ARTFUL URBAN RAINWATER HARVESTING

by

CHRISTOPHER WILLIAM SPARNICHT

(Under the Direction of Bruce K. Ferguson)

ABSTRACT

Until recently, stormwater management has been so integrated into the urban environment that the importance of proper stormwater management has not translated to the minds of the very people who take advantage of this amenity. The purpose of this thesis is to show that multiple small rainwater harvesting installations can dramatically reduce non-point-source runoff managed by city stormwater systems, and that this is best achieved in urban situations by articulating the process for inhabitants to see. By articulating stormwater management processes in an artful way, stakeholders can better understand and enjoy this natural resource. In this thesis, existing concepts for stormwater management are reviewed; artful concepts applicable to rainwater harvesting are considered; and two contemporary sculptors whose medium is water are reviewed. In addition, a densely built-up Five Points area of Athens, Georgia is assessed. A permeability model for Five Points finds only thirteen percent of our site is permeable today; the rest is either pavement or roof top. After applying rainwater harvesting techniques, rainfall data manipulation and artful articulation of water as a medium, a second permeability model is created to compare with the existing model. The proposed model shows improvement of permeability and thus better stormwater management, all while educating urban dwellers about artful urban rainwater harvesting in a potentially enticing and delightful manner.

INDEX WORDS: rainwater harvesting, urban amenity, stormwater runoff, stormwater management, artful rainwater design, artful stormwater management

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DEDICATION

To Christine L. Hoffman

You help realize goodness in others, wherever you go.

Even after 20 years of marriage, I still think of you as my girl friend. Here's to 20 more.

and To M. A. (Jacqueline) and Roderick E. Sparnicht

For helping realize a valuable education.

Other parents should look to your example as the ideal.

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CHAPTER 1

INTRODUCTION

When urban rainwater is viewed as a resource rather than waste, clearer objectives for urban stormwater management arise. Among those objectives should be articulating the flow of rainwater over the urban landscape so inhabitants can see where the water is coming from and where it ends up. Clarifying the path of rainwater through dense urban environments is best done artfully, in such a way that city dwellers not only understand the path of rainwater, but are proud of how their city and their landowners manage it.

1.1 Stormwater Management

As interest in rainwater harvesting grows, [1] many methods for creatively managing urban stormwater runoff are emerging. The U. S. Green Building Council's (USGBC's) Leadership in Energy and Environmental Design (LEED) and Construction Industry Research and Information Association's (CIRIA's) Sustainable Drainage Systems (SuDS) initiatives both include methods for stormwater runoff management and professional credentials [2, 3] to insure a consistency of design criteria with regards to sustainable design in general and stormwater management specifically. Even with these creative new methods, stormwater runoff seems often to be hidden away, or at least placed at the margins of the designed space. Uncovering stormwater runoff as it is managed by its appropriate urban amenities can at once educate, entice and delight the surrounding community in an artful way, all while performing the necessary tasks of stormwater attenuation, infiltration or additional use.

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[1] (Henneman 2006)
[2] (USGBC 2012)
[3] (CIRIA 2012)

1.2 What is Rainwater Harvesting?

"Rainwater Harvesting" is the collection of water for use. [4] Once collected, it may be stored in various ways and then released back into the environment to accomplish any number of tasks. Rainwater has been harvested for human consumption, lavatory and irrigation. Other benefits might include slowing down water to reduce flood hazard and encourage water table replenishment.

A modern rainwater harvesting system involves at least these three things: a collection area, a transport mechanism or conveyance and a use area. [5] (See Figure 1.1)

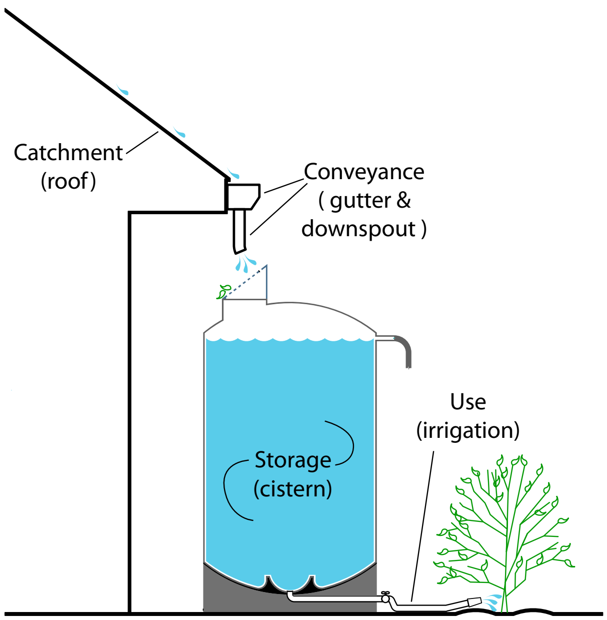

Figure 1.1 - Basic components of rainwater harvesting

While rainwater harvest for consumption is a common goal, the first consideration for this paper is stormwater *management* in terms of delay and infiltration. Water collected for irrigation and water-feature recirculation or other uses will be evaluated here in terms of stormwater management through rainwater harvesting. In the urban environment, rainwater harvesting can be viewed as urban amenity.

[4] (Hopper 2007) p. 387.
[5] (Hopper 2007) p. 387.

1.3 Art as Urban Amenity

Urban amenities can be defined as fixtures on-site sometimes taken for granted in our public spaces: street lights, benches, trash receptacles, flagpoles, signs, kiosks, hand rails, etc. Urban amenities provide "convenience, comfort, information, circulation control, protection and user enjoyment" all while blending into the background until they are needed. [6] The New Zealand Ministry for the Environment sees urban amenity a little more broadly:

> 'Urban amenity' means the things that people appreciate about their urban environment. An amenity can be a tangible thing, like a shopping centre or a park, and it can be an intangible thing, like a feeling of safety or sense of community.
> Beyond that broad definition, understanding urban amenity becomes more difficult.
> Some aspects of urban amenity, like 'clean air' or 'safety', are desirable to all communities in all urban areas. Other aspects of urban amenity, like 'green spaces' or 'innovative design', are desirable to some communities, but not to others. Within communities, too, people may have different ideas about urban amenity. [7]

Amenity does not have to be artful. It exists to perform its function. However, art can be an amenity, and amenities that are normally hidden can be articulated artfully.

Tim Hall and Iain Robertson, in their article *'Public Art and Urban Regeneration: advocacy, claims and critical debates'* [8] suggest that with regards to public art and urban regeneration, there are seven categories widely assumed to be reasons for the advocacy of public art in general. Paraphrasing from Hall & Robertson: [9]

Public art can:

1. Develop a *Sense of Community* through a sense of shared history, identity, needs and aspirations.
2. Develop a *Sense of Place* by instilling commitment of community members to the place itself.
3. Develop a *Civic Identity* by creating a distinctive public image that becomes noteworthy on a wider scale - perhaps developing tourism, fostering the local economy and general community advocacy of good will to visitors.

[6] (Hopper 2007) p. 601.
[7] (NZMFE 2002)
[8] (Hall and Robertson 2001)
[9] (Hall and Robertson 2001)

4. Address *Community Needs*. Artists can be problem solvers, providing functional needs like public benches or bus stops that are aesthetically pleasing yet functional.
5. Tackle *Social Exclusion*, using participatory art to reduce alienation and give marginalized members of society stepping stones toward fuller community participation.
6. *Educate*. Using various techniques art can reveal truths about the urban environment simply by highlighting those practices that might ordinarily not be pointed out.
7. *Promoting Social Change* can cause community members to think more deeply about current-events topics the community might not otherwise confront or discuss.

In this context, public art could well be considered as important an urban amenity as a park bench, a drinking fountain or an arch. Artful urban amenities serve the dual purpose of providing functional necessities and doing it attractively.

Echols and Pennypacker [10] suggest that "design [should combine] the utilities of stormwater management with the amenity of rich placemaking focused on the rainwater itself." They have raised critical awareness for the need to recognize rainwater as a resource, and not a waste product, and that stormwater is best managed *in situ*. Further, rainwater design can educate overtly, interactively or simply by being a joy to behold. [11]

While stormwater management is in itself infrastructural, the way roads, electric, phone and sewer lines are part of the literal fabric of urban living, the act of *managing* rainwater efficiently and safely can be viewed as an amenity. For all the above reasons, rainwater harvesting is an excellent example of an amenity that can be done artfully.

[10] (Echols and Pennypacker 2006)
[11] (Pennypacker and Echols 2008)

1.4 Rainwater Harvesting as Artful Urban Amenity

Rainwater harvesting provides a basic function that makes it more than an amenity. Under the best circumstances, it fulfills a need such as stormwater attenuation, infiltration or further distribution [12]. Often, these important municipal functions are hidden out of the way or underground, while water as a "feature" is employed as a wholly separate thing.

Dreiseitle, in his book *Waterscapes,* [13] suggests that one common trend among planners is that water features in a townscape are superfluous decoration. At the same time, stormwater, sewerage and potable water are all managed functionally with barely any aesthetics or articulation in their infrastructure. This split in theory *gets built into the physical environment*, unfortunately causing a similar dichotomy in the public eye. He further suggests that designers should be "able to experience water and gain insights into how to handle it sustainably." [14]

It is important to reconnect the urban community with one of its most important functions: water distribution, and to do this by articulating, *unhiding* this resource in a way that allows the community to discover and understand just how integrated water is into our everyday lives.

Bruce K. Ferguson suggests that human needs such as interaction, artwork, and entertainment can all be resolved and balanced with how urban stormwater runoff is handled. He reasons that water can forge associations with nature and climate in the public eye, contributing to mental and physical health by making water processes legible in the landscape. [15]

By recognizing artful stormwater management as an urban amenity, designers may be better able to add value to the surrounding urban environment, increase the use of open space, attract cultural tourism and even create jobs and reduce vandalism. [16] While doing the municipal business of the urban environment — redistribution of water as appropriate — implementations can also educate in artful, entertaining, compelling, and attractive ways. In so doing, one amenity does double duty both as rainwater harvesting and as artful urban amenity.

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[12] (Hopper 2007) p. 387.
[13] (Dreiseitl, Grau, and Ludwig 2001)
[14] (Dreiseitl, Grau, and Ludwig 2001) p. 9.
[15] (Ferguson 2013) presentation abstract - to be given at EDRA 44th Annual Conference, 2013
[16] (Policy Studies Institute 1994)

1.5 Thesis Approach

Chapter two will review existing stormwater management techniques and various characteristics of water as an artful medium. There will be a review of how some artists are using architectural elements that readily adapt themselves to revealing and expressing rainwater harvesting. In chapter three, there will be three case studies of successful artful rainwater harvesting and a short example of a temporary artful installation. Chapter four will be dedicated to reviewing and inventorying all aspects pertinent to artful rainwater harvesting for a particular urban area. Chapter five will apply the practical and artful values discussed previously to the same urban area. Additionally, comments and observations will be made. Chapter six will discuss lessons learned from applied water aesthetics in urban rainwater harvesting and how they guide sustainable urban design and planning.

CHAPTER 2

ARCHITECTURAL AND ARTFUL CONSIDERATIONS

2.1 Rainwater Harvesting Concepts

2.1.1 Harvest Potential and Use

Climatic and geographic differences affect rainfall intensities. Intensity-duration-frequency curves can be built from historic rainfall data. From these, estimation of design storm criteria can inform the design with regards to stormwater runoff risk assessment. [17] Stormwater is managed a number of ways. It can be harvested for later use, delayed to reduce downstream flooding and erosion, attenuated for bioremediation, or infiltrated back into the soil to replenish the local water table. We evaluate what might happen in an area under existing conditions and compare that with what is possible if we design for additional permeability, flow reduction and attenuation, with the understanding that any reduction in stormwater runoff that we can achieve must be better than existing conditions.

2.1.2 Cisterns and Earthworks

Rainwater can be harvested in one of two ways: catchment/cistern systems and earthworks. [18] These two methods are in no way exclusive of each other. They are often combined where the most appropriate use necessitates. Water use from cisterns can include domestic use, such as flushing toilets, watering plants or recirculating artful urban water features. Water use for earthworks usually includes attenuation, delay and infiltration of stormwater runoff. *Attenuation* in this context means to weaken the flow of water. As an example, water's velocity is weakened substantially when it flows over a sloped grassy surface rather than a cement surface with the same slope. Likewise, a swale with multiple well-placed check dams will dampen or attenuate the velocity of water better than a similar swale with no check dams. *Delay* means slowing the velocity of water to zero or near zero for a designed amount of

[17] (Ferguson 1998) p. 45.
[18] (Lancaster 2008) p. 5.

runoff over a specified period of time. For instance, if a given catchment yields about 500 gallons for a 1.2-inch rain event, a design may specify that the first 500 gallons from that catchment be contained in a cistern or reservoir that releases the water slowly over a specified period. If there is no overflow and the release rate of the reservoir is relatively small, the water held temporarily in the reservoir has almost no forward velocity. Water's flow is *delayed* before its next task or use. *Infiltration* means that collected water is allowed to percolate into the soil rather than be diverted to existing stormwater sewers. For instance a gravel infiltration pit may be designed to accommodate 500 gallons of water from a given catchment. Water in such a pit would slowly seep into the subsoil, helping to recharge a local aquifer or supply water to deeper-rooted vegetation.

2.1.2.1 Roof and Cistern systems.

With an urban cistern system, there are typically a roof, gutters and drain pipes, and a tank. Preferred modern collection surfaces include epoxy-coated metal and cement-fiber tiles for their combined economy, durability and water harvest quality. A typical pitched metal roof is impervious with a smooth surface resulting in a runoff coefficient of about 0.95. Typical asphalt shingle or concrete tile roof has a runoff coefficient of about 0.9. [19] Asphalt shingles are considered less useful for collection of potable water due to fossil organic compounds that leach out of asphalt. As more cities adopt 'cool roof' legislation, flat roofs are often sprayed with a white elastomeric polymer that creates an ideal surface for collection of precipitation. Existing flat 'cool roofs' in urban areas could easily be retrofitted for rainwater harvesting.

