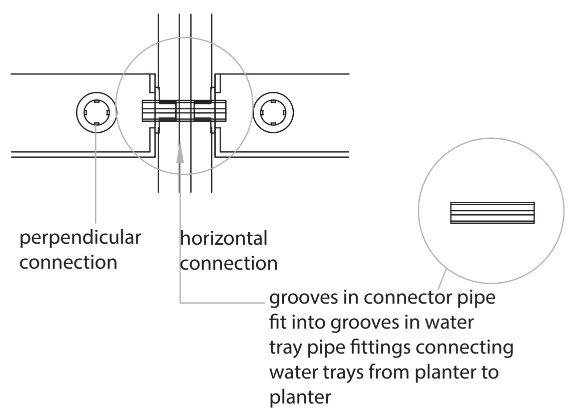


FIGURE VII: CONNECTOR PIPE DETAIL

The bench/rainbarrel module includes a groove, which fits a glass bench for seating. The module wall behind the bench is angled for comfortable eating but also fits neatly with the angles of the planter connected to it.

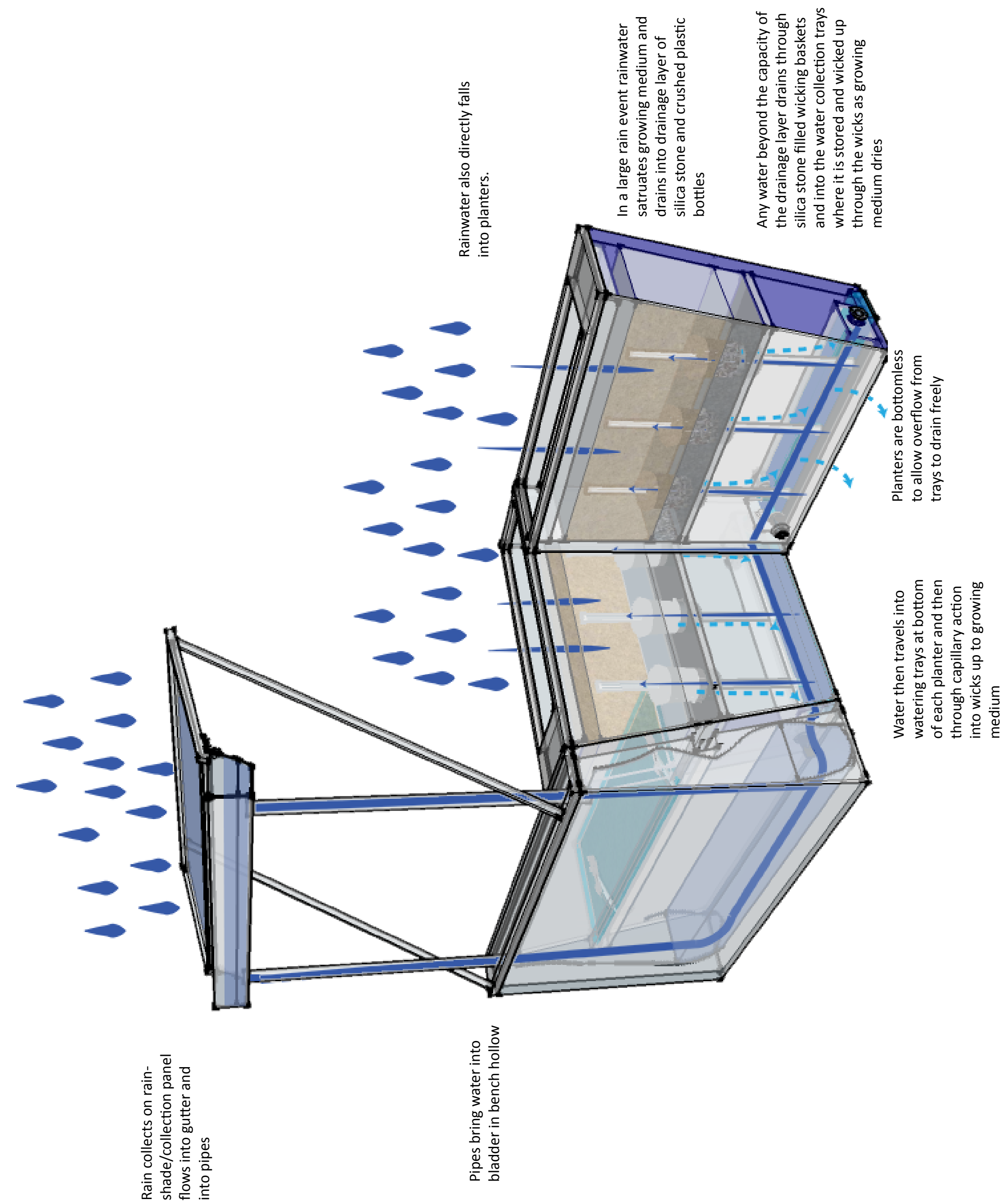


FIGURE VIII: WATER FLOW DIAGRAM PATIO CONFIGURATION

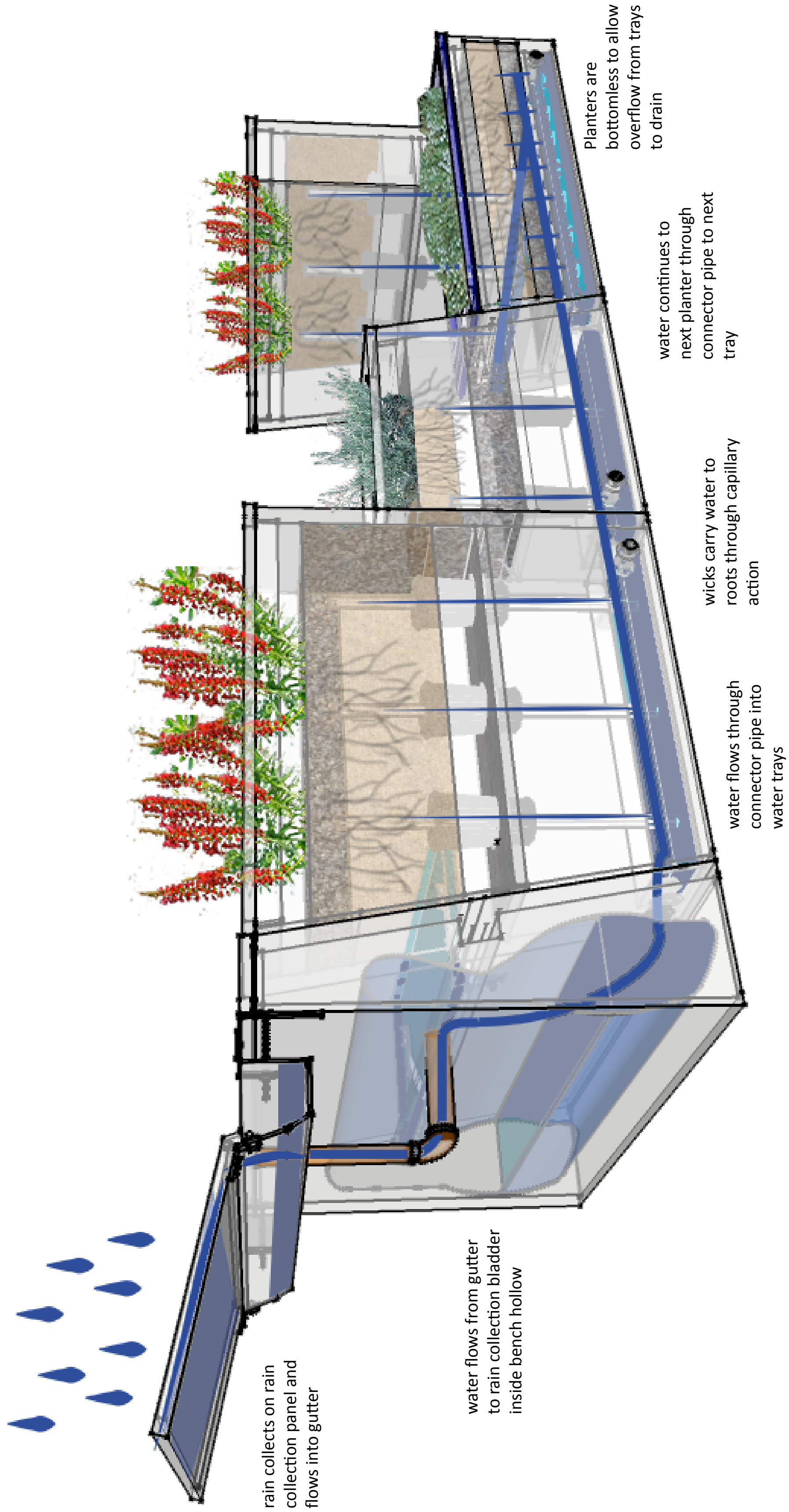


FIGURE IX: WATER FLOW DIAGRAM BALCONY CONFIGURATION

Section 2: Planters

The planters in this design are made of Compressed Agricultural Fiber (CAF) panels, which are essentially particle-board made of agricultural waste. These panels are fire, water, mold, termite and pest resistant and treated with resin for waterproofing. They can then be painted in a variety of colors. For the purpose of this design bright colors are chosen to contrast with the monochrome greys, browns and beiges of most apartment buildings. The planters also have an angled panel to give them some architectural interest and take them beyond rigid rectangular forms. They are also meant to fit together in a variety of arrangements. The following graphic depicts their sizes and shapes:

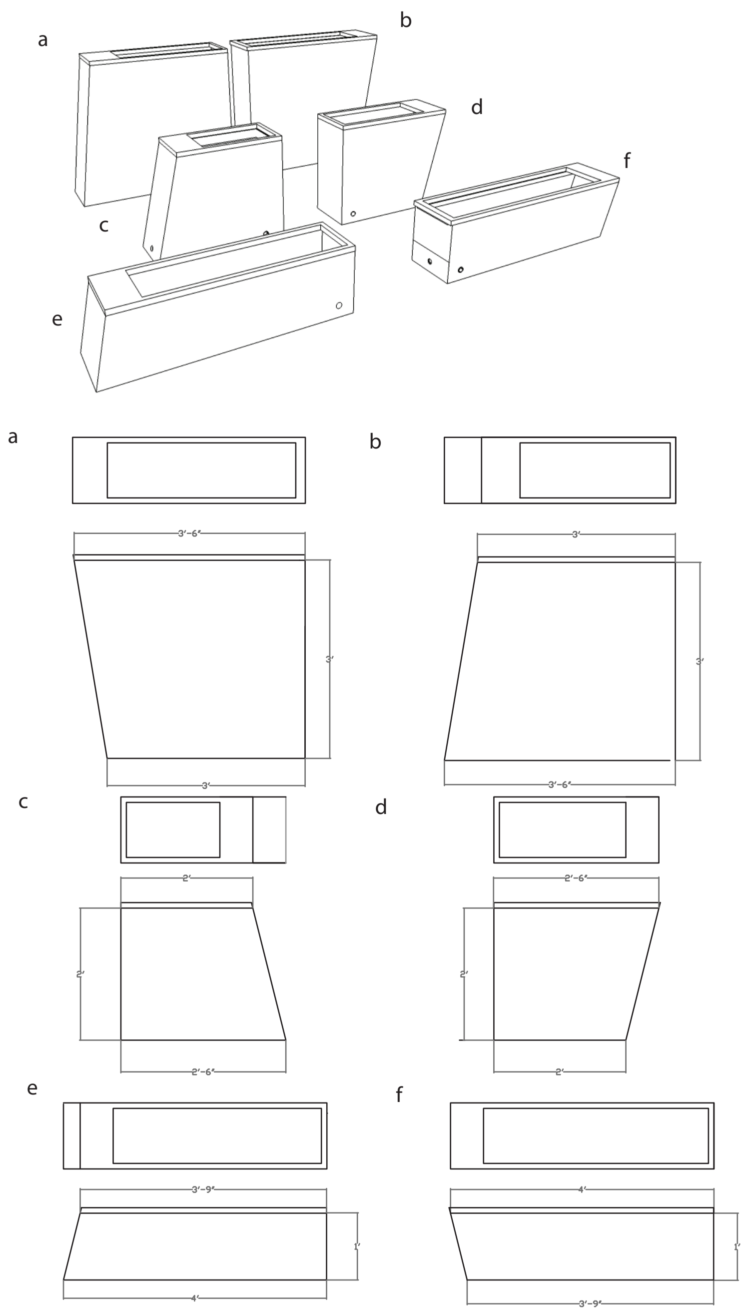


FIGURE X: PLANTER DIMENSIONS

Each planter consists of an outer shell, a shelf for growing medium with holes for wicks and drainage baskets. The ICF panels are designed to be flat packed and easily assembled with simple brackets, dowels and screws included in the package. A kit would also include any necessary tools such as an allen wrench.