Between rain events, collection surfaces unfortunately also collect debris such as leaves, pine straw and bird waste. Many modern gutters have built-in debris deflection. Conventional gutters with guards most suitable for collection are usually vinyl or epoxy-coated aluminum. There are also retrofit kits for gutter debris deflection and a number of debris traps that can be fitted to downspouts. In 1991, John Gould and Erik Nissen-Petersen in their book *Rainwater Catchment Systems for Domestic Supply* argued that fancy 'foul flush' systems are for the most part an urban myth, often published, but rarely

[19] (Downey 2009) p. 46.

used. [20] This may be true for an economy-sized fifty-five-gallon rain barrel that sits at the bottom of a downspout for harvest of water for immediate use on garden space, but for larger stationary cisterns used in public spaces, first flush diversion, additional filtration, sediment calming baffles and extraction devices become appropriate, especially for water to be used in an urban environment.

Prefabricated cisterns come in a variety of sizes in either plastic or metal. Built-in-place cisterns are often made of ferro-cement. Cisterns installed below ground are resistant to weather fluctuations, but may need an electric or manual pump to make use of the water. Cisterns installed at or above ground level may more likely make use of hydrostatic pressure for delivering the water to its intended destination.

Smaller debris inevitably evades deflection technology present in the gutter system. Somewhere along the conveyance before arriving at the cistern additional settling and filtering can allow the water to be better clarified. With an artful installation in an urban environment, people *will* touch the water if they can. Water recirculated through an artful installation will likely require further filtration and purification to meet local water safety regulations.

With stormwater runoff attenuation, delay and infiltration as our goal, the cistern will slowly release its contents back into the environment. What we do with the harvested water while it is still retained is where the urban artfulness may manifest. Examples of cistern water use include recirculating water features such as fountains, pools, or kinetic water sculpture. Some of the recirculated water will likely evaporate. Where possible, rainwater harvested via cistern systems will go through additional delay and infiltration via urban earthworks before being diverted to municipal stormwater systems.

2.1.2.2 Earthworks

Urban earthworks, used for slowing, reducing and infiltrating stormwater runoff include pervious pavements, rain gardens or vegetated infiltration basins, French drains, swales, berms, check dams, and gabions. Because parking and traffic surfaces are a large part of dense built environments, the greatest benefit of runoff reduction will likely come from pervious parking and paths. Where urban areas become

[20] (Gould and Nissen-Petersen 1999) p. 81.

more dense, open ground becomes rare. Users are less likely to see large rain gardens, French drains, swales, berms and gabions simply because of the density of the built environment.

2.1.2.3 Green Roofs and Green Walls

Flat roofs are well-suited for green roofing - a method that conflates collection, conveyance and use into the vicinity of the roof itself, in some ways similar to pervious parking - a sort of "aerial earthworks." Plants in lightweight soilless media act to cool the roof via evapotranspiration and/or shade, retard water flow off-property and in the case of safe roof accessibility, can become an artful inhabitable space. Retrofitting an existing flat roof as a green roof requires consideration for the additional weight load of plants, physical materials and design-storm-appropriate retained water. Pitched green roofs are possible too, using modified geocells to stabilize the media.

Green walls are vertical plantings either attached to a building or free-standing. Some green walls are simple trellises planted with vines that grow to cover the trellis. Other green walls are vertical engineered hydroponic lattices and specially selected plants inserted into lattice-held soilless media to form patterns of color and texture. While ivy- or ficus-covered walls may not technically be "green walls" they may achieve some of the same environmental and aesthetic effects.

2.1.3 The Stormwater Treatment Train

The Atlanta Regional Commission has provided minimum standards for water quality and stormwater treatment in Georgia that local communities may adopt. [21] Stormwater treatment involves removing pollutants from precipitation in the built environment before the water is allowed back into streams and rivers. Well-designed stormwater treatment systems include cisterns and earthworks as control structures. Typically, several structural controls may pass stormwater from one to the next in what is referred to as the "treatment train," providing ample opportunity for water to either infiltrate back into the ground or reduce pollutants and settle out debris prior to being allowed access to the municipal stormwater system. When multiple control structures are applied throughout an urban expanse, the

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[21] (Atlanta Regional Commission 2001)

cumulative effect can recharge aquifers, reduce downstream flooding, protect stream banks and prevent or reduce waterway pollution.

2.2 Artful Concepts

Landscape architecture at its best is a hybrid of engineering and art. Engineering makes the landscape safe, useful and economical, but art makes it compelling, attractive and inspiring. Some landscape architects make the artful application of engineering seem obvious and simple. To understand the artful decisions made by designers who have applied these concepts to water, it will help to review some outstanding designers who have used water as their medium.

> From time immemorial, mankind has ... investigated water from an artistic perspective. However, the deliberate use of water as a medium has not been subjected to in-depth study.
> — Oliver Herwig [22]

The stormwater management elements described above can be combined in ways that are both efficient and artful. This section will explore some of the more artful concepts used by successful landscape architects. According to Robert Woodward in *Waterscapes*, water...

> ... is the fundamental soft element. It is a sculptural medium unsurpassed in its potential to make the most of its form, transparency, reflectivity, refractivity, colour, movement and sound. It is a most desirable medium for a landscape designer. ...
> — Robert Woodward [23]

Woodward then goes on to list eight essential characteristics of water that inform the artist/engineer: Setting, Containment, Movement, Lighting, Wind, Sound, Color and Depth. For Woodward, these concepts are like daubs of paints on a palette for an artist - physical attributes that can be dialed up or down, blended in or left out, to suit the need.

James Van Sweden in his book *The Artful Garden* [24], does not talk about water specifically, but brings up a similar palette of characteristics that can help determine the design of a garden. His characteristics include Space and Form, Light and Shadow, Making the Scene, Rhythm and Movement, Texture, and Layering. To be sure, Woodwards 'Setting' and van Sweden's 'Making the Scene' are very similar in that they invite the

[22] (Herwig 2008) p. 6.
[23] (Dreiseitl, Grau, and Ludwig 2001) p. 12.
[24] (Van Sweden and Christopher 2011)

surroundings to participate in our experience. Further, Van Sweden suggests that we not only borrow the scenery but also allow our design to affect the surroundings. As an example, he explains:

> When I first planted [my St. Michaels garden], I was so careful not to interrupt the sweeping vista. Gradually though, I've let a select few of the juniper trees that invaded the meadow along the shore grow up, to interrupt the horizon and direct the eyes.
> — Van Sweden [25]

The same way microhabitats affect the larger ecological context, a designer relates site specifics in terms of setting, to its larger context, the surrounding landscape.

Van Sweden's Rhythm and Movement express not only the specific meaning of rhythm in sound and movement of physical objects but also the more painterly appreciation of the concepts. The eye is led with a spot of color or a striking shape. Repeating patterns or textures in plantings and in-built objects are introduced again to draw attention, and very often in the garden, to lead us through the garden itself[26]. Woodward's concept of Containment *can* imply stillness [27], but it can also imply expectation.

> [Water] can be to all intents and purposes devoid of intercourse with the surroundings, unwritten and amorphous in its inner structure. In a natural setting, this condition can bring an experience of something pristine, heavenly or spiritual, 'out of this world,' perhaps in a still dark grotto where water is hidden and secret as though waiting in suspense.
> — A. John Wilkes [28]

Still water is merely waiting to manifest its kinetic potential. When water does eventually pour out of its containment, this is the realm of movement, whether in the garden or in a painting. So Woodward's Containment could be viewed as a part of Van Sweden's understanding of Rhythm and Movement.

For Van Sweden, Light and Shadow in a garden design should be compelling for all seasons, all occasions, all times of the day and night, [29] but Woodward suggests that existing area lighting should also be taken into account and that artificial lighting can widen our palette with an ever-growing selection of water and landscape lighting choices. [30]

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[25] (Van Sweden and Christopher 2011) p. 71.
[26] (Van Sweden and Christopher 2011) p. 101.
[27] (Dreiseitl, Grau, and Ludwig 2001) p. 12.
[28] (Wilkes 2003) p. 25.
[29] (Van Sweden and Christopher 2011) p. 71.
[30] (Dreiseitl, Grau, and Ludwig 2001) p. 12.

For Woodward, water is seemingly formless, taking the shape of whatever contains it. It emulates both positive space and negative space. Water can be solid, liquid and gas — at times, all three appearing together in the very same landscape. The sense of place can change drastically with weather. Van Sweden suggests that some of the finest use of negative space are found in Japanese gardens. [31] He also suggests that a balance of positive and negative space, mass and void, are preferred. [32]

In his section on Light and Shadow, Van Sweden also suggests colors and palettes that are appropriate for the forceful sun and weather of tropic latitudes may not be well-suited to a cooler climate. [33] Woodward talks about lighting more from a technical standpoint and introduces the consideration for light's refraction and reflection in and on water. [34]

For an explanation of Layering, we turn to Diane Balmori as she describes Beatrix Farrand's design of the Lover's Lane Pool in particular, and Farrand's design of the gardens at Dumbarton Oaks in general:

> No other garden in this country has the power to evoke so many levels, other passages, other moments in time. It is the chambered nautilus of gardens, suggesting at every turn deeper levels of meaning and experience. It is this quality above all that makes Dumbarton Oaks an enduring work of art.
> — Diane Balmori [35]

[31] (Van Sweden and Christopher 2011) p. 12.
[32] (Van Sweden and Christopher 2011) p. 20.
[33] (Van Sweden and Christopher 2011) p. 44.
[34] (Dreiseitl, Grau, and Ludwig 2001) p. 12.
[35] (Balmori, McGuire, and McPeck 1985) p. 61.

For Balmori, visitors glimpse different meanings when they view the garden from different perspectives. This is very similar to George Hargreaves' views on design. Patterns and colors found in plaza tiles, the fig grove and other features of the Sydney, Australia Olympic Plaza appeal to visitors on one level and offer a heightened appeal to native Australians who recognize Aboriginal references on another. On yet a third level, local people familiar with site history may recognize a nod to the original structures that stood on the site. Hargreaves often overlays multiple concepts within a simple solution that purposefully offers a variety of meanings depending on the viewer's background. [36] This complex experience satisfies users of the space both subtly and overtly. Managing stormwater artfully, clearly can enrich the user experience. Further edification on artful management of water can be found by reviewing artists whose medium *is* water.

[36] (Gillette 2001)

2.3 Water Forms used by Sculptors of the Medium

Two contemporary artists in particular use their own terminology for directed water: William Pye and John Wilkes. Both artists have an interest in fluid mechanics and freely use terms from this area of science. William Pye is a water sculptor in the United Kingdom. He suggests a number of what he calls "concepts" on his website for the categorization of his water sculptures. These include "Brimming Bowl, Coanda, Deflection, Hydrostatics, Jets, Reflection, Roll-wave, Spouts, Transparency, Vortex, and Starburst". [37]

Figure 2.1 - Charybdis [38]

These concepts refer either to a significant form or action of the sculpture to which they are applied. Brimming Bowl, Spouts, Transparency, Reflection and Starburst are about form. Coanda, Deflection, Hydrostatics and Roll-wave refer to action primarily found in fluid mechanics.

The *Brimming Bowl* concept is a basin filled by strategically-placed internal hidden valves that cause the surface of the water to remain relatively calm while water continually flows uniformly over the entire edge of the basin or out through a weir or spout. (See Figure 2.2.)

[37] (Pye 2012b)
[38] photo credit: (Pye 2012b)

Figure 2.2 - Meniscus [39] **Figure 2.3** - Sibirica [40] **Figure 2.4** - Cedra [41]

Deflection for Pye is the use of spouts that pour water into cups which are sometimes deformed so as to deflect the water into a directed spray, rather than to simply overpour the cup. (See Figure 2.3.) Pye has named the *Coanda* form after Henri Coanda, considered by some to be the father of fluid mechanics. [42] Pye's *Coanda* form is a brimming bowl on a narrow column where the top of the narrow column morphs quickly into the bottom of a wide bowl. The water traverses and sticks to the sculpture surface from the brim to the bottom of the column. (See Figure 2.4.) *Hydrostatics* refers to water features that rely on pressure from a water source that is higher than the water feature itself. In his work "Torricelli"', Pye uses see-through pipes to expose the available pressure from another water feature higher up in the same garden. The same pressure is used to engage the fountains shown in Figure 2.5. When Pye talks about *Jets*, he is referring to laminar flow jets. Laminar flow jets create a contiguous stream of water in a directed arc. These are often computer-controlled as to direction and duration, allowing for a very playful interpretation of water that, if its path remains uninterrupted, does not splash or lose cohesion until it reaches its destination.

[39] photo credit: (Pye 2012b)
[40] photo credit: (Pye 2012b)
[41] photo credit: (Pye 2012b)
[42] (Pye 2012a) quote @ 2:36.

Figure 2.5 - Torricelli [43] **Figure 2.6** - Tarantella [44]

Reflection as concept is most often found with the Brimming Bowl such as "Meniscus" shown in Figure 2.2. According to Balmforth and Mandre, [45] "Roll waves are large-amplitude shock-like disturbances that develop on turbulent water flows." Pye narrows his concept to water flowing down relatively flat surfaces, such as is shown in his work "Offspring II". (See Figure 2.9.) We can see a repeating pattern of waves pouring down the surface of the sculpture. *Spouts* direct water gently down upon some other part of the sculpture, as shown in "Tavola" (Figure 2.7) in this case into small holes designed to make the water disappear into a recovery tank. *Transparency* describes a thin sheet of water falling unbroken until it meets the intended target or recovery basin. His work "Water Table" depicts this in Figure 2.8. *Roll-waves* on reflective surfaces like that of "Offspring II", when viewed under certain conditions can make a stainless steel sculpture appear almost transparent even though it is not. *Spouts* spill separate columns of water in his works "Sibirica" (Figure 2.3) and "Tavola" (Figure 2.7). The *Vortex*

[43] photo credit: (Pye 2012b)
[44] photo credit: (Pye 2012b)
[45] (Balmforth and Mandre 2004)

concept is best exemplified by "Charybdis" (Figure 2.1) showing a column of water in which is centered a giant whirlpool. Pye describes *Starbursts* (Figure 2.10) thusly:

> "Water is jetted from below up onto a circular disc of toughened glass. Droplets burst and radiate, changing and transmuting as they travel to the outer limits of their world, until they reach a moment at which they appear unable to hold on any longer, and reluctantly drop away into the abyss below."
> — William Pye [46]

Figure 2.7 - Tavola [47]

Figure 2.8 - Water Table [48]

[46] (Pye 2012b)
[47] photo credit: (Pye 2012b)
[48] photo credit: (Pye 2012b)

Figure 2.9 - Offspring II [49] **Figure 2.10** - Starburst [50]

John Wilkes, the author of *Flowforms : The Rhythmic Power of Water* [51], has come up with an additional concept he calls the *Flowform*. Flowforms are stackable bicameral basins that can be mass-produced to specific dimensions. Water from a higher basin flows from a weir common to the two sinuses of one flowform basin down to the center of next basin. While flowforms have a reputation for aerating bioremediation rentention ponds, they are also visually and acoustically compelling, and well worth using for their artfulness alone. Flowforms can be symmetrical (Figure 2.11) or irregular (Figure 2.13).

[49] photo credit: (Pye 2012b)
[50] photo credit: (Pye 2012b)
[51] (Wilkes 2003)

Figure 2.11 - Multi-basin [52] **Figure 2.12** - Single basin [53] **Figure 2.13** - Ovella [54]

Flowforms make use of the properties of water that cause it to pulse between the two sinuses of the basin at regular intervals. The depth and breadth of the basin sinuses affects the speed of the water's pulse. [55] The pulse causes lapping sounds that can be broad and slow like an ocean beach or short and intimate like waves on a lake shore. Flowforms have been created in a variety of shapes, each with unique visual and audio water pulse characteristics. Please see the video animations referenced below in order to gain a better appreciation of their artistic and kinetic value.[56]

Pye's work has defined lines and a distinctly urban character that draw attention for their form as well their activity. The work of Wilkes tends to have an organic quality reminiscent of leaves, bones, mushrooms, flowers or other forms found in nature. When surrounded with plants, flowform basins play less of a part in attracting attention than the water contained by them. Basins in an urban setting without plantings can become as distinctive for their form as Pye's. Both sculpture methods provide a stage for water to engage onlookers.

[52] photo credit: (Wilkes 2011) Multiple basin symmetrical example.
[53] photo credit: (Flowform.net 2012) Single basin symmetrical example.
[54] photo credit: (Charter 2012) @ 0:10. Single basin asymmetrical example.
[55] (Wilkes 2003) p. 31.
[56] Suggested flowform video examples: (Flowforms.net 2009), (RhythmicWater 2009), (Charter 2012)

Water sculptures that rely on captured rain in urban settings may require the aid of a filtered recirculating pump. The cistern allows the feature to recirculate its water as the cistern level intentionally recedes over a number of days, delaying stormwater release or allowing for infiltration, thus playing the roles of both urban rainwater *harvesting* amenity and urban *attraction* amenity.

2.4 Adaptation of Artful Water Forms to Rainwater Harvesting

After exploring cisterns and earthworks, artful aspects including light, form, color, texture and movement and various installations by water sculptors Pye and Wilkes, it is helpful to introduce examples of artful rainwater harvesting that already exist. Chapter three will explore three case studies: The Cedar River Watershed Education Center near Seattle, Washington, The Lady Bird Johnson Wildflower Center in Austin, Texas and 10th @ Hoyt, an upscale apartment green roof courtyard in Portland, Oregon. We'll also briefly introduce a temporary rainwater harvesting installation at the Bemis Center in Omaha, Nebraska.

Chapter 3

CASE STUDIES

In the following three case studies, stormwater is managed in such a way that the public can easily discern the path of the water from roof to use. Further, these articulated rainwater harvesting pathways are expressed artfully.

3.1 Cedar River Watershed Education Center

Jones and Jones Architects and Landscape Architects designed the Cedar River Watershed Education Center, located near North Bend, Washington, about 35 miles east of Seattle on the edge of a 91,000 acre protected watershed. It is owned by the Seattle Public Utilities. [57] The site was created by the Seattle Public Utilities to educate the public about where their drinking water comes from and why water conservation is important. [58]

The site manifests examples of artful stormwater management articulation including green roofs, rainwater harvesting, an exposed protected runnel, rain gardens, rain barrels, a constructed stream and rain drums. [59]

Eliza Pennypacker explains that the center's design honors both the history and nature of the site, but even better, it "educates and delights through a variety of interactive opportunities focused on water." [60] Even when rain is not falling, the water's path is clearly demarked from rooftop, to downspout, through the courtyard in a runnel, and finally to a bioretention swale below the courtyard. Movement is implied by the S-shape of the runnel. Near each of the downspouts, the runnel is exposed. In the center of the courtyard where there are gatherings, the runnel is covered by artistic grill-work. The purpose of the runnel is articulated without impeding foot traffic. Near downspouts, where there is no grill-work, the line

[57] (Owens-Viani et al. 2007), (Seattle Department of Planning and Design 2002), (Jones and Jones 2001)
[58] (Owens-Viani et al. 2007)
[59] (Owens-Viani et al. 2007), (Seattle Department of Planning and Design 2002), (Jones and Jones 2001)
[60] (Owens-Viani et al. 2007) p. 36.

of the runnel is continued using pervious materials, with the continuity of the design extending through the alternate materials. Downspouts pour into basins that slow the water before it pours into the runnel. (See Figure 3.1.)

Figure 3.1 - Runnel [61] **Figure 3.2** – Green Roof [62]

Mark Puddy in *'How the Center Reveals Water Processes'* suggests metal roofs can be seen to represent the impervious parking and roofs of the Seattle Area in juxtaposition to the green roofs that represent surrounding native forests. [63] When it rains, visitors can see how rain is delayed on the green roofs in contrast to how the water is collected from the metal roofs. (See Figure 3.2.)

Dan Corson, artist, created the rain drum installation. According to Corson, the seventeen drums are representative of different cultures. [64] When there is rain, the drums aurally highlight the occurrence. When there is no rain, the drums can be made to play using computer-controlled drip tubes. Visiting artists and musicians are invited to create additional computer-controlled drum songs. An additional

[61] photo credit: (Echols and Pennypacker 2007)
[62] photo credit: (Corson 2011) @ 0:08.
[63] (Owens-Viani et al. 2007) p. 37.
[64] (Corson 2011) @ 1:00.

public drum allows visitors to contribute their own percussive musings. The rain drums are shut off when the temperature freezes to prevent damage.

Figure 3.3, 3.4 - Dan Corson's Rain Drum Courtyard [65]

In the last 12 years at Cedar River, rain fell an average of 185 out of every 365 days — just about every other day. One hundred fifteen of those days each year saw less than half an inch per day. The maximum rainfall in a single day was 7.33 inches. Average rainfall for days with rain is 0.52 inches. The 30-year average yearly rainfall for Cedar River is 97 inches/year. In the last 12 years, a maximum of 120 inches fell in 2010 and a minimum of 72 inches fell in 2011. Most of Cedar River's rainfall happens in from August to December. [66] Because of the abundance of rain at this location, it was possible to build a constructed stream using water collected from the building roofs and grounds. Though the dearth of signage is intentional, the viewers' curiosity and intelligence have been engaged. Both Pennypacker and Puddy agree that stormwater management at this site is not only sustainable and visible, but articulated artfully. [67]

Figure 3.1 lends itself well as an example of how the artful concepts that were examined in Chapter 2.2 may be applied to a case study. The following Figures 3.5 through 3.10 below are shown to exemplify graphically how these concepts may be applied in the mind's eye to any case study. Similar graphics will not be applied to the other case studies for this treatise.

[65] photo credit: (Corson 2011) @ 0:48, @ 1:28.
[66] See Apendix A, Table 7.C.
[67] (Owens-Viani et al. 2007) pp. 36 - 37.

Figure 3.5 - Space

Figure 3.6 - Contrast

Figure 3.7 - Form

Figure 3.8 - Color

Figure 3.9 - Texture / Pattern

Figure 3.10 - Movement

The "room" that is expressed by the borders and corners of the courtyard help elucidate the concept of *Space* in Figure 3.5. While there are no walls, the perception of a "room" suitable for social gatherings and functions is implied. *Contrast* can be seen in the juxtaposition of the smooth surface of the parts of the courtyard highlighted in yellow where they abut rougher surfaces highlighted in blue, as seen in Figure 3.6. The runnel continues from cement and cast-iron grating through a transition to gravel and cobbles. Even though the materials contrast, a single element is implied — the runnel in its entirety. Figure 3.7 highlights *Form* in the basin - both square and circle. Figure 3.8 accentuates the color of the vegetation within the textured portion of the courtyard, though perhaps there are better examples for highlighting color. Figure 3.9 exemplifies *Pattern* and *Texture*. *Texture* is highlighted in the gravel, and *Pattern* is highlighted in the recycled square and circular terracotta pieces. Figure 3.10 features *Movement* implied by the runnel itself, not just by the water flowing in a particular direction, but also by the curving line that leads the mind's eye to the distance.

3.2 Lady Bird Johnson Wildflower Center

The Lady Bird Johnson Wildflower Center is comprised of almost 180 acres located south of Austin, Texas and was designed in collaboration with Darrel Morrison, Landscape Architect, Rick Archer, FAIA of Overland Partners, Robert Anderson, FASLA, and Eleanor McKinney of J. Robert Anderson Landscape Architects. Construction was completed in 1995. [68]

Stormwater is collected from 17,000 square feet of roof and is stored in five cisterns with a total capacity of 60,000 gallons. Collected water provides 10-15% of the center's gardening and landscape needs. [69] Additional stormwater management is seen in the arrangement of the visitor center parking.

In collaboration with the American Society of Landscape Architects and the United States Botanic Garden, the Lady Bird Johnson Wildflower Center has developed The Sustainable Sites Inititiative (SITES™) Guidelines and Performance Benchmarks. [70] These guidelines include methods for reducing potable water use, restoring native wetlands and bioremediation using rain gardens and treatment wetlands for parking. [71] The USGBC expects to incorporate SITES™ metrics into future versions of the LEED Green Building Rating System. [72]

Deborah Dalton points out in *'Restless About the Natives'* [73] that native plants can come across as shabby in the landscape and do not compete well with the more formal, orderly architecture found in this public garden. "Not withstanding that many visitors do not 'get' the landscape, it is one of my favorite places to visit because it reflects a different, 'messier' ecological aesthetic." [74] From an artful perspective, public gardens as an industry have given visitors the impression that the garden display should include continual performances in beds and displays of bold colors, contrasts and textures, all neatly framed and presentable. The Center's display garden is popular because it reads more formally than other parts of the Center. While they do their jobs well, the rain gardens and bio swales that infiltrate and remediate parking

[68] (Boyer 2004)
[69] (LBJWFC 2004-2005)
[70] (LBJWFC 2012b)
[71] (Dalton 2003)
[72] (LBJWFC 2012b)
[73] (Dalton 2003)
[74] (Dalton 2003)

lot runoff also do not leap out as exemplary to the uneducated visitor. This author has not been able to locate parking bioswale images, indicating that education about this subject may not yet be a priority for the LBJWFC.

Places where the LBJWFC gardens read well for the public often include articulated artful water features. Examples include the tower and entrance cisterns, the stone and metal aqueducts, and the Erma Lowe Hill Country Stream Garden. The wetland pond next to the main arch and across from the auditorium is very popular because of the plethora of insects and other native fauna attracted to the wetland vegetation, but also because the space is framed in mission style architecture that is historically appropriate to this locale. The roof of the auditorium acts as catchment for an aqueduct that conveys water to the 12,000-gallon cistern at the entrance garden. The courtyard garden is the Center's main attraction with a constructed Hill Country spring that emulates natural springs found in the region. [75]

While there are certain "messy" constituents in these water-enabled landscapes, they read as cared-for. Joan Nassauer in *Messy Ecosystems, Orderly Frames* [76] suggests that the key to making natives more palatable to the public is what she describes as "cues to care". For her, neatness implies that a person has been to this place and returns frequently. By "framing ecological function within recognizable systems of form", visitors cannot misinterpret a site as messy. One example she provides is mowing strips around native meadow areas where the meadow joins paths to establish a sense of order and intention. Nassauer further suggests these cues are easily adapted to urban sustainable ecosystems through the use of "bold patterns, trimmed shrubs, plants in rows and linear planting designs." [77]

Boyer, in his article *Lady Bird Johnson Wildflower Center: Implications for Sustainable Development on Water Sensitive Sites,* [78] suggests that the relocation of LBJWFC forced collaboration between design professionals at a time when this was a unique experience. Bringing a multi-disciplinary approach to design from the outset created success as lines between the disciplines dissolved. The Center

[75] (LBJWFC 2012c)
[76] (Nassauer 1995)
[77] (Nassauer 1995)
[78] (Boyer 2004)

succeeds in its mission "to increase the sustainable use and conservation of native wildflowers, plants and landscapes", [79] not only through passive education of visitors, striking landscapes and cues to care, but also by actively changing how designers and builders perceive their part in the process through creation of the Sustainable Sites Initiative guidelines.

Austin receives 82 days of rain out of the year. For 50 of those 82 days per year, rain that fell amounted to less than one-quarter inch per event. Most of those rain days were in early summer and again in early fall. In the last 12 years, average rainfall for days it has rained is 0.4 inches. During the same 12-year period, the maximum rainfall in one event was 7.55 inches. Only one other event was over four inches. The maximum amount of rain in one year was in 2004 with 52 inches. The minimum rainfall received in one year was 16 inches in 2008.

Though this is an arid climate, there are times that when it rains, it rains prodigiously. Multiple cisterns are this climate's best method for managing the scarce resource of water. Because water evaporates quickly in this warm climate, we do not see water features that include large showy fountain sprays or walls of water. Water is introduced softly and subtly, around corners and in protected spaces. Also, because the site is about sustainability, water surfaces are kept relatively placid, making them ideal for native animal and insect life.

Figure 3.11 - Wetlands left, auditorium right, courtyard entrance center [80]

[79] (LBJWFC 2012a) See mission statement.
[80] photo credit: (Viel 2010)

Figure 3.12 - Aqueduct leading from the auditorium roof to the cistern in the entrance garden [81]

Figure 3.13 Entrance garden cistern with dragonfly sculpture installation [82]

[81] photo credit: (Wilkinson 2010)
[82] photo credit: (Wilkinson 2010)

3.3 Tenth @ Hoyt

Tenth @ Hoyt is a gentrified upscale apartment building comprising an entire city block in the Pearl District of Portland, Oregon, built in 2003 by Ankrom Moisan. [83] Interior to the high-rise is a street-level courtyard covering 8,500 square feet, and designed by Steven Koch and Koch Landscape Architects. [84] While the courtyard is street-level, it is technically a green roof suspended over sub-street-level parking provided for building tenants. [85] The courtyard serves triple purposes as stormwater delay facility, as gathering space for building inhabitants and as an example for interested students of rainwater harvesting.