Within this shell, each planter has a water collection tray made of molded plastic. Each tray is 4" tall and 6" wide no matter the size of the planter to ensure water flows evenly from planter to planter. A cloth wick runs from the tray through a basket of silica stone to the soil medium in each planter. A core of wire gives each wick structural support. The basket of silica stone helps store water for the plants but also drains any excess water accumulating in the planter's drainage layer (see image) The planter shells are bottomless allowing any water exceeding the capacity of the water trays to drain freely over the walls of the tray and out of the planter.

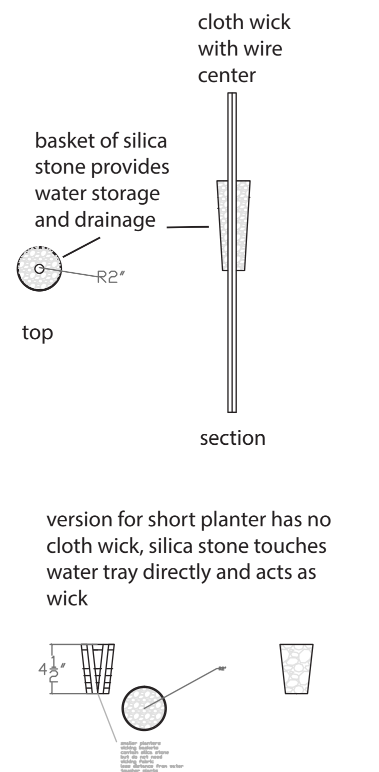


FIGURE XI: WICKING BASKET DETAILS

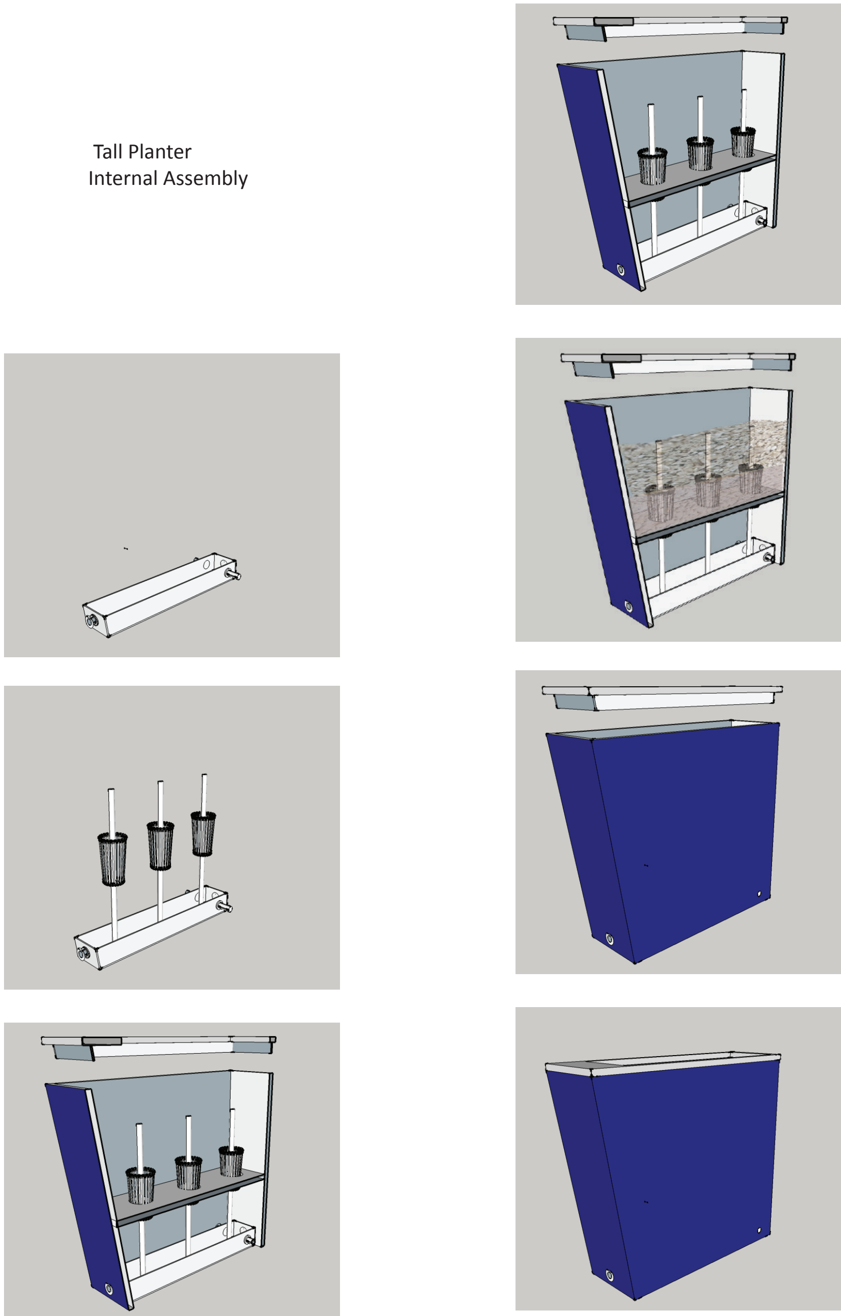


FIGURE XII: ASSEMBLY

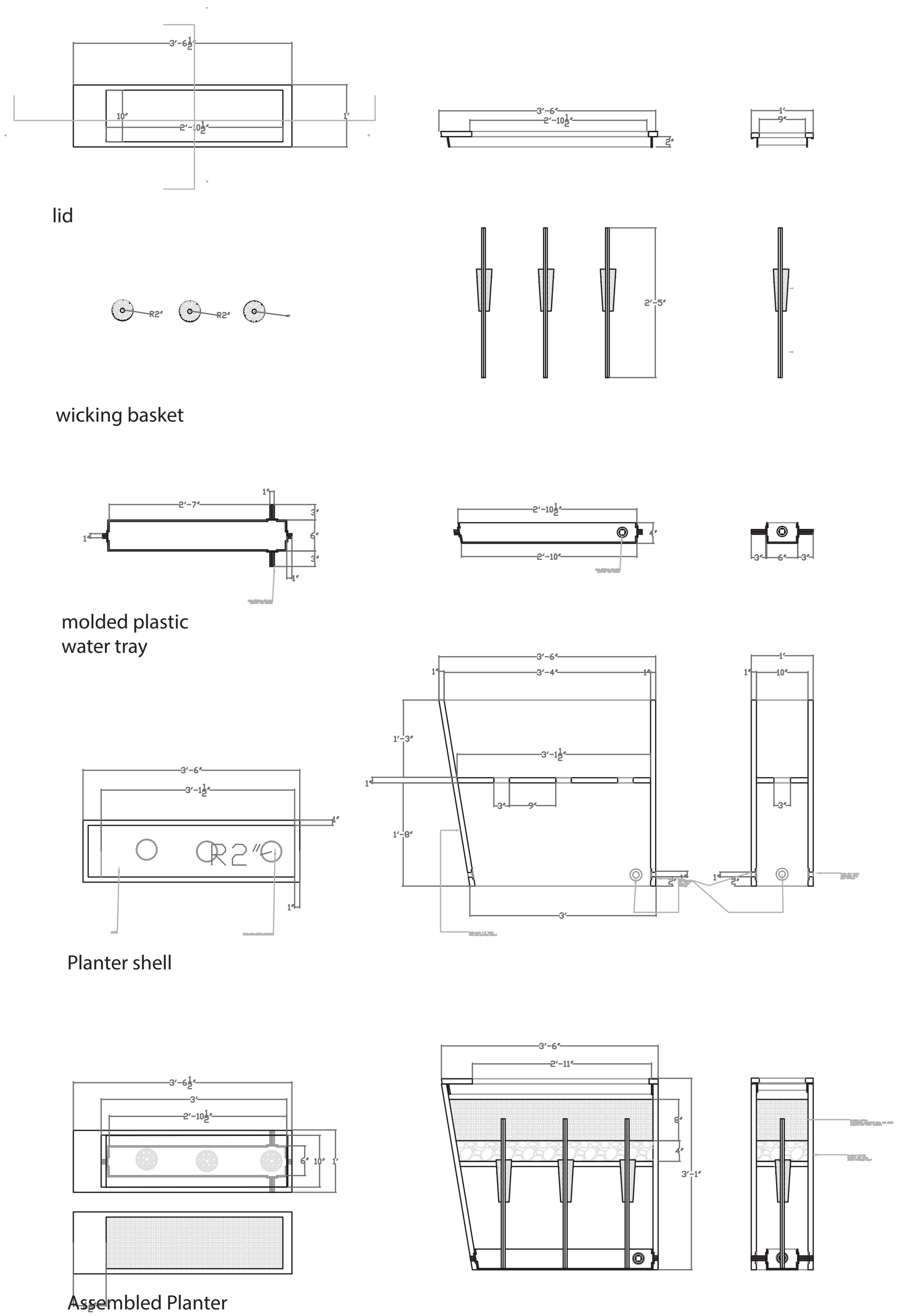


FIGURE XIII: TALL PLANTER INTERNAL DETAILS

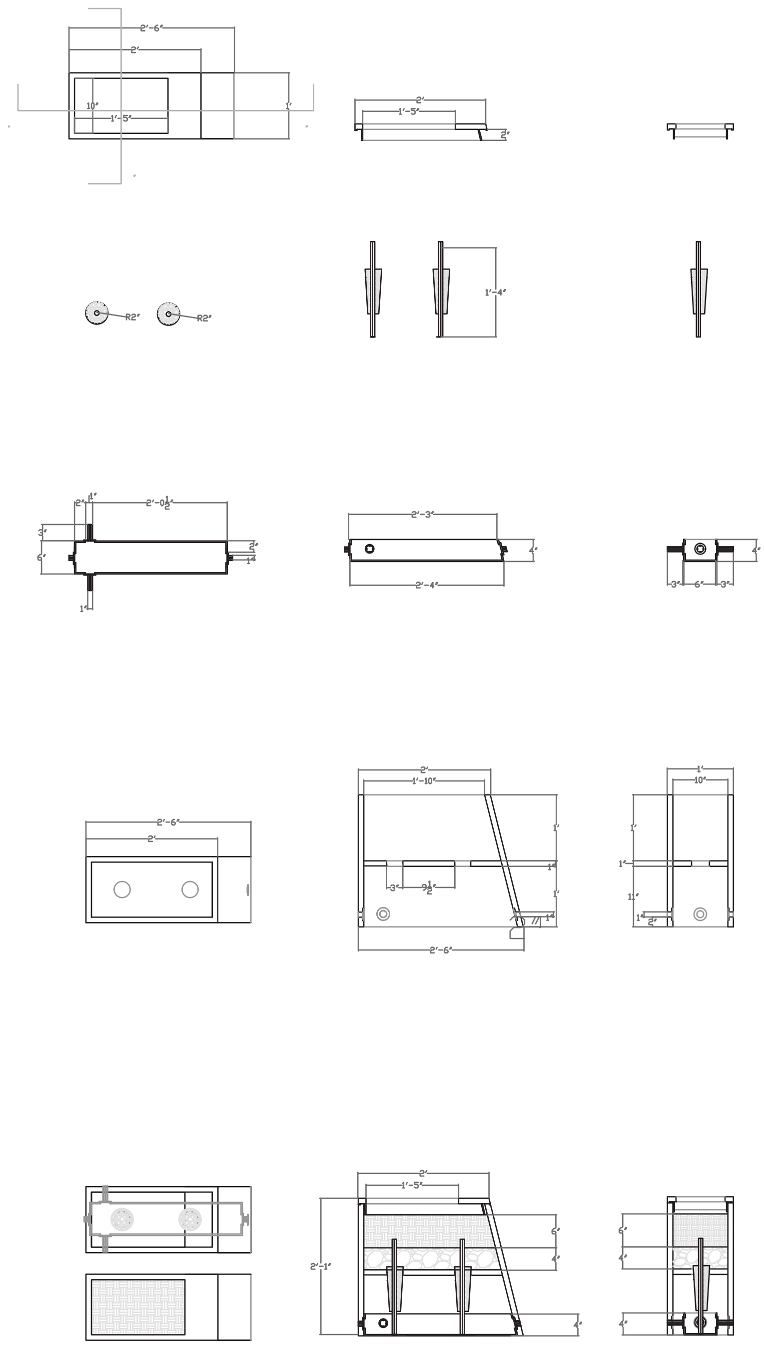


FIGURE XIV: MEDIUM PLANTER INTERNAL DETAILS

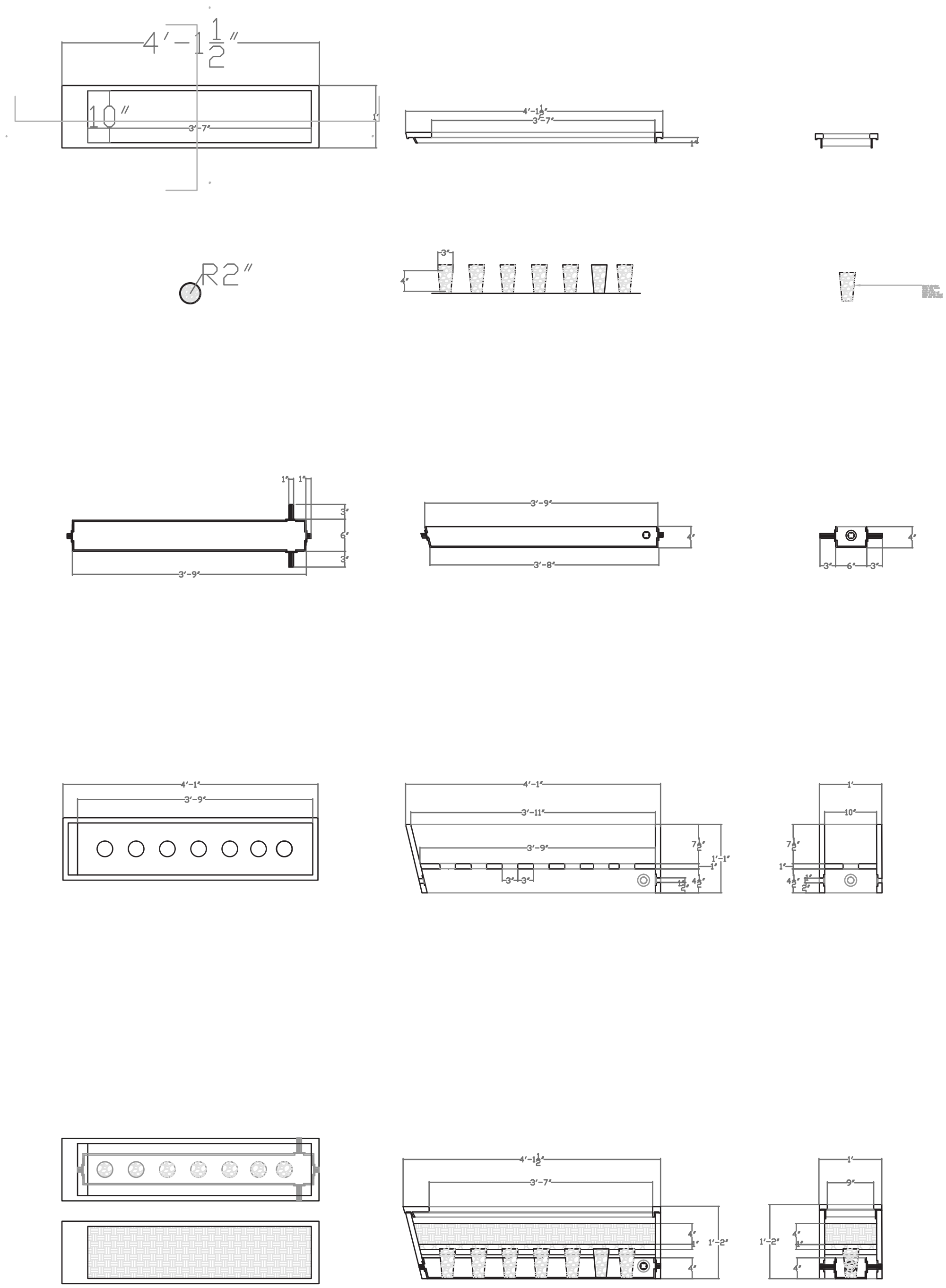


FIGURE XV: SHORT PLANTER INTERNAL DETAILS

The planters connect to each other using connector pipes that fit into the water tray pipe fittings and connect one platner's water tray to the next through holes in the planter walls. The angled sides of each planter into the angled side of the next planter as well as the angled front of the bench.

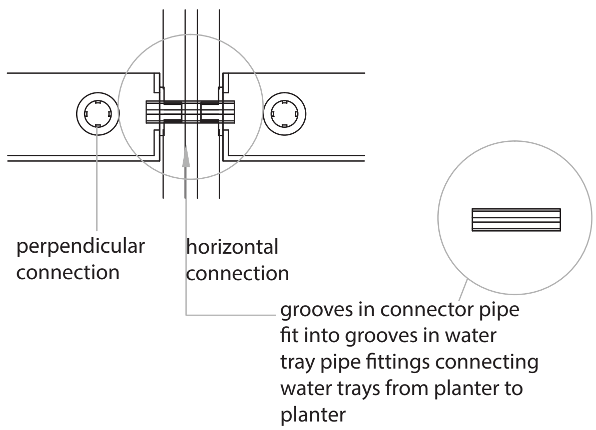


FIGURE XVI: CONNECTOR PIPE DETAIL

Section 3: Water Storage Capacity

The below calculation was used to determine the amount of water a single 1.5'x5' rain collection panel would collect for 1 year, 2 year and 10 year storm events. (Maryland Department of the Environment 2009)

Maryland state statistics for Prince George's County assess 2.7 inches of precipitation for a 1 year 24 hour storm event. Using the following calculation the amount of water collected in a one year storm event can be determined.

2.7/12 x Rain collection panel area 7.5 sq. ft. x runoff coefficient of .95 x 7.48 (gal/cu.ft) = 11.99 gallons

For a 2 year event at 3.3 inches

= 14.66 gallons

For a 10 year event at at 5.3 inches

= 23.53 gallons

A single bench bladder for this design, sized to fill the hollow of the bench back, holds 40 gallons. For a bench/rain barrel unit with a single collection panel this is enough capacity to hold and store a 10 year event.

The sample balcony design used in this thesis involves one bladder to four collection panels. Using the above calculation, these panels would collect a total of 47.95 gallons during a one year storm even exceeding the capacity of the bladder. However, the bladder is intended to slowly drain into the molded plastic trays at the bottom of the planters. For this design there are two large planters, one medium planter and two short planters. The total tray capacity for this sample design is a little over 9 gallons. In addition, water would gradually be wicked up by the wicks into the soil medium and drainage layer. As such, the system could easily hold and gradually use the water from a 1 year storm event. In the case of a 2 year or 10 year storm, however, the water collected by the panels would saturate the system, but would drain from the planter bottoms.

The planters on a patio are not sheltered from the rain as they would be on a balcony and also collect and store rainfall directly. Any rainwater not soaked up by the plants drains into the trays below the plants for storage and reabsorption through the wicks. Rainwater collection and storage in the bench/rainbarrel functions as a source of supplemental water for dry days rather than a primary source of irrigation as it does for the balcony plants. For the sample patio design with a single collection panel for each rain storage bench, the bladders would contain far less water- = 11.99 gallons