There are at-grade and above-grade planters and plants in pots strategically placed within the courtyard, as well as wood benches and subtle suspended lighting. Water features are also placed symmetrically within the courtyard. These features are made of Cor-Ten® and are studded with colored glass buttons lit from the feature interior during the evening. When walking into the courtyard through the street-level entrance, the axial nature of the site stands out. The eye moves from the rust-red water features at the far side of the courtyard, up the runnels and chadar, to the downspout starting six stories above. The use of the roof water in the garden reads clearly to all courtyard visitors. Additional asymmetric downspouts, chadars, and runnels capture water from other parts of the building and feed other water features. Below the Cor-Ten® water features is a 4000-gallon cistern capable of delaying 1/8th inch of rain from city sewer lines for up to 30 hours. Pumps recirculate the water while it lingers in the cistern, allowing water to play over the water features on and after rainy days. Overflow during heavier storms passes through the garden into the city rainwater overflow management system[86]. It is compelling to experience this courtyard at night in the rain. [87]

[83] (Rodes 2007)
[84] (Echols and Pennypacker 2006)
[85] (Rodes 2007)
[86] (Echols and Pennypacker 2006)
[87] (Rodes 2007)

This example is certainly the most urban application of the three case studies. The design has clean symmetry, reminiscent of historic Persian gardens. [88] The water features make no attempts at looking natural. They are manifestly human-engineered. Plants are neatly managed more like furniture and less like a landscape, making this site unabashedly, even proudly, urban. Unlike the other two sites, with a mission promoting education about water as a resource, this site is meant to always present itself as nature with its teeth brushed and its hair combed. With all its spare formality, the courtyard still lends itself to meditative and informal relaxation. Echols and Pennypacker suggest that this site could have benefited from allowing the rainwater to pass through the planters. This would have naturally filtered the water, reduced the volume of water going back into the city stormwater system and further delayed runoff. However, this might have drastically changed the planting plan and would likely have meant seasons when the formal courtyard would have presented as subpar to upscale residents expecting a formal outside living room they could share with their guests.

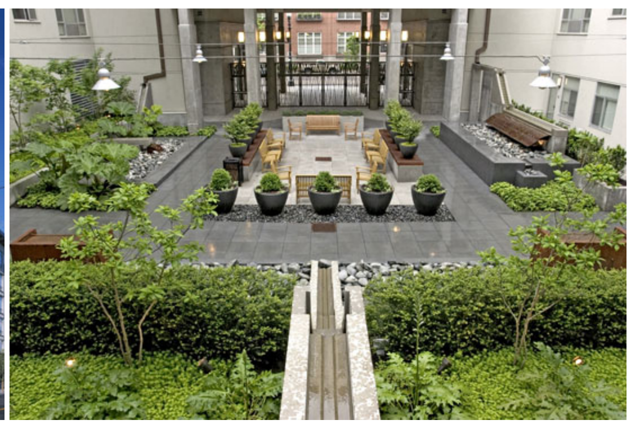

Figure 3.14 - 10th @ Hoyt from the outside [89] **Figure 3.15** - Courtyard interior showing axial formality [90]

In the last 12 years, it rained 159 days per year in Portland, Oregon. That averages out to just over twice a week from the perspective of the coarser granularity of days-per-year, though monthly rainfall averages suggest more of those days of rain happen in the colder months. Of the 159 days that it rains in Portland, 79 of those days accrue rain at 1/8th inch or less. This courtyard mediates fully about half the

[88] (Koch Landscape Architecture undated)
[89] photo credit: (AMAA 2012)
[90] photo credit: (AMAA 2012)

rain events that pass through its cistern. It is also significantly helpful for another 68 of those days with rainfall between 1/4 and 1/2 of an inch, meaning this striking urban setting actually meets its design goals.

Figure 3.16 - The courtyard on a rainy night [91]

Three installations have been reviewed. One is a private garden informally available to the public, but with no educational mission. The two others have missions centered on education. Not all organizations with education missions are strictly about sustainability or water, but there is no reason why a wider number of institutions could not present installations of a temporary nature that fit the institution's mission yet provide a new perspective on artful rainwater harvesting in the urban environment.

3.4 Temporary Installations of Artful Urban Rainwater Harvesting

Museums, galleries and facilities dedicated to education and culture become marvelous settings for temporary artful rainwater harvesting installations that also educate and delight. One example was Michael Jones McKean's installation at the Bemis Center in Omaha, Nebraska entitled *The Rainbow: Certain Principles of Light and Shapes Between Forms.* [92] While the exhibit included many indoor pieces, the main attraction was the "rainbow machine". With enormous collaboration between sponsors, design/installation professionals, artists and center staff, McKean was able to create rainbows that ensconced the entirety of the Bemis Center in the summer of 2012. Six 10,500-gallon cisterns were used

[91] photo credit: (AMAA 2012)
[92] (BCCA 2012)

to harvest rainwater from the 20,000 square foot roof surface of the Bemis Center. No other water was used. Nine nozzles strategically placed on the building roof and exterior were supplied with pressurized water via a 60-horsepower pump powered by renewable resources.[93] Rainbows were best viewed in the mornings and evenings when the sun's angle was ideal. For this reason, twenty minutes shows were publicized when enough water was collected. Water was sprayed as an enormous fan along a specified axis so that optimal views could be had from one side of the building or another depending on the time of presentation.

Figure 3.17 The Bemis Center under a constructed rainbow[94]

[93] (BCCA 2012)
[94] photo credit: (BCCA 2012)

3.5 Toward Application at Five Points

Five Points, like 10th @ Hoyt is driven by commercial endeavor more than by civic, cultural or eco-educational considerations. Retrofitting existing conditions to overtly educate customers and visitors may have a certain contemporary green appeal, but may not fit the budget or desires of proprietors or parcel owners. Tenth @ Hoyt's greatest lesson to urban designers is that in the "urban jungle", nature is what we make of it. In urban areas slated for renovation, plants that thrive in the existing conditions are often called weeds. As plants can be integral to artful rainwater harvesting, these very weeds may be useful parts of our renewal palette. We can identify and use native and domesticated plants that thrive in urban spaces and can withstand hours or days with their roots submerged. With earthworks and cisterns, artful concepts and a view to water as medium, we can artfully harvest water for delay and infiltration, while at the same time revealing inviting space at Five Points and elsewhere in urban settings.

Chapter 4

FIVE POINTS SITE REVIEW

The Five Points location in Athens, Georgia was chosen for its example density of impermeable surface and for its mixed commercial and residential space and public alleys. The surrounding community is built up, but has considerably more unpaved surface. Adjacent parcels to the designated site show most off-street parking is gravel. In recent years, some businesses in the study area have been flooded multiple times by poorly-managed stormwater. By managing rainfall as close to its point of precipitation as possible, fewer flooding events may occur. By making the path of rainwater harvesting clear to community members in an artful way, a stronger sense of ownership and pride in community can be developed by commercial interests, neighbors, visitors and customers alike.

4.1 Five Points Site Parameters

The working area is bounded on one side by Milledge Avenue, on a second side by Lumpkin Street and the third by Milledge Terrace. (See Figure 4.1.) A public alley is the approximate center of the working space. Looking at the existing area from an aerial photograph, we see that almost ninety percent of the surface is impervious. Of course this wasn't always true. There was a point at which the site was less urban. Prior to that, there is evidence of a pecan orchard that once covered much of the Five Points area. Homes in the adjacent neighborhood show extant pecan trees in what were once clearly an orchard layout. Home and business owners in Five Points still harvest the nuts. Water table replenishment for this space is far below the values we might have seen prior to development. Runoff is diverted almost immediately via conveyance and rushed away. Because it would be beneficial to the surrounding environment to discover ways to attenuate runoff and infiltrate flow, the goal of this chapter will be the following:

- To determine how much of the specified area is currently pervious versus impervious.
- To expose stormwater management methods in an artful way while attempting to increase storm water delay, attenuation and infiltration.
- To compare existing total pervious surface with proposed total pervious surface to determine how much stormwater we may be able to newly manage.

Figure 4.1 - Scope of rainfall model is highlighted in blue. Area buildings are in green. [95]

[95] This image is derived from the Google Earth Windows application and overlaid with ArcGIS and author-created art.

4.2 Physical Considerations for the Site

Having addressed the scope of the site, the next step is to identify and list important features that may impact how water traverses the site. Figure 4.2 below shows our site selection with public alleys. Public Alley "A" is at the center of our site. About two-thirds of the alley's length has been converted from asphalt service road to sidewalk. The remaining asphalt road is in poor repair and is used to some extent as extra parking by the business owners in adjacent buildings. This blocks some pedestrian traffic in the alley. From the stop sign and road composition, it can be implied that this was once a fairly-well-used service road. (See Figure 4.3.) Public Alley "B" is used almost exclusively by EarthFare and Add Drug for exiting the rear parking by customers, commercial delivery services and landfill/recycling haulers. Various infrastructural features that affect or can be affected by stormwater runoff are shown in Figure 4.5. Table 4.5.a includes totals of the same features.

One and one-half acres of roof are mediated by 67 downspouts and scuppers. All of the downspouts pour directly or indirectly onto asphalt or cement adjacent to each building. The bulk of all stormwater on this site passes from parking lot to street, or roof to parking to street. The only exception is the parking lot for building "D" in Figure 4.5, which has a rock swale with a weir that is directly connected to municipal drainage. The arrows in the same figure show the general direction of flow for stormwater runoff. Figure 4.4 shows the rock swale and weir next to building "D". All other runoff from these properties is handled by the six street-side municipal stormwater drains.

There are 230 parking spaces for the entire site, not including extralegal alley parking or the below-ground tenant parking for building "D" in Figure 4.5. The only existing on-street commercial parking in all of Five Points is directly across the street for businesses at that location. No other commercial endeavors have on-street parking in Five Points. Building "D" is a mixed-use building with businesses on the ground floor and condominium and office space above. Building "J" is a condominium. Vehicular access to Building B crosses the public alley (sidewalk) and exits via the driveway for building "D". All other buildings are commercial with one floor. There are nine driveway street entrances on this site.

The general impact from what is seen in Figure 4.5 is that stormwater is drained off the site through the driveway entrances into the streets and down the municipal stormwater drains. Little or no delay or infiltration has been implemented.

Figure 4.2 - Site selection with buildings and public alleys

Figure 4.3 - Two views of Public Alley "A", one with cars parked in it

Figure 4.4 - Two views of a rock swale and weir that handles all drainage from mixed-use Building "D" parking

Figure 4.5 - Identification of Various Features in the Five Points site

Table 4.5.a - Total impervious and pervious area (in square feet)			
Entire	Total space of parcels to edge of street	222,147	sq ft
Unpaved	Total of unpaved areas	29,349	sq ft
Impervous	Paved area = Entire - Unpaved	192,798	sq ft
Total Roof	All building roof tops	65,607	sq ft
Parking Area	Navigable by cars *and* pedestrians	93,236	sq ft
Sidewalk	Existing mostly non-motor-vehicular access	22,580	sq ft
Drains	Municipal stormwater drains and one weir	7	qty
Scuppers	Downspouts and scuppers on buildings	67	qty

4.3 Additional Environmental and Social Evaluation

Because the scope of this thesis is the artful expression of stormwater management, design features will be shaped for relative magnitudes of flow that could be generated from their catchment areas. All sizing and hydraulics are subject to refinement using quantitative stormwater modeling. Likewise, it is appropriate that harvesting stormwater runoff should include practices such as CIRIA's Sustainable Drainage Systems (SuDS) methodology. Again, these measures will be assumed as they are outside the purview of this study.

Any part of the project that involves design of streets, alleys or other city-owned public areas should involve concerned stakeholders of the local community. Neighbors, business owners, land owners and legislators should have reasonable input into the process in order for such a design to meet the needs of the people who will actually use the space. Again, these criteria are outside our scope, so they will not be included here.

4.4 Finding Pervious Surface

To determine the amount of pervious surface on our site, a satellite photo was dropped under an ArcGIS-created map of the Five Points area and subsequently placed into Autocad. In Autocad, areas of permeability were traced, such as turf and planting islands in parking lots. Then the summed total area of parcels and subtracted permeable area were configured. The site consists mostly of parking lots and roofs - all of them impervious. When impervious surfaces were subtracted from the five acres of land, pervious surface was found to be two-thirds of an acre - or 13% of the entire area. (See Table 4.5.b.)

Table 4.5.b - Total impervious and pervious area (condensed)					
Entire	Total space of parcels to edge of street	222,147	sq ft	5.10	acres
Unpaved	Total of unpaved areas	29,349	sq ft	0.67	acres
Impervious	Impervious Area = Entire - Unpaved	192,798	sq ft	4.43	acres
% Unpaved	Percent unpaved = (Unpaved/Entire)*100	13.21%			

4.5 Soil Considerations

In the map and table below (Figure 4.6, Table 4.6), we can see that the soil for the study area is Cecil sandy loam with two to six percent slopes, eroded. According to the web soil survey the soil is "well drained, residuum weathered from granite and gneiss and/or residuum weathered from schist." [96] Additional earth movement from historic urban building practices and decades of traffic will have disturbed and compacted the soil, probably slowing permeability to some degree, but not completely impeding reasonable permeable pavement and earthworks techniques for stormwater attenuation and infiltration.

4.6 Weather Patterns and Precipitation

To better understand what kinds of artful stormwater management might be suitable for this Athens site, it helps to look at rainfall from various perspectives. It is useful to know how much rain can be expected on a site; whether rainfall happens in some seasons more than others; how intense rainfall ordinarily is; and what extremes we may see with regards to maximum and minimum rainfall per event, per month, and per year. It is also useful to know what to expect in the way of cycles of abundance and drought.

Using known daily rainfall amounts for the last 12 years [97], how rain falls was modeled not only in Athens, Georgia but also in Portland, Oregon and Austin, Texas. These widely-separated areas were chosen to find out how differing climates and precipitation might affect the outcome for the design model. They were also chosen because they have excellent examples of rainwater harvesting for case studies. (Cedar River, Washington was omitted from the graphs in order to reduce complexity of presentation in this thesis, though data was researched for this case study as well.) The first thing to consider was 30-year average monthly rainfall as presented in 2010 by the National Climatic Data Center.

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[96] (USDA 2012)

[97] (NOAA 2012) All rainfall data graphs and tables in this thesis are derived from this online data source. A twelve-year span of data was chosen for the following reasons: First, 12 is divisible by 2, 3 and 4, which might have come in handy. Second, thirty years of data would be better served from a database rather than a spreadsheet and would be beyond the scope of this thesis.

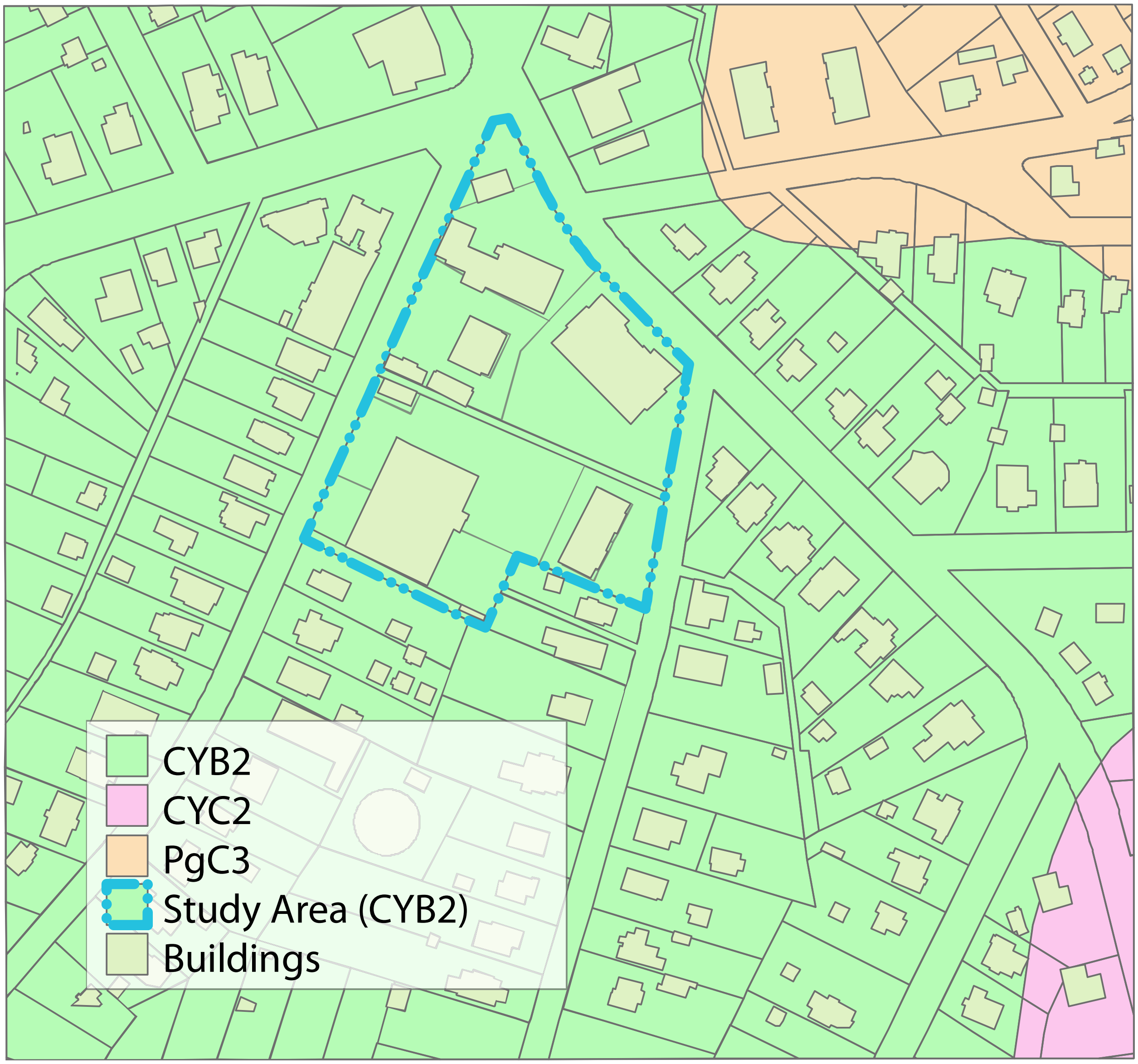

Figure 4.6 - Study area is Cecil sandy loam. [98]

Table 4.6 - NRCS Web Soil Survey for Five Points			
Clarke County, Georgia (GA623)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
CYB2	Cecil sandy loam, 2 to 6 percent slopes, eroded	**47.8**	89%
CYC2	Cecil sandy loam, 6 to 10 percent slopes, eroded	**1.2**	2%
PgC3	Pacolet sandy clay loam, 6 to 10 percent slopes, severely eroded	**4.6**	9%
Totals for Area of Interest		**53.6**	100%
Source:	*http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx*		

[98] (USDA 2012) Data are from web soil survey. Image is author-generated.

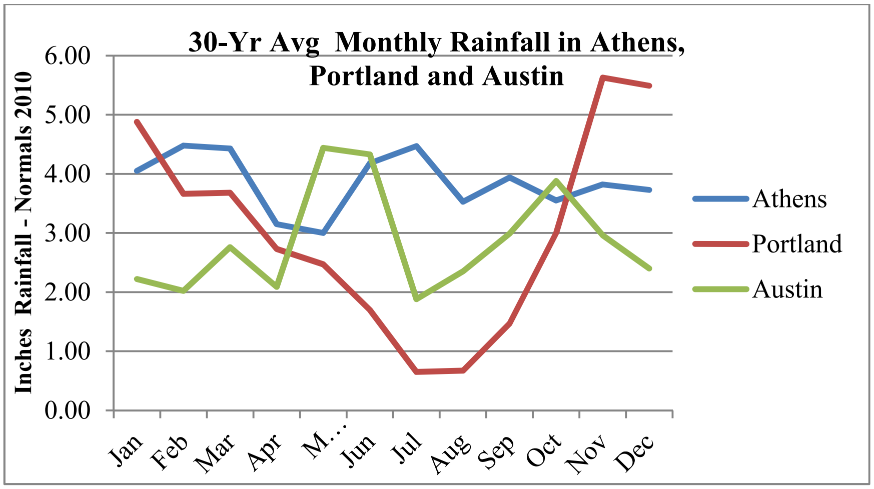

Figure 4.7 - 30-Year Monthly Average Rainfall in Athens, Portland and Austin [99]

Right away, we can see that Athens receives the most rain and the steadiest amount per month. (See Figure 4.7 above.) Athens does not fit the saying, "April showers bring May flowers". Unlike Portland, there is a good deal of precipitation throughout the year, whereas Portland has a peak in winter and Austin has peaks in early summer and early fall.

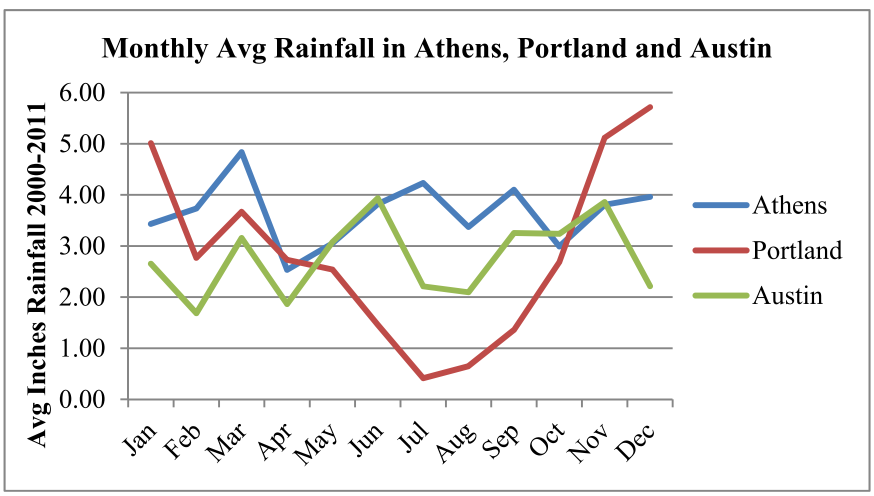

Figure 4.8 - Monthly Average Rainfall in Athens, Portland and Austin - 2000 to 2011

From Figure 4.8 above, averaging the rainfall for the last 12 years manually corroborates what is seen in the 30-year normalized averages.

[99] See Appendix A, Table 7.C for a list of exact values.

It is also appropriate to graph total yearly rainfall sequentially to get a sense of what we could expect from year to year and compare that with cities from the case studies. (See Figure 4.9.)

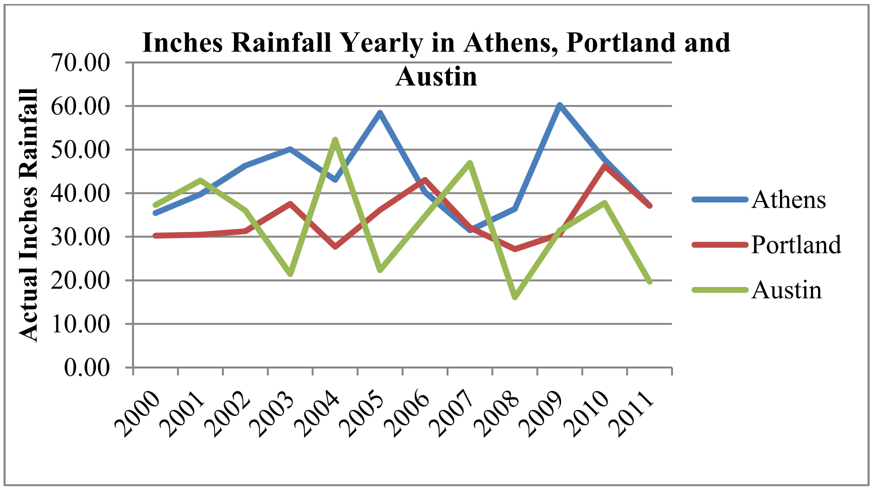

Figure 4.9 - Inches Rainfall Yearly in Athens, Portland, and Austin

Rainfall in Athens varies from 60 inches down to 30 inches in a five-year oscillation. This suggests that there could be years when the harvest isn't going to produce much attraction on a fairly regular basis. Compare that with Austin which seems to swing from 50 inches down to 20 inches on a two-to-three year cycle, and Portland which seems to be oscillating on a five-year period similar to our own, just with less rain and phased forward one year. While Portland's total precipitation varies the least yearly, it is a toss-up as to whether Austin is more severe than Athens, or vice versa. Both Athens and Austin oscillate over a range of about 30 inches, but Austin gets much less rain in the lean years. Athens receives more precipitation during lean years, but has more lean years between abundant years.

4.7 Available Water Days

Interactive artful installations of rainwater harvesting will often necessitate the use of a cistern system. Cisterns used for stormwater runoff treatment can be set manually to drain slowly over a period of time from several hours to a week, as we saw with the 10th @ Hoyt cistern. In an effort to understand how many days of interactivity a cistern-enabled installation could provide, this author created a reservoir balance model. In this model, *Available Water Days* is the number of days during which an artful installation can be active in a model year. The number depends on the capacity of the cistern, the number of days by which the cistern should completely drain, the amount of precipitation and whether the installation requires winterization (preparation for winter storage).

Spreadsheet document *Rainfall Data.xlsx* contains precipitation data for every day for the last 12 years. For practical reasons, the spreadsheet file is not included in the thesis document. All calculations can be recreated by entering the formulas introduced in appendix A into a new file at any time in the future.

Using this precipitation data for the cities of Athens, GA, Portland, OR, and Austin, TX, the model allows the user to plug in numbers for catchment size, cistern size and various other parameters in order to get another perspective on what type of cistern installation might be useful. This spreadsheet is limited to active rainwater harvesting installations with a cistern that is used specifically as the main reservoir or perhaps backup reservoir. It is assumed pumps may be used to recirculate water through the feature. It is further assumed that many features will lose water as they recirculate, partly from evaporation and partly from designed and implemented drainage or infiltration. With stormwater runoff delay as the main goal, water is released from the cistern intentionally over a fixed number of days to suit local stormwater regulations and artful interactivity considerations. Variables that can be manipulated include:

- **Roof Catchment Area** (in square feet)
- **Runoff Coefficient** - In our model this is assumed to be 0.90 or 0.95.
- **Cistern Capacity** (in gallons)
- **Rate of** cistern **release** per day **-** By default it has been set to arbitrary numbers selected from a list matching selected capacities. However, this can be set manually if preferred using the '**Release Rate Override**' field. This number is in gallons per day. It will be smaller than the cistern capacity. Things that govern the release rate might include local stormwater infiltration or delay regulations and how long an artful urban installation might make use of harvested water.

- **Use Freeze Dates -** If the installation is to be winterized — closed down for winter — this needs to be "Yes." If the installation will not be winterized, it should be "No." Typically, installations are winterized by first freeze in winter and turned back on after last freeze in spring. These dates averages are included in our calculations.
- **Recirculation shutoff volume -** This is the number of gallons of water remaining in the cistern, below which a recirculating installation should actively shut off and finish draining.

Some variables have been plugged in to give examples. A number of things can be determined in Figure 4.10 below. First, the number of Available Water Days shows a graph that looks fairly similar to our Monthly Average Rainfall graphs.