For a one year event, 14.66 for a two year event and 23.53 for a 10 year event.

As a result, while additional watering with potable water may be necessary to establish plantings in the first few weeks of system implementation, very little potable water should be necessary after that. These systems should be largely self-watering with the exception of a long period of draught. As can be seen in the next sections, growing medium and plants are also selected for draught tolerance minimizing the need for outside water even when conditions are hot and rainwater is scarce.

Section 4: Growing Medium

The modules will contain a growing medium that is soilless, lightweight, able to hold nutrients and drains easily. This medium bears close resemblance to that used on an intensive green roof. Any mixture would require testing for fine tuning, but an initial mix would contain:

20% Fine grade expanded clay

40% Vermiculite

30% Cocopeat (saturated percent)

10% leaf mulch compost

Soilless medium eliminates the presence of silt, which can clog drainage. The presence of organic components is kept at less than 40% as these components break down over time and will also clog drainage if overused. (Siciliano 2014)

Expanded clay is very lightweight, porous, and completely sterile. It is also impossible to compact, and reusable. It adds drainage to the media but holds water. The choice of vermiculite is due to its ability to aerate but also retain nutrients and water. Cocopeat increases water use efficiency, with an ability to hold up to nine times its weight in water and delivers phosphorus and potassium content. When dry it is very light and compact expanding to twice its size once water is added. (progressivegardening.org 2013, Evans 2013)

Green roof professionals recommended leaf mulch compost as the most consistent and successful compost for intensive green roofs. They also recommended that the mix be precise and consistently blended through a blending plant where raw materials are loaded into bins hanging above a conveyor belt that adds exact amounts of each component. (Siciliano 2014)

This mix is mostly dry on installation and thus lightweight. Upon delivery the growing medium weights approximately 16ibs. per cubic foot. Standard potting mix, by comparison, is about 20ibs per cubic foot. The design also limits the amount of medium used through the system of wicks, drainage medium and water storage as well as plant choice. As a result, the largest planter module in this project contains 1.8 cubic feet of growing medium at 29 Ibs when dry.

Once water is added the mix becomes saturated and far heavier. The mix is intentionally course as it is intended for succulents, herbs, draught tolerant perennials and grasses, which prefer free draining course media.

The planters hold from 4-8" of growing medium, but each also has a layer of drainage material below the medium. This layer allows for further water storage with minimal additional weight. The drainage layer is composed of a mix of silica stone and crushed plastic bottles. Silica stone holds up to 150% of its weight in water and releases it gradually. The crushed plastic bottles provide an opportunity to recycle but are also a good filler for the drainage layer as well as cheap and lightweight.

Below the drainage layer, drainage baskets hang. These baskets hold the wicking fabric that delivers water from the water tray and also function as a drainage component. The silica stone in the baskets absorbs water draining from the growing medium. If the growing medium is completely saturated these stones store some of the water for later reuse by the plants and release the rest to the water trays below for storage.