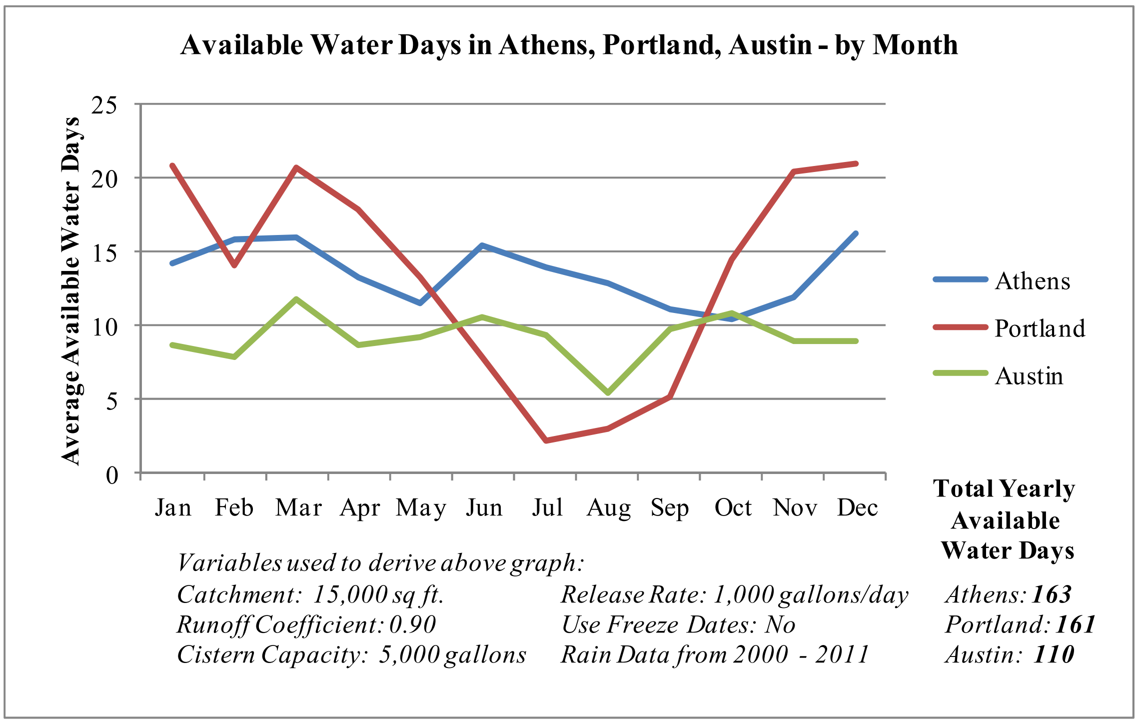

Figure 4.10 - Available Water Days in Athens, Portland and Austin, unwinterized, example one

Comparing Figure 4.10 with Available Water Days for the same install when it is winterized, (see Figure 4.11,) it is clear how drastically the total Available Water Days can change in general. Winterizing an installation in Athens means 44 percent of its Available Water Days are lost for this model. Portland loses 55 percent because most of its precipitation is on the cold side of the year. Austin loses the least at 27 percent because Austin receives less rain in the winter.

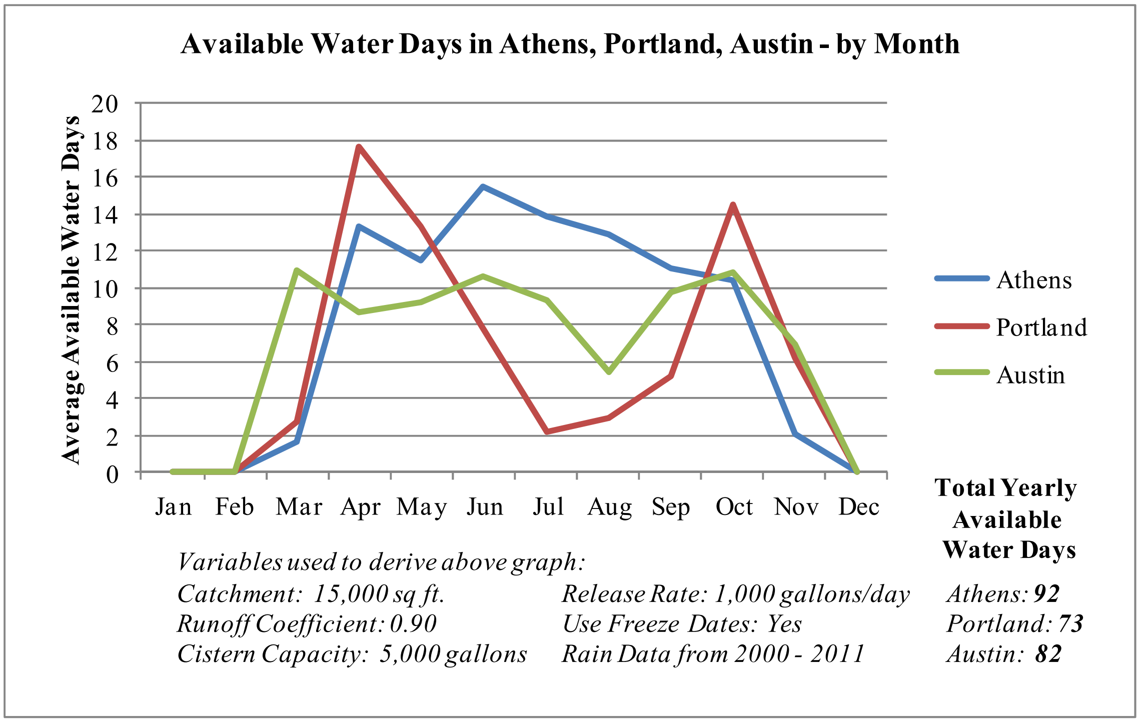

Figure 4.11 - Available Water Days in Athens, Portland and Austin, winterized, example one

Variables such as catchment size and runoff coefficient are less likely to change greatly for retro-fit installations, but cistern capacity, and release rate can be modified fairly easily to come up with very different results. For the second example, as seen in Figures 4.12 and 4.13, a design has been specified for a very much larger 65,000-gallon capacity cistern, while the rate of release remains at 1,000 gallons of water each day, the same as in example one, Figures 4.10 and 4.11. The data for Athens in Figure 4.12 show that water is available for use from the cistern 351 days out of the year. This suggests that a cistern could be modeled so that water would be available for every day of the year, provided we use a big enough cistern and catchment and a small enough release or use rate. However, Figure 4.13 shows what happens in example two when we winterize the same model. Once again, there is a drastic reduction in the number of Available Water Days. This brings us to the next consideration - changing one parameter alone - cistern capacity - in order to discover a full-year solution for cistern capacity where all other variables remain constant.

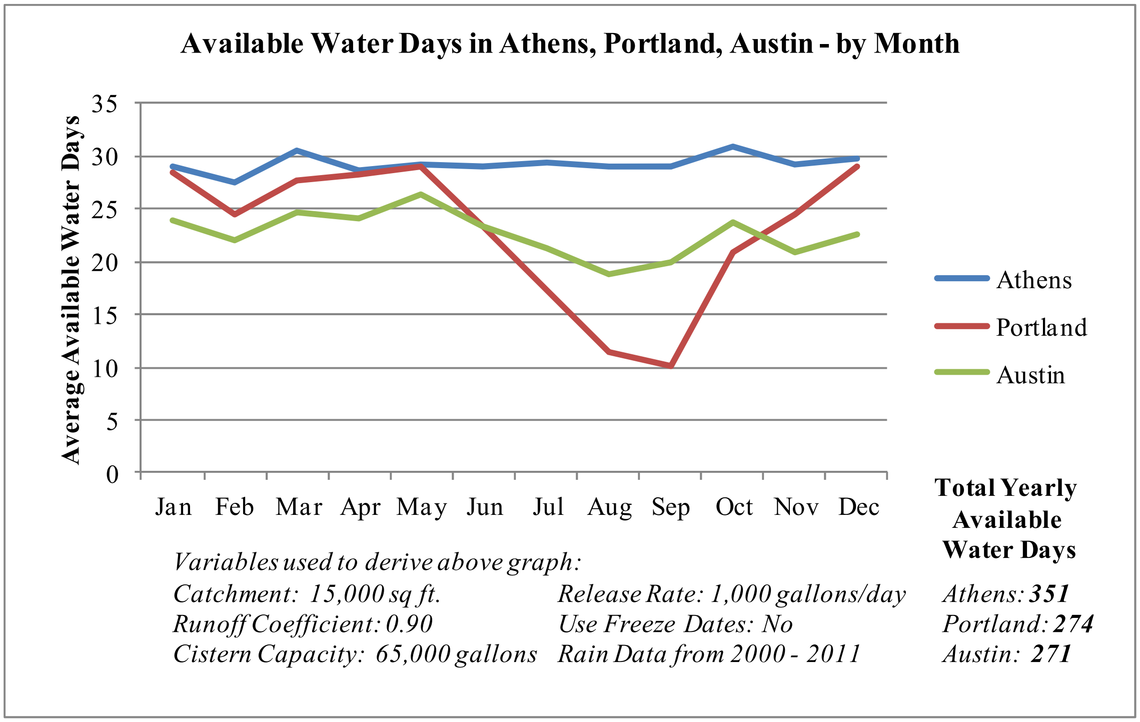

Figure 4.12 - Available Water Days in Athens, Portland and Austin, unwinterized, example two

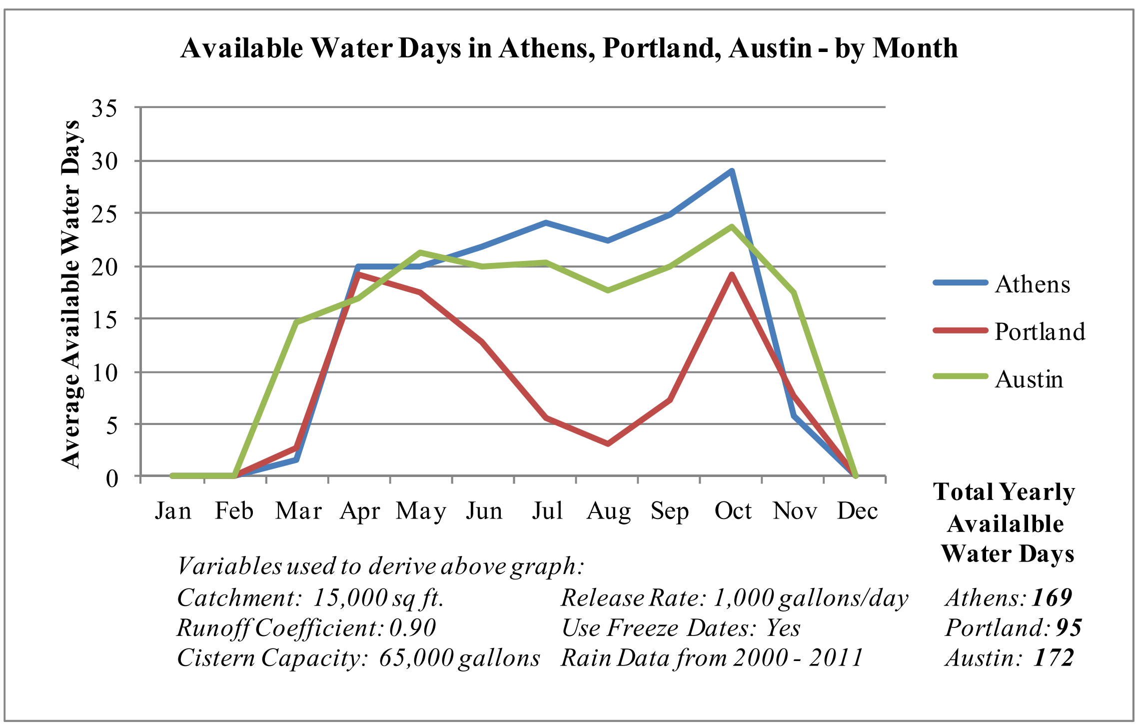

Figure 4.13 - Available Water Days in Athens, Portland and Austin, winterized, example two

As an exercise to explore this consideration, in Table 4.14 cistern capacity has been assigned multiple example volumes to find out how Available Water Days will change with increased capacity where all other variables remain constant. Rate of release has been brought down to 300 gallons per day in order to show what happens when overall supply of rain exceeds demand. Under such circumstances, Available Water Days will always reach or approach a maximum of 365 total days. Table and Figure 4.14

Table 4.14 - Derived values where Cistern Capacity varies and Release Rate is constant

	Not Winterized					
Cap	**Athens**	**Portland**	**Austin**		Roof Catchment Area (sf)	15000
100	0	0	0		Runoff Coefficient (E)	0.9
300	0	0	0		Cistern Capacity (gal)	Varies
600	92	140	66		Rate of Cistern Release per Day	300
1,500	215	224	151		Use Freeze Dates	No
3,600	317	284	244		Active Art Day Portion(gal)	.75 r_rate
9,100	360	327	320			
23,100	365	362	361			
59,500	365	365	365			
154,000	365	365	365			

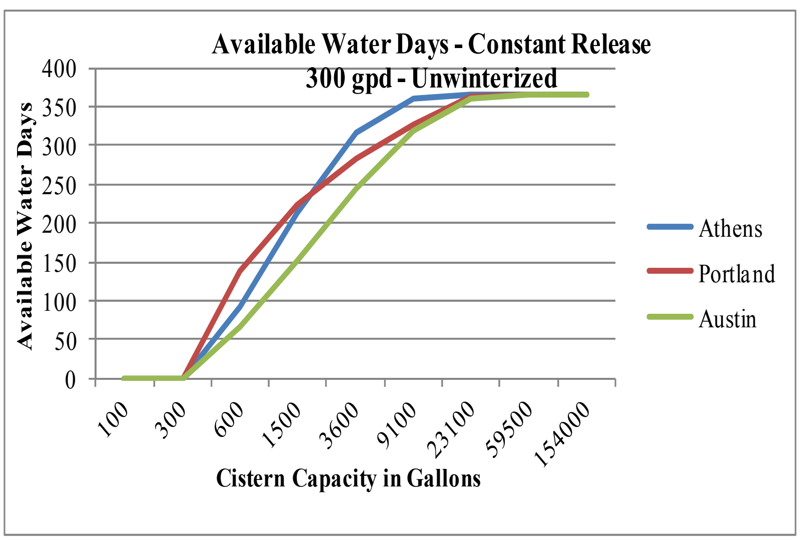

Figure 4.14 - Available Water Days with small constant release rate

show just such an exercise. From Figure and Table 4.14 above, for Athens, Portland and Austin, a 24000 gallon cistern is sufficient in all three regions where only 300 gallons per day are used or released. Any larger is extravagance.

The next data exploration was to test two progressions at once with the two most likely changing variables being Cistern Capacity and Release Rate. Capacities and release rates were arbitrarily derived from the Fibonacci sequence of numbers to produce an organic progression of values from reasonable to excess. [100] Table 4.A shows how Cistern Capacity (Cap) and Release Rate (R_Rate) were derived for this

Table 4.A - Custom Cistern Capacities and Release Rates						
These are arbitrarily based on the Fibonacci sequence simply out of a need						
to have a reasonable progression of capacities and release rates.						
	Fib	**Fib^2**	**Div_A**	**Div_B**	**Cap**	**R_Rate**
Fib = First derive Fibonnaci column.	1	1	1	1	100	50
Fib^2 = Derive Fibonacci squares	2	4	0	3	300	75
Div_A = F/F^2 all over 2	3	9	0	6	600	100
Div_B = F+F^2 all over 2	5	25	0	15	1,500	150
Cap = Div_B * 100 (Cistern Capacity)	8	64	0	36	3,600	225
R_Rate = Div_A * Cap	13	169	0	91	9,100	350
	21	441	0	231	23,100	550
	34	1,156	0	595	59,500	875
	55	3,025	0	1,540	154,000	1,400

exercise. From there, Cap and R_Rate were plugged in to get total yearly Available Water Days for each city. (See Table 4.15.)