Section 3: Plant Palette

The plant palette for this project is strongly influenced by plants recommended for green roofs. These plants tend to be drought tolerant, tough and able to thrive with very little organic material. They require less growing medium than most plants and very little care.

As such plants are chosen to match the various sizes of planters. Those that require deeper medium are selected for the tall planters, which have 8" of medium while those that can thrive in only 4" of medium are designated for the shortest planters. Some, like the herbs, are planted in multiple planter types as a low growing border that is both edible and semi evergreen. The best plants for this project are long bloomers and/or have winter interest in the form of evergreen leaves. They are categorized below by planter designation and divided into those that need full sun and those that will do well in shade.

Full Sun:

Tall Planters- 8" of medium, 4" of drainage- these planters contain three types of plants. The largest are the "thrillers" or the large dramatic plants- large grasses and perennials that add height and architectural form. Then on the border of the planter are herbs to soften the edges as well as spring bulbs that are dormant most the year but add interest when very little else is growing in early spring.

Perennials:

Lavandula angustifolia 'Hidcote Superior'

Purple blue flowers in late summer, gray green foliage is evergreen, 16 inches tall, 10 inch spread

Scabiosa columbaria 'Misty Butterflies'

Pink-Purple flowers from early summer to early autumn, green foliage, 10 inches tall, 10 inch spread

Echium russicum

Dark red flower spikes early to late summer, green foliage, 23 inches tall, 8 inch spread

Grasses – these are selected for ability to survive in shallow medium, drought tolerance, and aesthetic appeal. Both are still attractive in winter but would have to be cut back for new growth in spring.

Bouteloua gracilis

Light brown flowers in midsummer, green foliage, midsummer bloom, 12 inches tall, 12 inch spread

Sporobolus heterolepis

Brown flowers, mid summer- early autumn, green foliage, 30 inches tall, 12 inch spread

Bulbs:

Daffodills, tulips, mini irises, muscari, crocus

Edible herbs:

Origanum vulgare

Purple or white small flowers from July to October, Semi evergreen in mild winters

Rosmarinus officinalis

Pale blue to white small flowers late summer- semi evergreen in mild winters- 2' tall, 2-4' spread

Thymus praecox 'Coccineus'

Rose purple flowers, green foliage, Blooms midsummer, 4 inches high

Medium Planters- 6" of medium, 4" of drainage – plants for these planters are perennials able to take less growing medium as well as herbs. Plants are chosen to include an evergreen component.

Perennials:

Euphorbia myrsinites

Yellow/green flowers in late spring, blue green foliage is evergreen, 10 inches tall, 10 inch spread

Gallium verum

Yellow flowers from late spring to early autumn, green foliage, 12 inches tall, 8 inch spread

Hieraciaum villosum

Yellow flowers from early to late summer, hairy green foliage, 12 inches tall, 8 inch spread

Artemesia ludoviciana

Yellow flowers in late summer, silvery grey foliage, 22 inches tall, 10 inch spread, weeping habit- good for softening edges.

Edible herbs:

Origanum vulgare

Purple or white small flowers from July to October, Semi evergreen in mild winters

Rosmarinus officinalis

Pale blue to white small flowers late summer- semi evergreen in mild winters- 2' tall, 2-4' spread

Thymus praecox 'Coccineus'

Rose purple flowers, green foliage, Blooms midsummer, 4 inches high

Short Planter- 4" growing medium, 2" drainage medium- these planters have shallow medium largely restricting the types of plants that work in them. However, they are perfect for succulents and can accommodate herbs as well. Planters containing a mix of succulents can be colorful with an interesting mix of textures and heights.

Herbs:

Origanum vulgare

Purple or white small flowers from July to October, Semi evergreen in mild winters

Thymus praecox 'Coccineus'

Rose purple flowers, green foliage, Blooms midsummer, 4 inches high

Succulents:

Low Growing:

Jovibarbra 'Emerald Spring'

White flowers with pale yellow and greenish tinge in early summer, green foliage, turns red in winter, 4 inches tall, 4 inch spread

Sedum album ‘France’

White flowers, blue green foliage in summer and reddish in winter, 8 inches tall, 8 inch spread

Sedum album subsp. Teretifolium ‘Murale’

White flowers in midsummer, generally red foliage, 6 inches tall, 8 inch spread

Sedum spurium ‘Voodoo’

Blood red flowers in autumn, red foliage- into winter- attractive in drifts, 6 inches, 8 inch spread

Sempervivum arachnoideum ‘Sparkle’

Pink flowers in summer, yellow green to red foliage, 5 inches tall, 6 inch spread

Sempervivum ‘Georgette’

Pink flowers in summer, green to bright red foliage in winter, 6 inches tall, 6 inch spread

Taller succulents:

Sedum ‘Matrona’

Pink flowers in early autumn, green gray foliage, 12 inches tall, 10 inch spread

Sedum telephium ‘Emperor’s Waves’ (Crassulaceae)

Purple red flowers in late summer, blue green dark foliage, 16 inches tall, 8 inch spread

Part Shade- Most urban balconies or patios get some sun but plenty are in the shadow of large buildings for at least part of the day. Balconies that face north also generally need to contend with the shade from an overhang. Dry shade is a tough combination for many plants, but some plants benefit from a respite from the urban heat island that a half day of shade provides. The plant choices below generally still need some sun, but thrive in partial shade and need less water than they would in full sun. Herbs do not do well without full sun and are not included in the plant palette for part shade. However, there are plenty of succulents that thrive in part shade.

Tall Planter:

Marrubium incanum

White flowers in early to late summer, silver foliage- hairy, 16 inches tall, 10 inch spread

Penstemon smallii

Purple flowers from early to late summer, green foliage, 22 inches tall, 10 inch spread

Agastache rupestris

Orange flowers from mid-summer to mid-autumn, blue green foliage, 25 inches tall, 10 inch spread

Grasses:

Bouteloua gracilis

Sporobolus heterolepis

Bulbs:

Daffodills, tulips, hyacinths, muscarti

Medium Planter:

Herniaria glabra

White flowers in late summer, green foliage- groundcover- like thyme- but more drought tolerant and shade tolerant, 2 inches tall, 10 inch spread

Scuttellaria alpine

Purple flowers with white lips from early to late summer, green foliage, 10 inches tall, 8 inch spread

Aquilegia candensis 'Little Lanterns'

Red flowers with yellow cents from early to mid spring, green foliage, 10 inches tall, 8 inch spread

Short Planter- while these cannot contain herbs in part shade, a mix of succulents is a colorful and easy to maintain solution. The taller and more dramatic sedums also need full sun so the texture in shade will be more even in the short planters. Some planters can also contain a mix of alliums which do not need deep medium, like part shade and can be planted in a mix that includes multiple bloom times.

Alliums:

Allium cernuum

Rose and white flowers in late summer, green foliage- nodding habit

Allium oreophilum

Purple flowers in early summer, green foliage, 6 inches tall, 6 inch spread

Allium schoenprasum

Most common for green roofs and edible, pink edible flowers in late spring, blue green foliage, 10 inches tall, 6 inch spread

Allium senescens subsp. Motanum var. glaucum

Pink flowers in early autumn, blue green foliage, 8 inches tall, 6 inch spread

Succulents:

Low Growing:

Sedum makinoi

Yellow flowers in mid-summer, green foliage, 4 inches tall, 8 inch spread

Sedum spurium 'John Creech'

Strong grower, widely adapted, one of the more widely used green roof sedums, heavy display of pink flowers in summer, evergreen, 4-6 inches tall, 6-8 Inch spread

Sedum pachyclados

White flowers in early to mid-summer, blue green foliage, 3 inches tall, 6 inch spread

Sedum spurium ‘Fuldaflut’

Pink flower from mid-late summer, green to red foliage- red in fall and winter, tough plant does well in some shade, 6 inches tall, 8 inch spread

Sedum stoloniferum

Pink flowers in mid-summer, light green light reflecting foliage, 6 inch tall, 10 inch spread- good choice for dry shade

Sedum spurium ‘Summer Glory’

Dark pink attractive flowers in mid-late summer, green foliage- evergreen, 6 inches, 8 inch spread

(Missouri Botanical Garden 2014, Snodgrass 2006, Etera 2011)

Section 4: The Package

Each module is flat packable which means it can be taken apart into pieces and put into a box that includes everything from plants to watering tray. To see what this would look like this design was modeled in sketch up and the largest planter was then taken apart and put together in the most compact form possible. The resulting disassembled module fits in a 9”x3’6”x3’ box including all parts. (See below) While this is pretty compact considering what it includes, a full balcony or patio is still heavier and larger than desired in packed form. Follow up work on this design would seek ways to minimize the materials and create a more portable design. A full balcony design would require two of these boxes, a similar sized one for the bench and water collection components, as well as three somewhat smaller boxes for the medium and short planters. This would be 6 not insignificantly sized boxes- more than one regular sedan could fit. Even a compact design would likely require truck delivery. However, the design would not be a much larger delivery than a large couch.

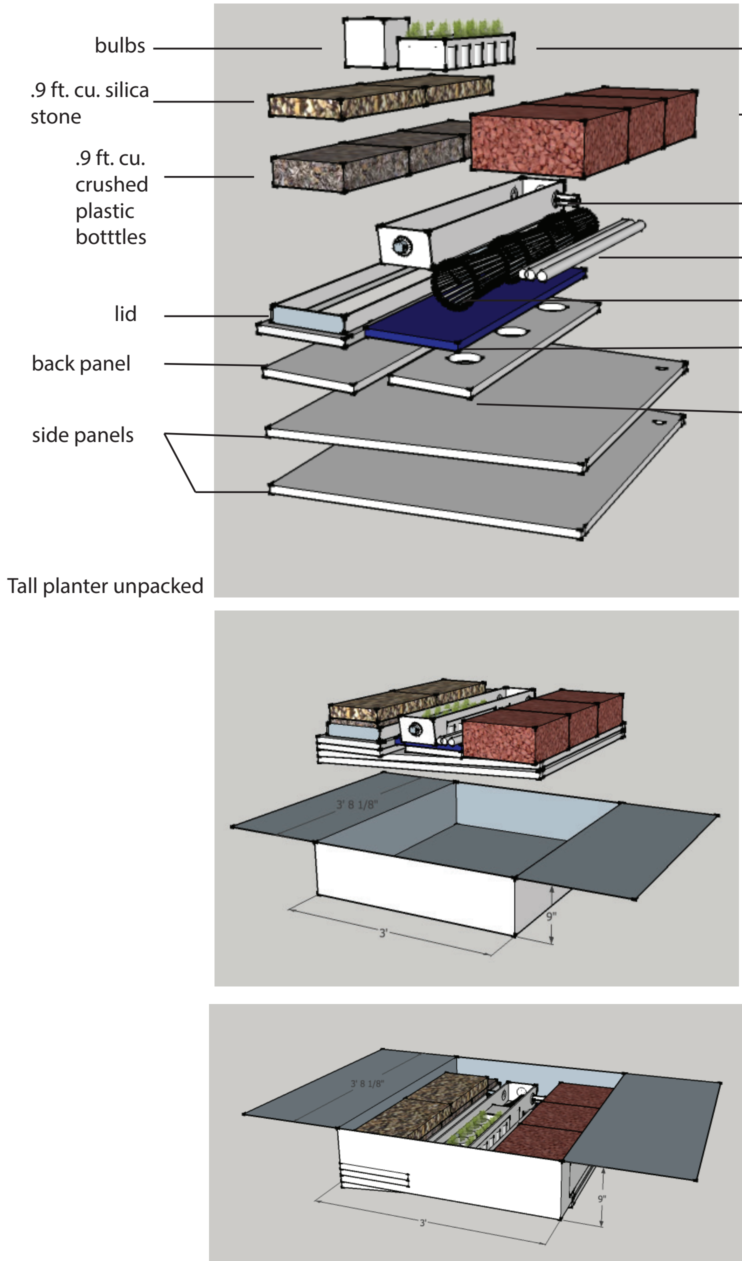


FIGURE XVII: TALL PLANTER PACKED

Chapter 8: Sample Layouts

This thesis includes four designs: A balcony in full sun, a balcony with part shade, a patio in full sun and a patio in part shade. The two balcony designs are essentially the same but their plant palette is significantly different. The same is true of the patio designs.

Balcony Design

The balcony design includes a bench, water collection equipment and five planters. Plants are chosen to compliment the architectural forms of the planters with taller plants in the taller planters and shorter plants in the lower planters. The full sun allows for use of taller sedums however in the short planters adding some height to them.

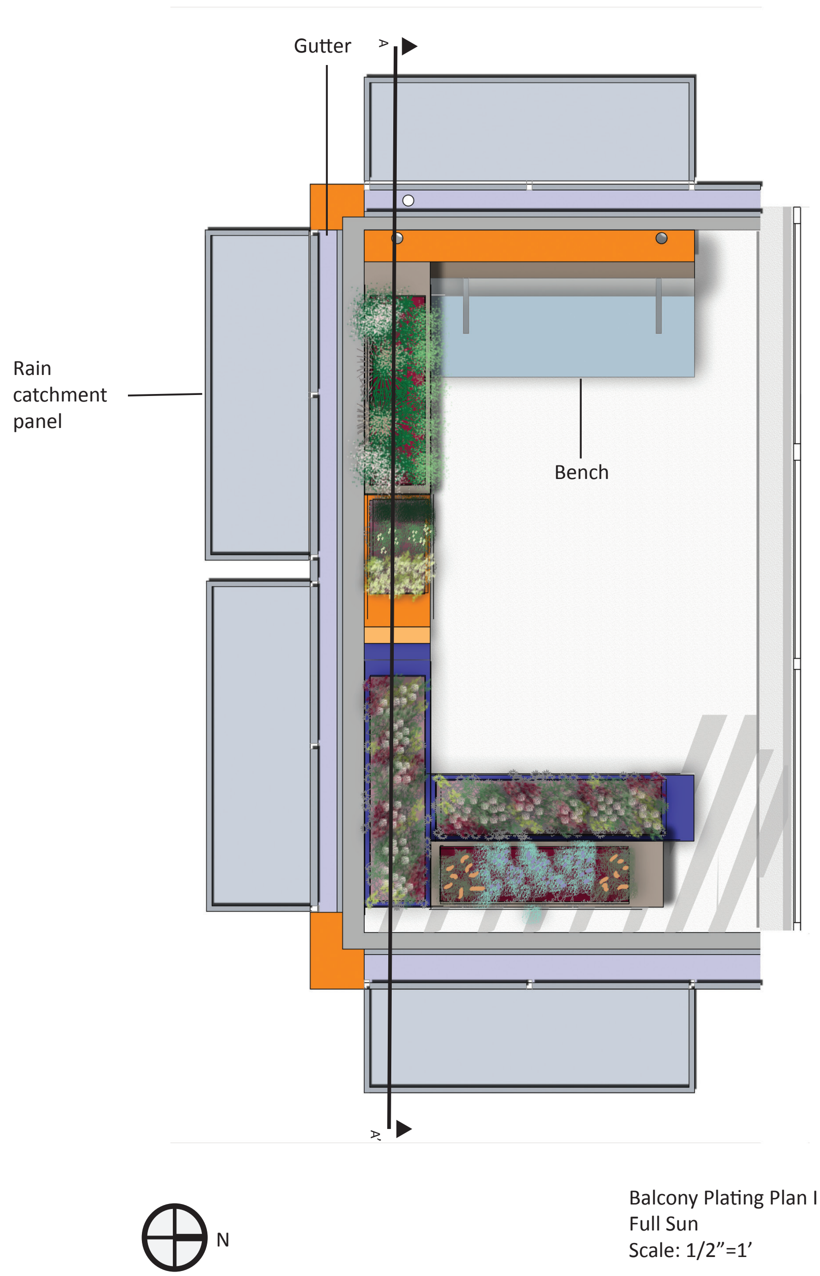
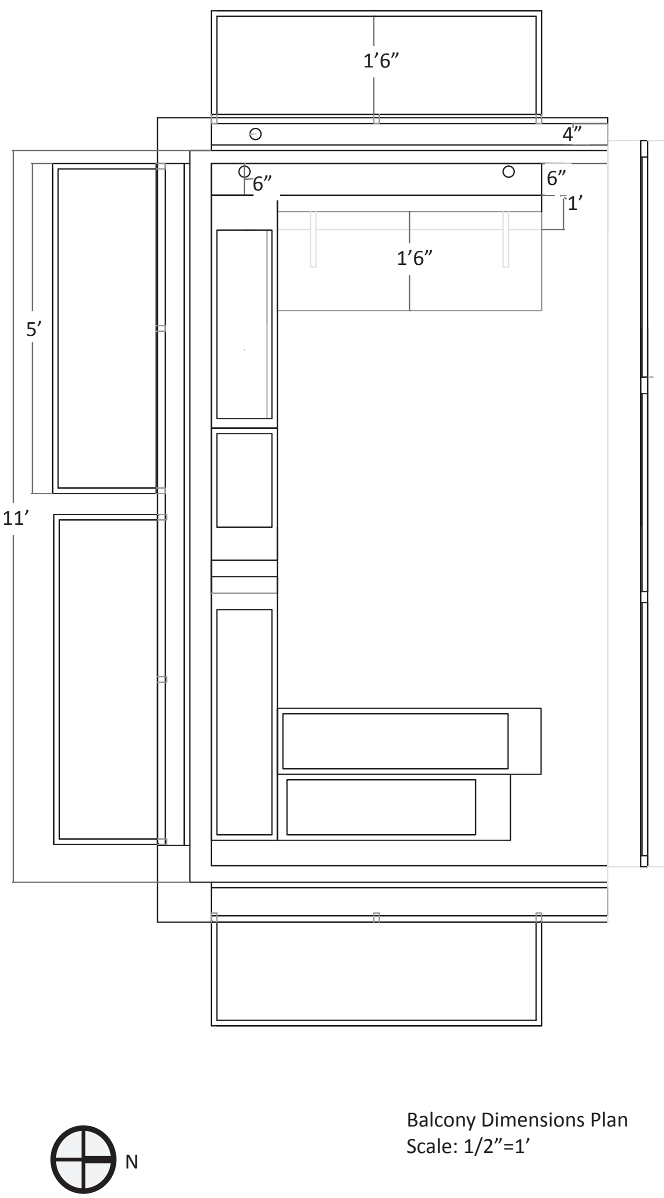


Figure xviii: Balcony

Plan



Balcony Dimensions Plan
Scale: 1/2”=1’

FIGURE XIX: DIMENSIONS

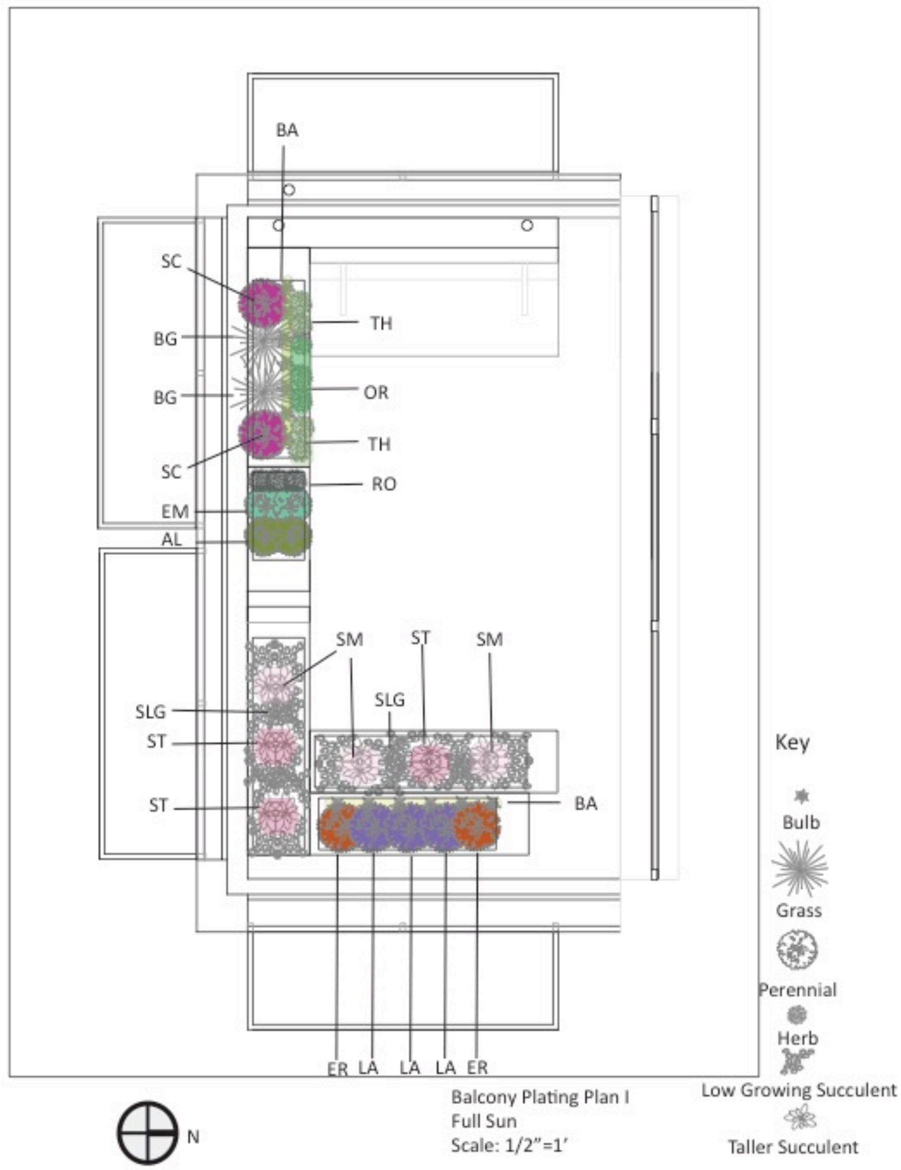


FIGURE XX: PLANTING PLAN FULL SUN

FIGURE XXI: PLANTING TABLE FULL SUN

Abbreviation	Common Name	Latin Name	Quantity
LA	Lavender	*Lavandula angustifolia* ‘Hidcote Superior’	3
SC	Dwarf Pincushion Flower	*Scabiosa columbaria* ‘Misty Butterflies’	2
ER	Echium russicum	*Echium russicum*	2
BG	Blue Grama	*Bouteloua gracilis*	2
EM	Spurge	*Euphorbia myrsinites*	2
AL	White Sagebrush	*Artemesia ludoviciana*	2
SLG	Low Growing Sedum Mix	*Jovibarbra* ‘Emerald Spring’	20
		Sedum album ‘France’	
		Sedum album subsp. Teretifolium ‘Murale’	
		Sedum spurium ‘Voodoo’	
		Sempervivum arachnoideum ‘Sparkle’	
		Sempervivum ‘Georgette’	
SM	Stonecrop	*Sedum ‘Matrona’*	6
ST	Sedum ‘Emporer’s Waves’	Sedum telephium ‘Emperor’s Waves’	6
BA	Bulbs- assorted: Daffodil, iris, crocus Muscarti		12
OR	Oregano	*Origanum vulgare*	3
RO	Rosemary	*Rosmarinus officinalis*	3
TH	Thyme	*Thymus praecox* ‘Coccineus’	4