[100] Phi and the Fibonacci sequence of numbers are found everywhere in nature. This sequence was used to derive cistern capacities and release rates for this exercise. The derived capacities and their respective suggested release rates are designed merely to show *limits* using release rates that would not be out of the realm of possibility for their complimentary suggested cistern capacities and catchments where catchment area remains constant. These numbers should not be considered as any sort of guideline for release rates with respect to cistern capacity outside of this exercise. These numbers were used because earlier attempts to create graphs using cistern capacities of 50,100, 500, 1000, 5000, etc., and release rates where the rate = .2 * cistern capacity resulted in ugly, choppy graphs that were difficult to relate to reality. This sequence was chosen specifically because the resulting numbers curve more naturally on a graph of limits than do other more-arbitrarily-chosen progressions. So while the choice of numeric progression *was* arbitrary, for technical and artful reasons, it was *less* arbitrary than merely applying a progression consisting of adapted relative factors of ten.

Table 4.15 - Derived values where cistern capacity and r_rate varies while all other values are constant						
	Example for varied size urban water feature - fountain, pool, etc.					
	Winterized cistern (No winter activity)					
Cap	**R_Rate**	**Athens**	**Portland**	**Austin**	Roof Catchment Area (sf)	15,000
100	50	64	78	59	Runoff Coefficient (E)	0.9
300	75	122	120	113	Cistern Capacity (gal)	Varies
600	100	153	137	140	Rate of cistern release per day	Varies
1,500	150	188	161	178	Use Freeze Dates	Yes
3,600	225	206	175	203	Active Art Day Portion(gal)	.75 r_rate
9,100	350	214	176	220		
23,100	550	211	157	223		
59,500	875	181	111	184		
154,000	1,400	133	60	131		

Figure 4.15 derived from Table 4.15 makes some things even more apparent:

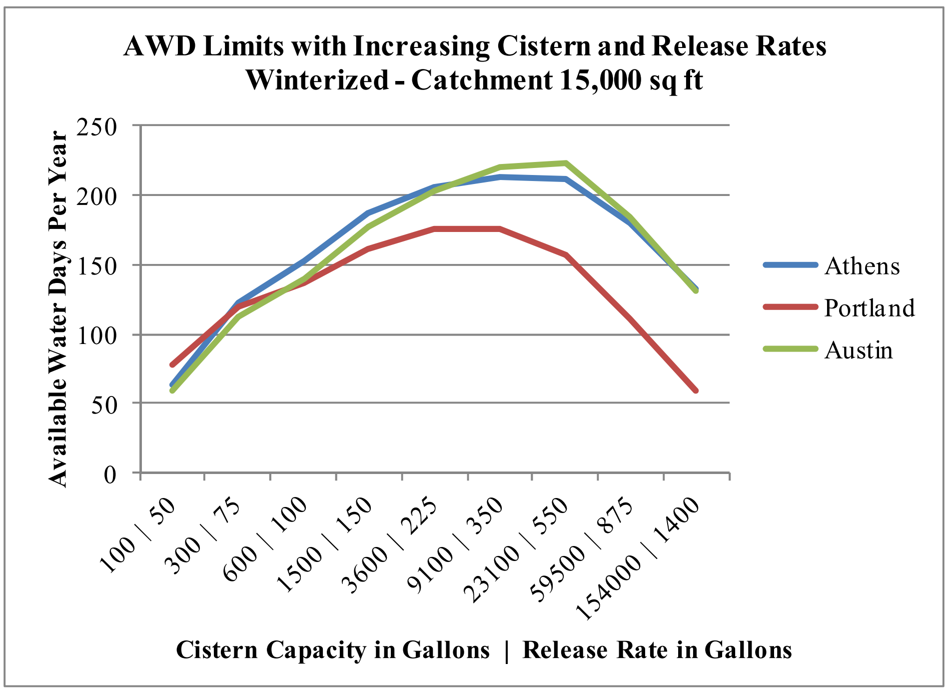

Figure 4.15 - Available Water Days limits with winterized cistern size and release rate varying to excess

Cisterns are sized to meet a use requirement. As an installation gets bigger, the release rate is likely to grow as well to meet the demands of the use, whether it is infiltration, recirculation or delay. In this exercise, even though release rates haven't climbed grossly compared to cistern capacity where catchment remains constant, there is a point after which the size of a release can exceed even large capacity cisterns, and total yearly Available Water Days begins to decrease. Enough rain simply cannot fall on the fixed-sized catchment to compensate for the increase in release rate. Even though there is more than enough cistern capacity, the demand of the release exceeds capacity. Taking this to extremes, if we had a reason for release rate to exceed *catchment* capacity, it is as if there were no cistern at all or that it was a damaged cistern. The same pattern is also the case with *unwinterized* total yearly Available Water Days, as shown in Table 4.16 and Figure 4.16 below.

Table 4.16 - Derived values where cistern capacity varies while all other values are constant

	Example for varied size urban water feature - fountain, pool, etc.					
	Not Winterized.					
Cap	**R_Rate**	**Athens**	**Portland**	**Austin**	Roof Catchment Area (sf)	15,000
100	50	106	159	82	Runoff Coefficient (E)	0.9
300	75	206	231	158	Cistern Capacity (gal)	Varies
600	100	260	258	197	Rate of cistern release per day	Varies
1,500	150	317	292	247	Use Freeze Dates	No
3,600	225	343	311	282	Active Art Day Portion(gal)	.75 r_rate
9,100	350	355	315	303		
23,100	550	358	310	306		
59,500	875	342	280	269		
154,000	1,400	246	179	184		

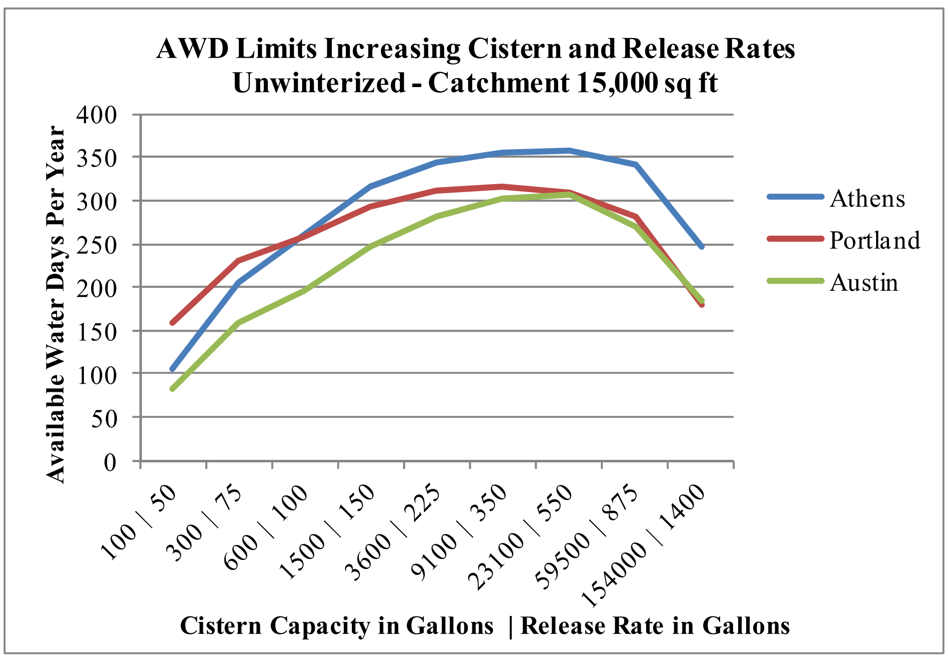

Figure 4.16 - Available Water Days with unwinterized cistern capacities and release rates varying to excess

For the Figure 4.16 model, anything with a release rate as high as 550 gallons per day is going to be about the largest installation that might be worth having if the installation is dependent solely on rainwater harvesting. This does not mean that cistern capacity has to remain as low as 10,000 gallons, but suggests that if there are no other drains on the cistern as a resource, building one this large is, again, excessive. However, because this is a model created to determine *limits* for a specified catchment, it should not be implied that release rate is dependent solely on cistern size. Release rate should be determined by stormwater detention goals. For instance, if the goal is to conserve enough water to use or treat it over the average interval between rainfall events rather than over a specified number of hours, as it was in the 10th @ Hoyt example, it is important to determine the average number of days between rain events and use that number of days to determine the release rate for the model.

In Table 4.B below, it has been determined that there are on average about 3.43 days between any given rain event and the next in Athens, GA. Additional rain event information that could be useful includes days between heavier rain events. For example, there are about twelve days between any one-half-inch-or-larger event and the next similar event and almost a month between any one-inch-or-larger event and the next. Events over four inches in depth happen about every six years.

Table 4.B - Days between rain events of increasing depth in Athens, GA - 2000 - 2011

	Max Days	Min Days	Average Days	
days >0, <=1/8"	51	1	8.29	
days >1/8"	52	1	5.87	**Avg Days Between**
days >1/4"	62	1	7.79	**Any Given Rain Event**
days >1/2"	68	1	12.31	**3.43**
days >1"	178	1	29.03	
days >2"	587	7	136.97	
days >3"	1,179	9	313.07	
days >4"	2,940	572	2,191.50	

The above examples may be seen as an attempt to create cistern models that never completely empty. If the cistern is never empty, the installation is always running. Part of the design considerations may be such that there *should* be days when there is *no* water in the system. Silence can be as thought-provoking as the splash of water, and will give the site more contrast and variation if in fact the cistern is a little smaller than at never-empty capacity. The Available Water Days reaches a peak in both Figure

4.15 and Figure 4.16 as cistern capacity and release rate rise to a point. After that point, the release rate begins to overcome the capacity, and the number of Available Water Days begins to decline. This causes a curve, with the top being the highest likely number of Available Water Days achievable in the model. The preferred number of Available Water Days that an installation should have in a year is solely at the discretion of the designer.

There is a point at which, for economics and space, a reasonable installation for the example cities might be somewhere to the left of the top of the curve depending on the size of the installation, the preferred amount of stormwater runoff to delay and the preferred number of Available Water Days as the goal. This combination of variables and the location on the graph at which they coincide could be thought of as the design limits. For instance, looking at Figure 4.15 above, a preferred design limit of 200 Available Water Days could be assigned. Because urban density will likely preclude a greater-than-154,000-gallon cistern, the left side of the curve will be more useful. Looking at where the Athens curve meets 200 Available Water Days, a lower limit of a 300-gallons capacity with a release rate of 75 gallons per day is found. (See Table 4.15.) The design limits for cistern capacity will be somewhere between 300 and 23,000 gallons for this catchment. Once catchment has been balanced with preferred cistern size, the release rate can be manipulated in the spreadsheet's named variables until the preferred number of Available Water Days is achieved, as depicted in example Figure 4.17.

4.8 Regulated Stormwater Management Considerations

Determining release, use or infiltration may depend on local stormwater regulations. For example, the Georgia Stormwater Management Manual suggests that control structures such as cisterns and earthworks attempt to treat a Water Quality Volume generated by the first 1.2 inches of rainfall in any given event. According to the manual, this allows for the removal of about eighty percent of annual average Total Suspended Solids (TSS) in typical post-development urban runoff. [101] In other words, water is returned in a relatively clear state back to Georgia's streams and rivers when these design goals are met.

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[101] (Atlanta Regional Commission 2001) These regional guidelines are set up so that local legislators may easily adopt them for towns and counties in and around the region of Atlanta, Georgia.

The rain event depth limit of 1.2 inches was derived by analyzing rainfall for 12 locations in Georgia and then averaging the 85th percentile storm depth for those locations. [102] This number and the Water Quality Volume formula will be used in the next chapter to aid design, but it may help to view an example.

In Figure 4.17 below, an arbitrary roof catchment of 1,500 square feet yields a Water Quality Volume of 1,066 gallons. (Using the formula from the Georgia Stormwater Management Manual, WQ_v = 1,500 sq ft * 1.2 inches rainfall * runoff coefficient 0.95 * 0.6233 gallons per cubic feet of water, yielding 1,066 gallons of collectible water.) For this example, it is assumed there is space and budget to fit a commercially-available 1,200 gallon tank that will exceed the Water Quality Volume requirement. The release rate of 200 gallons per day in this example was arbitrarily chosen to yield about five Available Water Days for a rain event of about 1.2 inches.

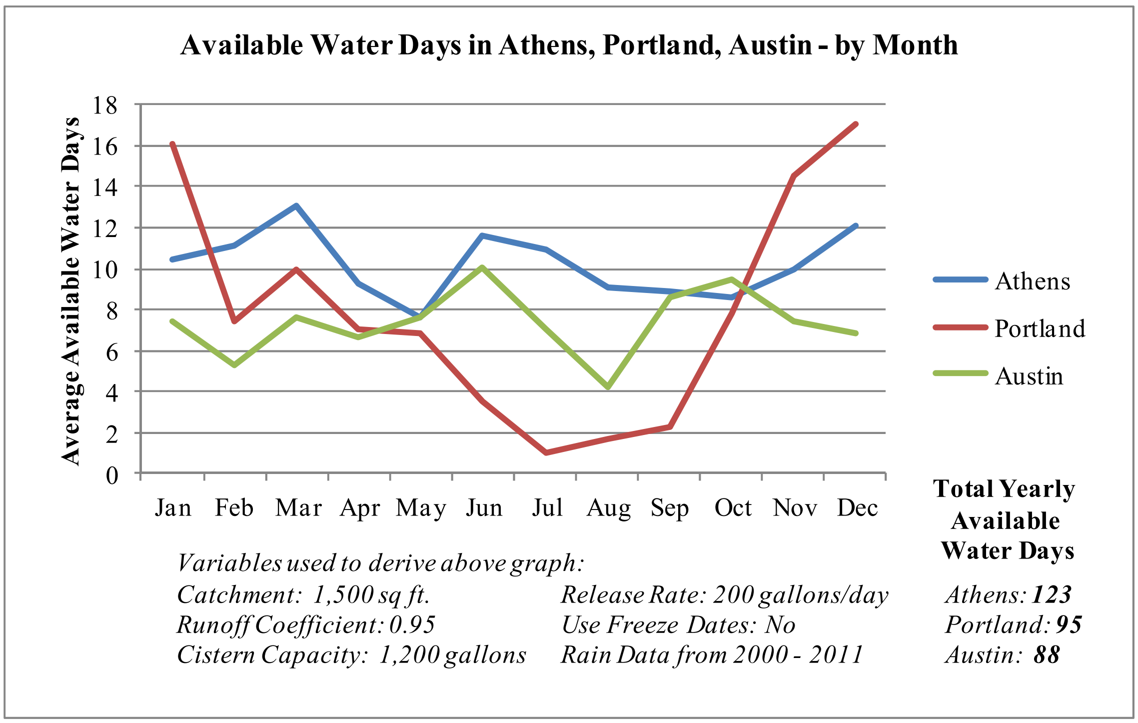

Figure 4.17 - AAD in Athens, Portland and Austin, example three

[102] (Atlanta Regional Commission 2001)

The average amount of rainfall for any given day with a rain event is 0.41 inches in Athens, Georgia. (See Appendix A, Table 7.F.) On such an average day, possible harvest for a 1,500 square foot catchment would be about 364 gallons, offering almost two Available Water Days per average event. If there is prior storage in the tank, there may be overflow. If not, the tank may be partly filled on any average rain day. For the roof catchment area that was chosen, runoff is treated for any rain event of 1.2 inches or less - which is the goal of the model in Figure 4.17. [103]

4.8 Applying Site Knowledge

The Five Points site has been shown to have reasonably well-drained soil that will not interfere greatly with infiltration, even though the site has a great deal of impervious surface. There appears to be a five-year abundance-drought cycle where total rainfall can vary from roughly 60 to 30 inches per year. Unlike Austin, Texas and Portland, Oregon, Athens, Georgia receives roughly between three and four inches of rainfall per month, with perhaps slightly less rainfall in April. Given properly-sized catchments and cisterns, it should be possible to design a few reasonable cistern-based water features that captivate passers-by. Chapter 5 will apply what was learned in this chapter to artful urban rainwater harvesting as amenity in Five Points.