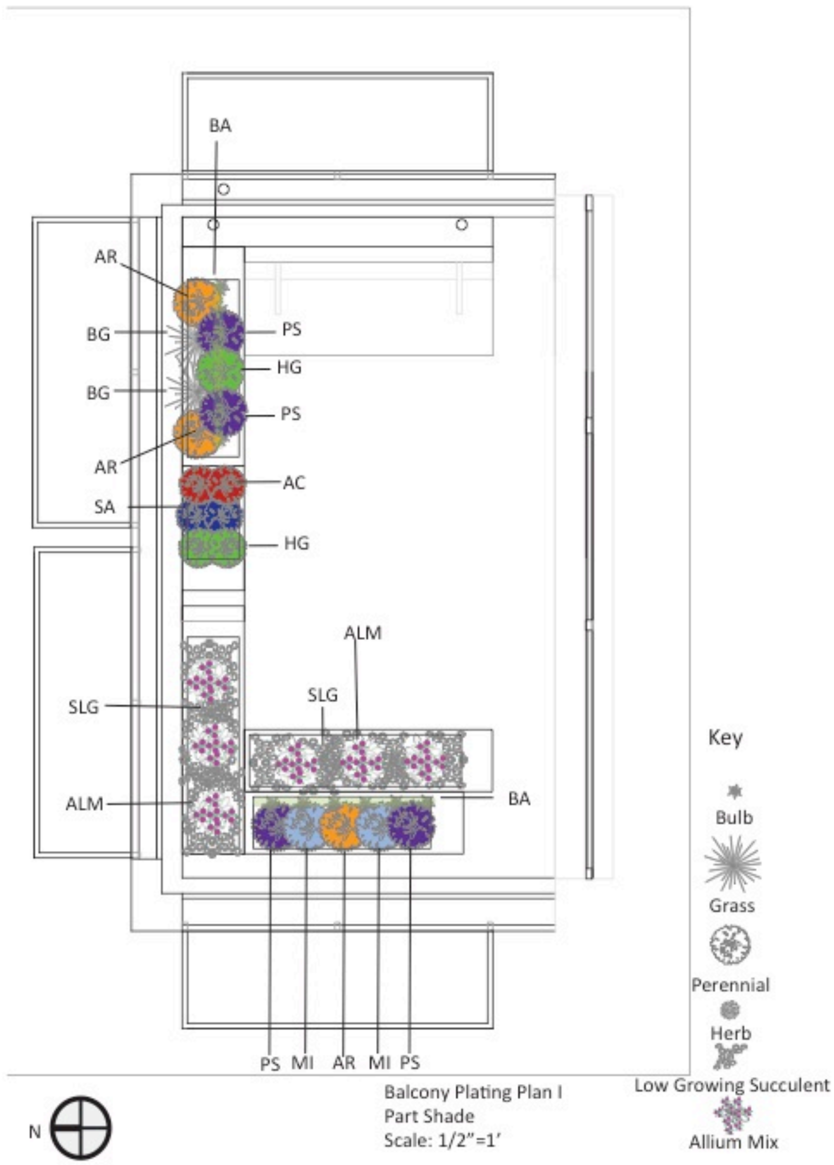


FIGURE XXII: PLANTING PLAN PART SHADE

FIGURE XXIII: PLANTING TABLE PART SHADE

Abbreviation	Common Name	Latin Name	Quantity
MI	Horehound	*Marrubium incanum*	2 plugs
PS	Small's Beardtongue	*Penstemon smallii*	4 plugs
AR	Licorise Mint Hyssop	*Agastache rupestris*	3 plugs
BG	Blue Grama	*Bouteloua gracilis*	2 plugs
HG	Green Carpet	*Herniaria glabra*	3 plugs
SA	Alpine skullcap	*Scuttellaria alpine*	2 plugs
AC	'Little Lanterns' Dwarf Columbine	*Aquilegia candensis* 'Little Lanterns'	2 plugs
SLG	Low Growing Sedum Mix	*Sedum makinoi*	20 plugs
		Sedum spurium 'John Creech'	
		Sedum pachyclados	
		Sedum spurium 'Fuldaflut'	
		Sedum stoloniferum	
		Sedum spurium 'Summer Glory'	
ALM	Allium Mix	*Allium cernuum*	40 bulbs
		Allium oreophilum	
		Allium schoenprasum	
		Allium senescens subsp. Motanum var. glaucum	
BA	Bulbs- assorted: Daffodil, iris, crocus muscarti		12 bulbs

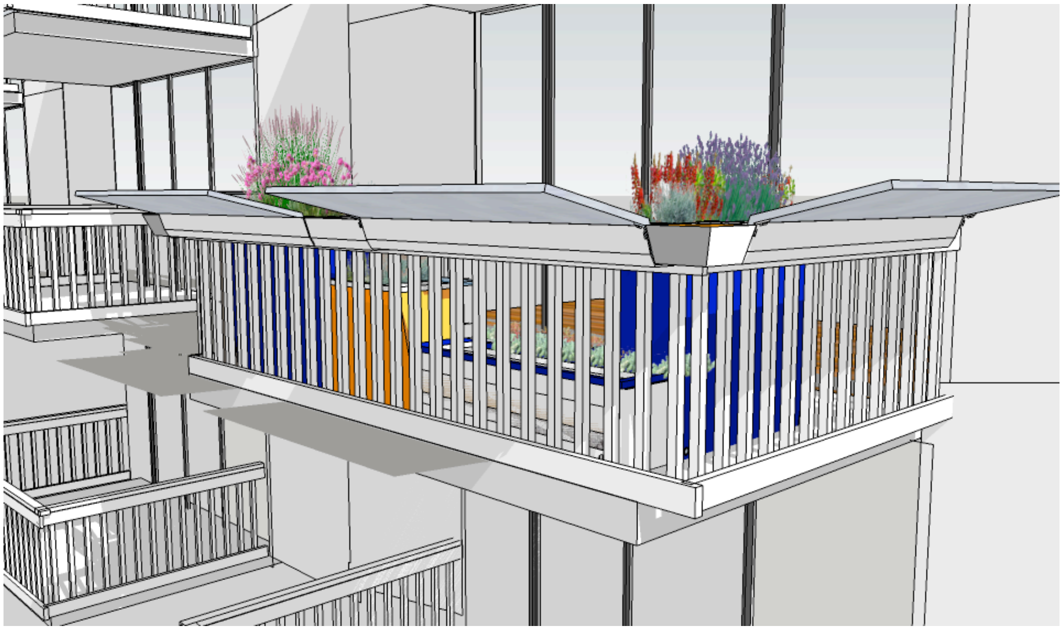


FIGURE XXIV: BALCONY IN CONTEXT

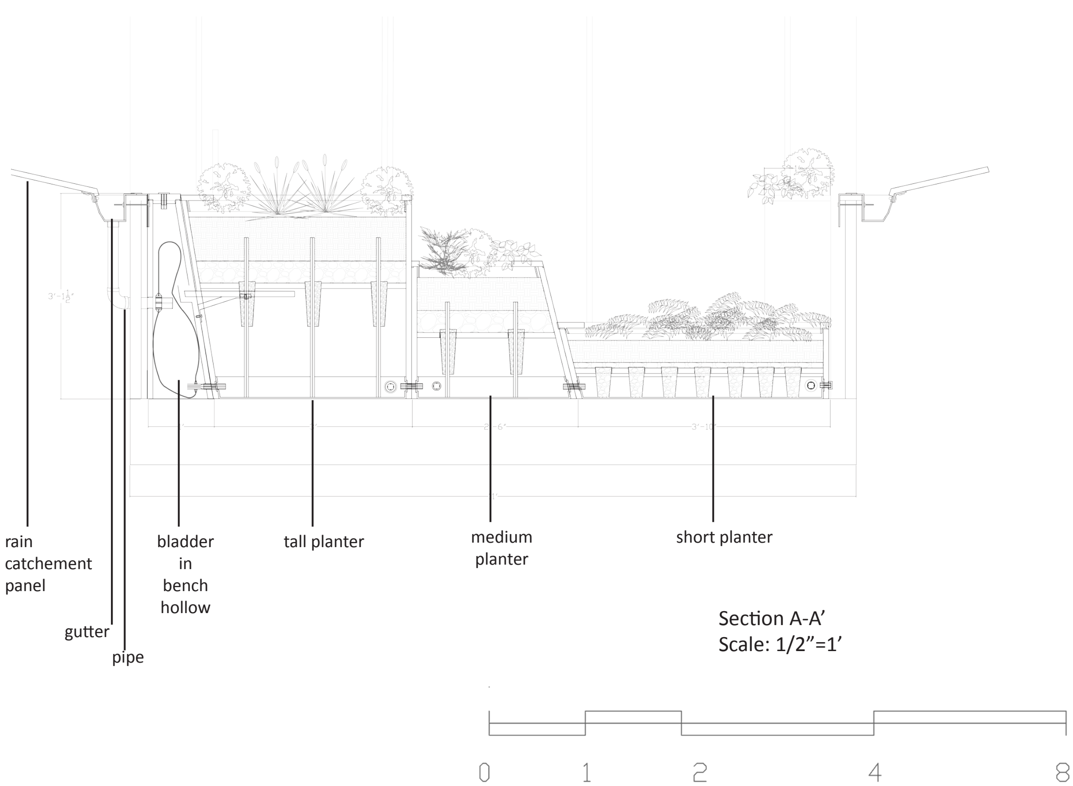


FIGURE XXV: BALCONY SECTION

FIGURE XXVI: BALCONY VIEW FROM APARTMENT

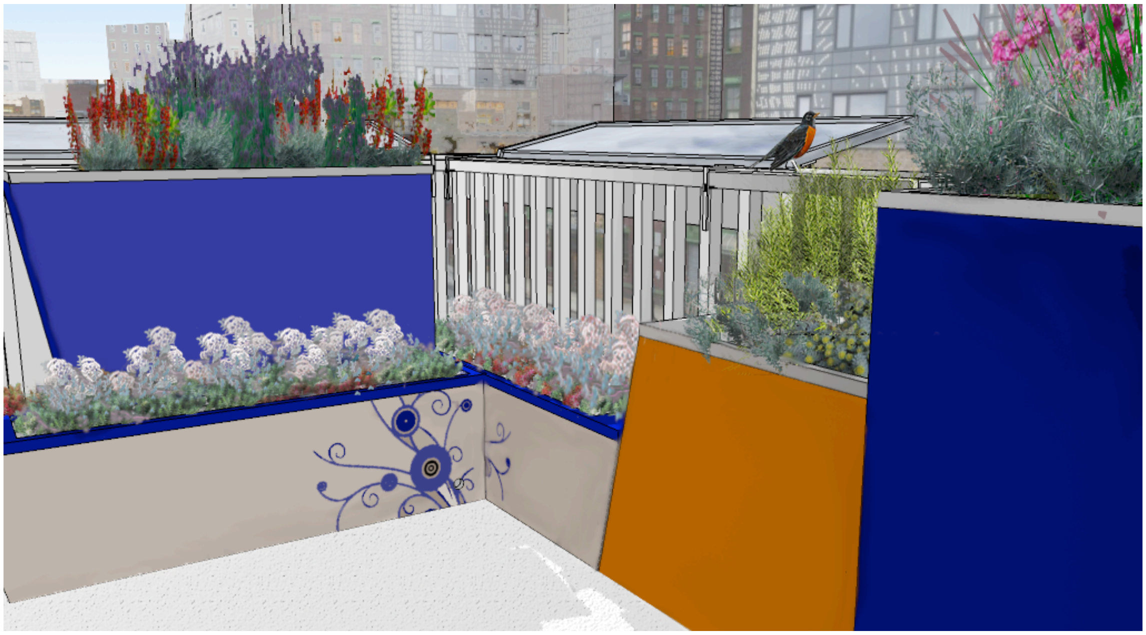


FIGURE XXVIII: VIEW FROM BENCH

FIGURE XXVII: VIEW TOWARDS BENCH

Patio Designs

The Patio is a much larger space at 23’x20’. It is a rarer space to find in an urban setting but one that offers far more opportunity. However, it also has a drawback. A large patio like this can look very barren with a lot of hardscape to cover. For a renter, this is a challenge. How do you create architectural intimacy in a large blank and empty space. This design aims to do so with the least number of planters possible to reduce cost. It also aims to create outdoor rooms- places to sit and socialize right outside the apartment.

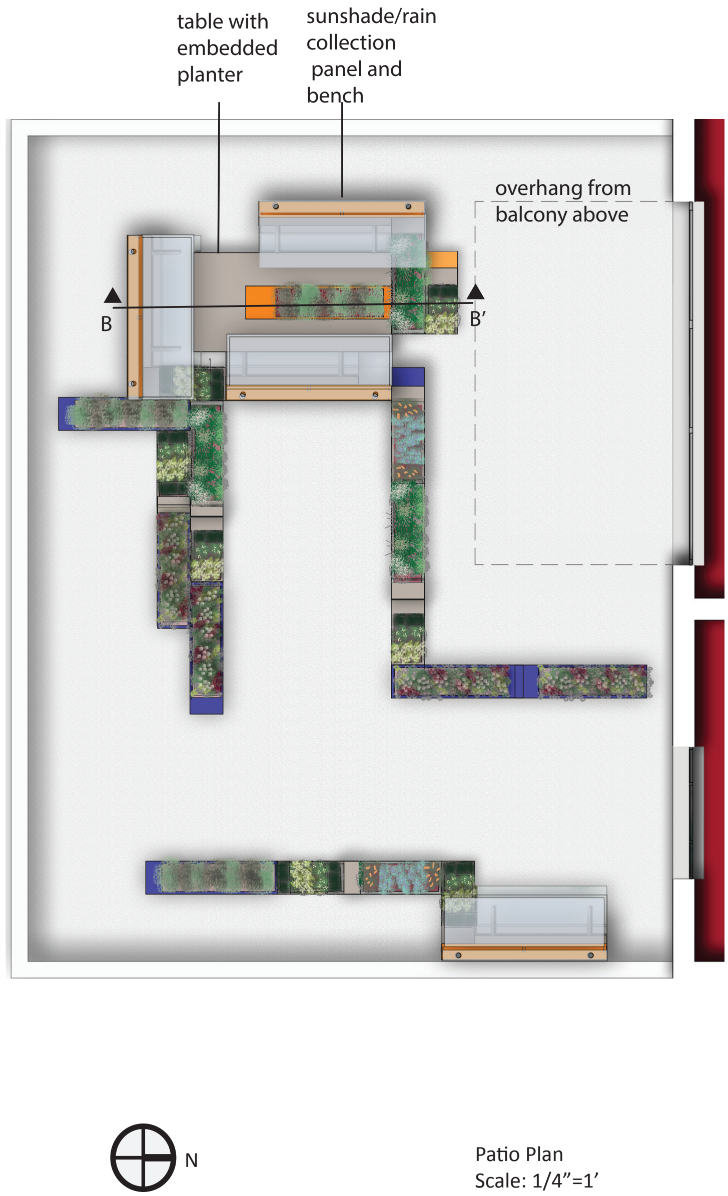


FIGURE XXIX: PATIO PLAN

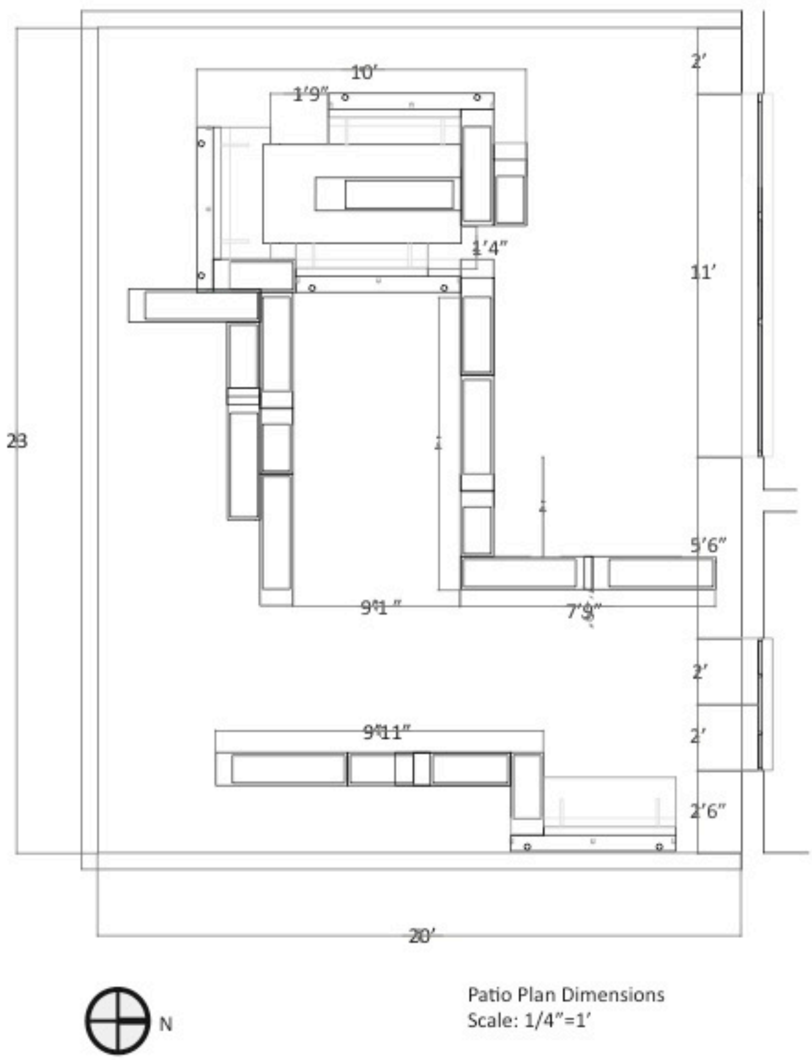


FIGURE XXX: PATIO DIMENSIONS

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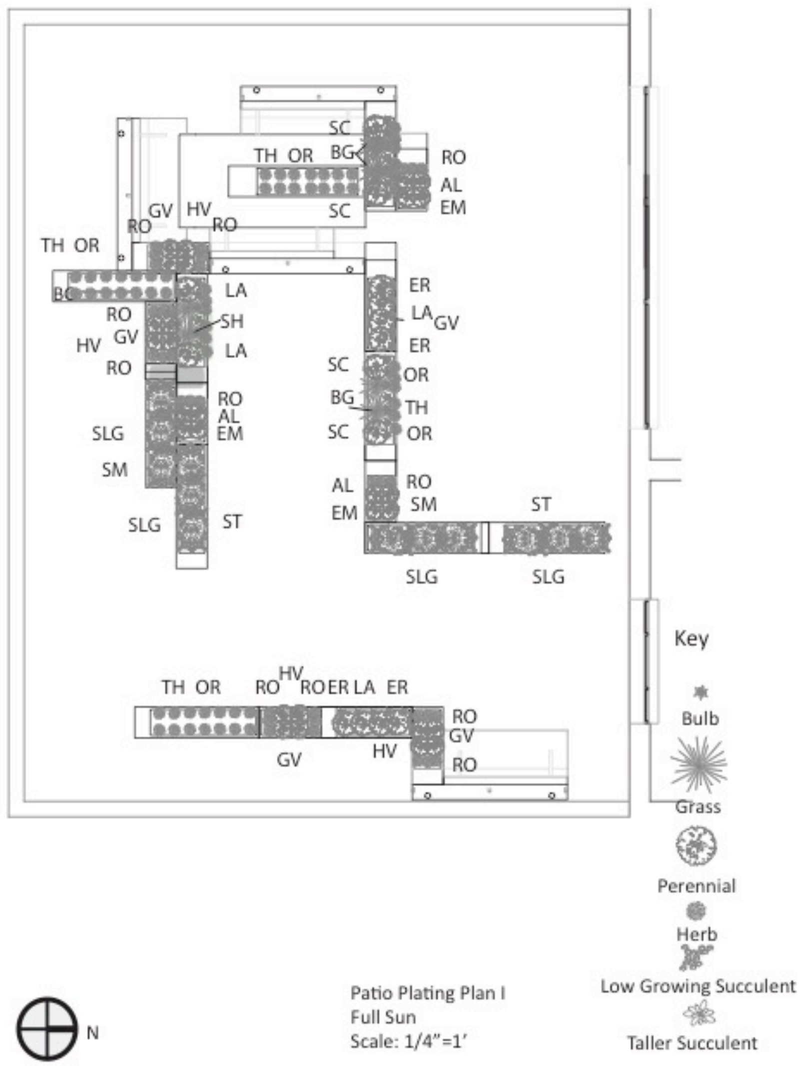

FIGURE XXXI: PATIO PLANTING PLAN FULL SUN

FIGURE XXXII: PATIO PLANTING TABLE FULL SUN

Abbreviation	Common Name	Latin Name	Quantity
LA	Lavender	*Lavandula angustifolia* 'Hidcote Superior'	6
SC	Dwarf Pincushion Flower	*Scabiosa columbaria* 'Misty Butterflies'	4
ER	Echium russicum	*Echium russicum*	4
BG	Blue Grama	*Bouteloua gracilis*	4
SH	Prairie Dropseed	*Sporobolus heterolepis*	2
EM	Spurge	*Euphorbia myrsinites*	6
AL	White Sagebrush	*Artemesia ludoviciana*	6
GV	Lady's Bedstraw	*Gallium verum*	8
HV	Shaggy Hawkweed	*Hieraciaum villosum*	8
SLG	Low Growing Sedum Mix	*Jovibarbra* 'Emerald Spring'	40
		Sedum album 'France'	
		Sedum album subsp. Teretifolium 'Murale'	
		Sedum spurium 'Voodoo'	
		Sempervivum arachnoideum 'Sparkle'	
		Sempervivum 'Georgette'	
SM	Stonecrop	*Sedum 'Matrona'*	12
BA	Bulbs- assorted: Daffodil, iris, crocus Muscarti		60
OR	Oregano	*Origanum vulgare*	25
RO	Rosemary	*Rosmarinus officinalis*	33
TH	Thyme	*Thymus praecox* 'Coccineus'	25

FIGURE XXXIII: PATIO PLANTING PLAN PART SHADE

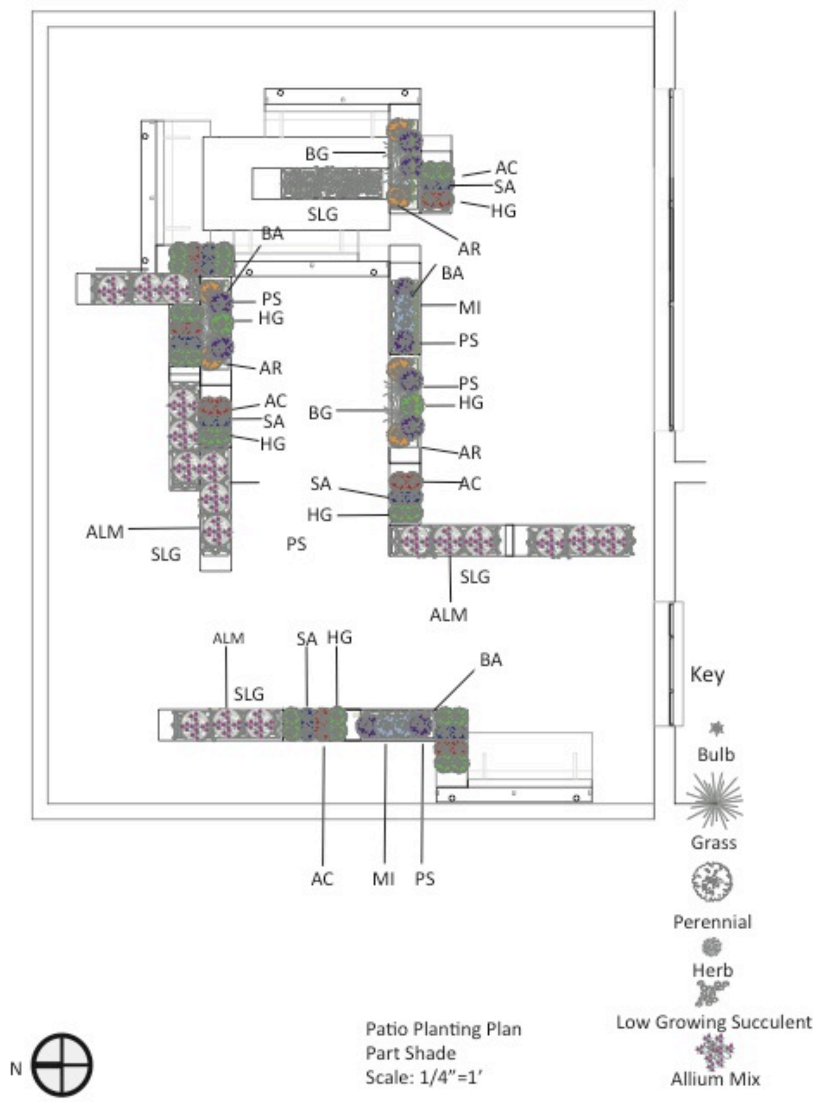

FIGURE XXXIV: PATIO PLANTING TABLE PART SHADE

Abbreviation	Common Name	Latin Name	Quantity
MI	Horehound	*Marrubium incanum*	4 plugs
PS	Small's Beardtongue	*Penstemon smallii*	10 plugs
AR	Licorise Mint Hyssop	*Agastache rupestris*	6 plugs
BG	Blue Grama	*Bouteloua gracilis*	6 plugs
HG	Green Carpet	*Herniaria glabra*	24 plugs
SA	Alpine skullcap	*Scuttellaria alpine*	14 plugs
AC	'Little Lanterns' Dwarf Columbine	*Aquilegia candensis* 'Little Lanterns'	14 plugs
SLG	Low Growing Sedum Mix	*Sedum makinoi*	80 plugs
		Sedum spurium 'John Creech'	
		Sedum pachyclados	
		Sedum spurium 'Fuldaflut'	
		Sedum stoloniferum	
		Sedum spurium 'Summer Glory'	
ALM	Allium Mix	*Allium cernuum*	90 bulbs
		Allium oreophilum	
		Allium schoenprasum	
		Allium senescens subsp. Motanum var. glaucum	
BA	Bulbs- assorted: Daffodil, iris, crocus Muscarti		30 bulbs

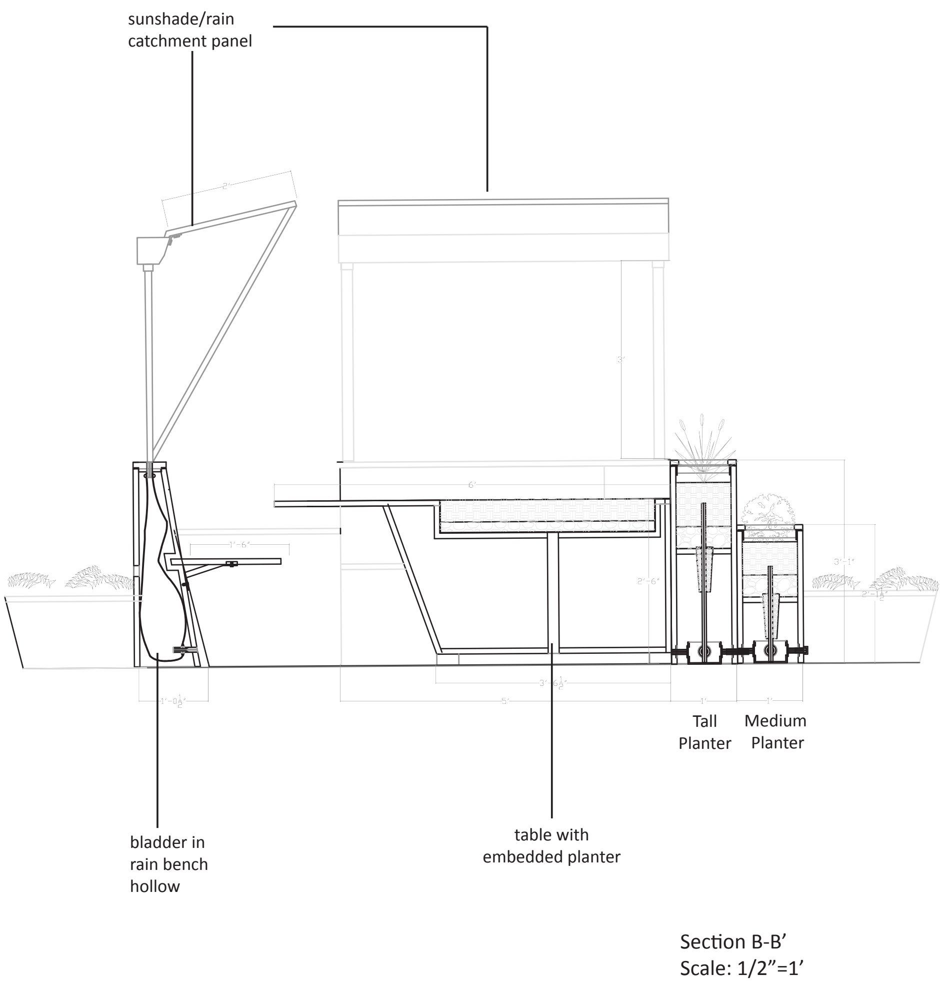

FIGURE XXXV: SECTION B-B' - PATIO TABLE AND BENCHES

FIGURE XXXVI: PATIO BIRDSEYE VIEW

FIGURE XXXVIII: VIEW OF PATIO FROM APARTMENT

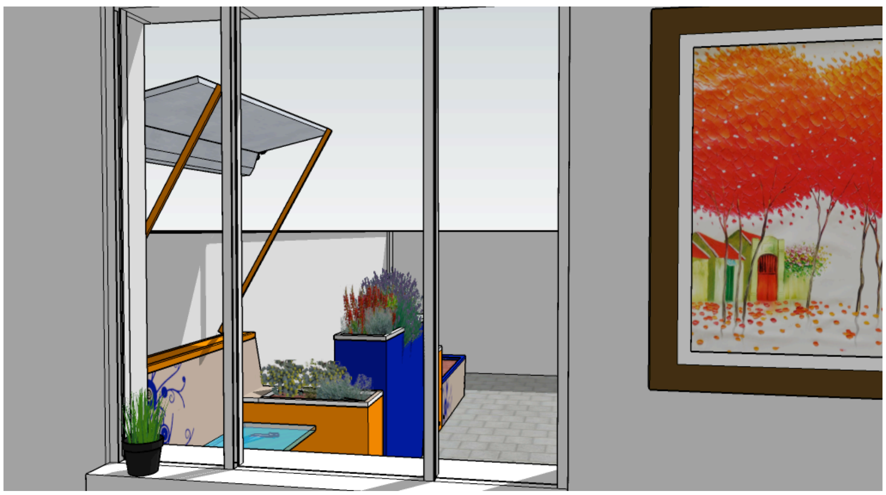

FIGURE XXXIX: VIEW FROM BEDROOM

FIGURE XXXVII: VIEW FROM BENCH

FIGURE XL: VIEW FROM TABLE

Chapter 9: Budget

For budgeting purposes this thesis uses a balcony design as a model. A patio design would inherently cost more, but could be easily extrapolated from the balcony model.

Each planter price is an estimation of planter materials, water tray, baskets, wicks, growing medium, silica stone, plants and piping. Without including labor, delivery and further testing, the the balcony design would cost the following

Item	Cost per unit	# of units	Total
Tall Planter	$96	2	$192
Medium Planter	$56	1	$56
Short Planter	$89	2	$178
Bench (including bladder)	$73	1	$73
Gutter (5’)	$4	4.5	$10
Rain catchment panel	$25	4	$100
Total			$609

This budget is very much an approximation and would require far more research to solidify. It also does not require labor and manufacturing costs which would add a significant amount. However, if we assume a $400 additional cost for labor etc….. the balcony would cost about $1,000. This is the price of a sofa, a high quality mattress or a dining room table.   It is not cheap, but It is a price that a renter could consider paying for a complete balcony garden.

If this garden arrived with a flat shipping rate of $100, this shipping price would be comparable with shipping rates for IKEA and would be worth considering for a renter without a truck at their disposal. It would once again be a price regularly paid for furniture delivery by a renter in an urban setting.

Chapter 10: Testing Viability

For implementation the modules would need extensive testing. Growing medium would need testing for water and nutrient retention over time. Plants would need testing to ensure survivability within the medium in urban settings. Medium composition and plant choices would need tweaking in response to test results.

In addition the water collection and storage system would need extensive testing to see whether it does, in fact, collect the amount expected and successfully deliver it to plants.

Module materials would also need testing to ensure they weather properly and react well to moisture. They need to last at least 5 years to be viable.

Lastly, the system as a whole would need testing for the human dimension. Testing would determine whether is is:

-Easy to pick up or deliver with minimal trips

-Easy to put together

-Actually low maintenance.

-Requirements for maintenance over time

Testing would result in tweaking of the design to ensure it meets design goals. Different materials, medium and plants may turn out to be better choices and the final product may look very different than the original.

Chapter 11: What's Next

Once a successful prototype is developed these modules point to potential next steps.

Verticality:

Since these modules are already designed with a wicking system that allows for different levels of medium and planting a more vertical design built with interlocking shelves may be possible. This may be useful to retain floor space or to create a more vertical element in a large flat space.

Soft Walls:

Taking the idea of portability and affordability to its logical conclusion would ideally rely on a format that is lighter and cheaper. A new level of research could lead to the development of walls that are soft and connected to a framework of supports. This would change the look of the units, but improve their portability and affordability.

Growing Food:

While this thesis did not focus on vegetables due to the challenge of keeping them alive in a tough urban concrete setting, further research may yield more possibilities for a gardener willing to put in more maintenance work for significant yield. The growing medium would need adjusting to include more organic material and design elements would need to be included to protect plants from the heat and include more water and more regular irrigation.

Connecting to Downspouts:

Currently these gardens would be difficult to connect to downspouts without cooperation from the apartment building management. This is unlikely for most renters. However, in the long term, if modules like these become popular, apartment management may choose to divert roof water into them on a more systematic basis. In this case, the apartment building would need a system that ensured each module received a relatively equal amount of roof water likely through adjustments to a downspout system.

Connecting Architecture and Landscape Design:

On a macro level, this micro design points to a greater coordination between architects and landscape architects on building homes that incorporate greenery in an urban setting. Apartment buildings can have built in planters on patios and balconies with systems intended to bring gardens to every renter. Connections can be built between the indoors and the outdoors enabling gardeners without outdoor spaces to use these gardens indoors. This thesis design is intended for the individual seeking to adapt a space that is otherwise inhospitable to plant life. Future designs offer potential to integrating growing things into the built environment in a much more systemic and ideal fashion.

Developers can plan buildings with apartment gardens in mind, incorporating more permanent versions of this design into apartment infrastructure. For a renter choosing between suburban sprawl and urban life, this sort of development may tip the balance towards a density that does not obviate a connection with land and growing things.

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