[103] Further calculations by this author reveal that the 85th percentile rain event for Athens, GA alone from 2000 to 2011 yields a depth of 0.85 inches. The limit of 1.2 inches more closely approximates the 92nd percentile rain event for Athens. Should Athens adopt the region-wide limit of 1.2 inches at some future date, this lower limit could be taken into account for designs where the 1.2-inch limit is not practical.

Chapter 5

PRACTICAL APPLICATION AND VALUES IN ARTFUL URBAN RAINWATER HARVESTING

After having laid out considerations for soil and weather, identifying important features of the site and looking at case studies, it is time to apply what has been learned to the Five Points site. This will be the order of implementation and application in this chapter:

- Identify areas where pervious parking will work.
- Identify areas where pervious sidewalks and pedestrian areas will work.
- Identify spaces where cisterns could exist.
- Identify spaces where rain gardens and green roofs could exist.
- Add up proposed pervious and delay surface and compare with existing.
- Suggest artful water features that could be fed by proposed cisterns.
- Show examples of how to meet the Water Quality Volume goals by using 1.2 inches as the rain depth in design considerations.
- Make comments and observations about implementation and installation.

5.1 Pervious Parking

In Figure 5.1, the areas labeled "Proposed pervious parking" and "Proposed impervious parking" together show the limits of the entire useable parking surface for the site. Proposed impervious parking will remain as original surface. Proposed pervious parking will be paved with permeable pavers. Driveway aprons will be left as original impervious materials. Table 5.1.a shows the total area of parking compared with total area of pervious parking.

Where feasible, pervious parking will use Uni-Lock permeable pavers outlined by a six-inch-wide curb flush to existing parking surfaces. Existing curbs will become the remaining boundaries for permeable pavers where appropriate. Subgrade will be compacted where traffic and vehicle weight require additional stability. The various aggregate layers will be typical for permeable pavement. Geotextile will line the interface between subgrade and aggregate layers also as typical. Underdrain will be installed typically and sized and connected to existing municipal drainage as appropriate.

Paver shape, color and finish may be left to the discretion of the various parcel owners, with the provision that Solar Reflective Index should meet or exceed LEED standards. Suggested paver colors, textures and finishes for pervious parking surfaces may be found in Table 5.1.b.

Figure 5.1 - Proposed limits of pervious parking

Table 5.1.a - Total parking area compared to proposed permeable parking						
Total Parking	Navigable by cars *and* pedestrians		93,236	sq ft	2.14	acres
Pervious Parking	Proposed		64,312	sq ft	1.48	acres
Percent of total parking converted to proposed permeable			69%			

Table 5.1.b - Suggested shapes, finishes and colors for pavers				
Area	**Paver Shape**	**Finish**	**Color**	**SRI**
Area A	Eco-Optiloc	Smooth Finish	Nevada	33
Area B	Eco-Optiloc	Smooth Finish	Sandstone	46
Area C	Uni Eco-Stone	Series 3000 - washed aggregate	Ice Grey/Chardonnay Tan random mix	38/44
Area D	Eco-Optiloc	Series 3000 - washed aggregate	Chardonnay Tan	44

5.2 Pervious Sidewalks and Pedestrian Areas

Figure 5.2 shows buildings with sidewalks and other pedestrian areas. All pervious sidewalks would use the same permeable paver conventions discussed in pervious parking above. Proposed pervious sidewalks would consist of Eco-Priora paver rectangles laid herringbone-fashion. Proposed unchanged areas would remain as they are. Remaining pervious areas will include more site-specific applications shown separately in thesis section '5.6 Artful Water Features fed by Proposed Cisterns'. Table 5.2 shows existing square feet of sidewalk and permeable pavement in comparison.

Water Quality Volume for pervious parking and pervious sidewalks as shown in Table 5.A is based on a minimum of six inches of level base aggregate (open-graded #57 stone), where the volume of the open-graded aggregrate has a minimum of 37.7 percent open volume. [104] Given that 1.2 inches is the goal, it is valid to suggest that 37.7 percent of a six-inch rain depth will always yield 2.62 inches of depth, or just about the 98th percentile of rainfall events for Athens, GA, far exceeding the 1.2-inch goal. For pervious parking and sidewalks in Table 5.A, the Design Volume column in gallons always exceeds the Water Quality Volume in the adjacent column, thus exceeding the Georgia state-wide goal for WQ_v. The excess available treatment volume becomes important when considering rooftops as catchment. Where practical and necessary, the base aggregate minimum depth of a pervious parking lot could be increased in order to accommodate adjacent roof treatment for dense urban sites like this one if more water quality volume is deemed appropriate.

Table 5.A - Pervious parking - Water Quality Volume vs. Design Volume					
		Area (sq ft)	Acres	WQ_v (gal)	Design Vol (gal)
Pervious Parking	Proposed	64,312.05	1.48	45,700.14	86,144.77
Pervious Sidewalks	Proposed	7,156.31	0.16	5,085.28	9,585.74

[104] (Ferguson, Ferguson, and Mickalonis 2012) p. 5. Open-graded #57 stone can vary in open volume from 37.7 to 44.5 percent of total volume. The lower limit of 37.7 percent was adopted for this thesis. Due to the wide variance between limits, it might be wise to ascertain the true open volume on a case-by-case basis for obtained open-graded aggregate where space and practicality become crucial in an already-dense urban design.

Figure 5.2 - Proposed Pervious Sidewalks

Table 5.2 - Areas of proposed pervious sidewalk compared with existing					
Existing Sidewalk	Total existing pedestrian areas	22,580	sq ft	0.52	acres
Pervious Sidewalk	proposed	7,156	sq ft	0.16	acres
Special Case Areas	proposed permeable	4,876	sq ft	0.11	acres
Percent of total converted to proposed permeable		32%			

5.3 Cistern Placement Suggestions

Unlike permeable pavers, cisterns are less about infiltration and more about storage, reuse and delay. In Figure 5.3, placement for various cisterns is suggested. Cisterns can be used for stormwater runoff delay, while also acting as a reservoir for recirculating water features or for watering plants. All cisterns in this proposal remain unwinterized for simplicity's sake. The parcel containing Building A has a small area that is used neither by vehicles nor pedestrians to the west of its patio (in yellow, Figure 5.2). A cistern for a recirculating water feature could be installed at Location 1 and incorporated with the patio adjacent to Yoforia (Building A.) There are already rain barrels at the Five and Ten and Hodgson Terrace (Buildings B and D), so there is certainly community interest in rainwater harvesting. (See Figure 5.4.) Those at Location 2 near the Five and Ten are used to water plants in galvanized planters along the building's south wall. The two rain barrels at Hodgson Terrace (Locations 6 and 7 in Figure 5.3) are unfortunately serving as ashtrays for customers of businesses inside the Hodgson Terrace building. End-use for the rain barrels at building D is not apparent to the public. Site users are not getting a clear message about rainwater harvesting.

There is a ledge south of The Hub Bicycles (Building B) at Location 3 which could hold a cistern fed by the south face of the building for Catchment B.ii. (See Figure 5.3.) This cistern system could be used for a water feature in the outdoor cafe seating east of Jittery Joe's (also building B) or to water the ginger strip south of Building B, or both. The Bottle Shop extension (Building F) could serve as catchment for a cistern at Location 4. The catchment for this building could feed a cistern-enabled water feature in the public alley and water the planted terrace east of the Bottle Shop (Building C.) Rain barrels at Location 2 could be replaced by a more presentable, artful cistern or the existing rain barrels could be made more artful. Rain barrels at Building D could be painted bolder colors. Articulated, grill-covered runnels could either water the slopes off the patio northeast of Building D or fill the cistern at Location 6.

In sizing cisterns for this site, catchment area and available space play roles in determining cistern size. Taking a cue from 10th @ Hoyt, a cistern could be sized to meet half the rainfall events in a year. However, since Georgia has a stormwater management methodology in place, it will be more appropriate to attempt to save the first 1.2 possible inches of rainfall per event where practical. Rain falls 106 days out of the year in Athens, GA. Rainwater harvesting of all rainwater 0.85 inches or less in depth would be sufficient to delay 85% of all rainfall events in Athens, GA. However, the attempt will be made to meet the *region-wide* goal of 1.2 inches of saved rain for proposed cistern and reservoir examples where practical.

Figure 5.3 - Proposed cisterns and existing rain barrels

Figure 5.4 - Existing rain barrels

As an example for cistern capacity and Available Water Days, the roof catchment area for the Yoforia building is 1670 square feet. A 1.2-inch rainfall would yield a Water Quality Volume of 1187 gallons for this roof. A tank of this size would not fit comfortably in the patio space, but we can use a gravel infiltration bed beneath the patio area that will collect roof water and patio water as it overflows from a small cistern. The area for the patio is about 560 square feet, which has its own catchment WQ_v of 398 gallons for a 1.2-inch rainfall. The WQ_v goal is expressed as: 1187 + 398 = 1585 gallons. To meet this goal, pervious pavers will cover the patio area, with one change, where the open-graded base course will be to a minimum depth of twelve inches instead of six inches. The resulting infiltration area would be 560 (square feet) * 12 (inches depth of base course) * 0.95 runoff coefficient * 0.377 (open-grade conversion) * .623 (gallon conversion) to yield 1500.22 gallons of storage volume in our infiltration bed. This, coupled with a 250-gallon above-grade cistern will meet our requirement of 1.2 inches of infiltration or delay. The cistern would be smooth metal and painted to match the color treatment of the Yoforia building. A metal aqueduct would lead from the roof of Yoforia to the top of the cistern, serving as an enhancement and backdrop for the patio. An overflow pipe would redirect the bulk of the roof-collected rainwater from the cistern to the infiltration bed below the patio. The overflow pipe could be designed so that the last couple of inches end just above a grate in the surface of the patio, exposing some of the flow of water to the infiltration bed for people to see. Appropriate underdrain and overflow would be implemented between the infiltration bed and the municipal stormwater system.

A small stucco alcove would be built into the side of the cistern tower with a small recirculating water feature that drains in an arbitrary number days to the adjacent infiltration bed. Available Water Days for 1.2-inch of rainfall and a 250-gallon cistern with a release rate of 50 gallons per day yields 204 Available Water Days in a year, with a full tank emptying within five or fewer days of a single 1.2-inch rain event. If the release rate is made 100 gallons/day, Available Water Days drops to 107 days per year, with a full tank emptying within about two days of a rain event.

Table 5.B - Average rainfall in inches for days with rain						
Days with rain in twelve years			1,276.00	days		
Total days in twelve years			4,383.00	days		
Average rainfall in inches for days with rain			0.41	inches		
Maximum rain fall for one day in twelve years			6.22	inches		
Average days of rain per year			106.33	days/year		Consistency
		days/year				check
	total days	59.42	713.00	days >0, ≤.25	55.88%	55.88%
Total days with rain > .25	563.00	17.25	207.00	days > .25, ≤.5	16.22%	72.10%
Total days with rain > .5	356.00	17.08	205.00	days > .5, ≤1.0	16.07%	88.17%
Total days with rain > 1.0	151.00	9.92	119.00	days > 1.0, ≤2.0	9.33%	97.49%
Total days with rain > 2.0	32.00	1.50	18.00	days >2.0, ≤3.0	1.41%	98.90%
Total days with rain > 3.0	14.00	1.00	12.00	days > 3.0, ≤4.0	0.94%	99.84%
Total days with rain > 4.0	2.00	0.17	2.00	days > 4.0	0.16%	100.00%
Consistency check		**106.33**	**1,276.00**			

Table 5.3 gives example cistern sizes based on respective catchment areas depicted in Figure 5.3. "Water Quality Volume" is derived from the following formula: WQ_v = Square Feet of Catchment * 1.2 inches rainfall * runoff coefficient (0.95) * gallon conversion (0.623). Cistern size is arbitrarily decided as a standardized tank size at or around the amount of delay gallons found. Cistern placement is numbered as designated in Figure 5.3. Mentioned in Figure 5.2 were several special case areas. These are cisterns or delay reservoirs with artful applications. Note also that cistern sizes suggested in Table 5.3 may not be practical, and are only given in this table as an example of how commercial cistern size might be determined by known Water Quality Volume.

Table 5.3 - Example cistern size based on 1.2-inch harvest in gallons from example catchments				
Catchment	**Sq ft**	**WQ_v**	**Cistern Size**	**Cistern Placement**
A	1,671.42	1,237.20	1,200	1
B.i	1,151.12	852.07	1,000	2
B.ii	2,923.90	2,164.30	2,500	3
D.i	3,954.43	2,927.10	3,000	6
D.ii	610.13	451.63	500	5,7
H.i	3,487.76	2,581.67	2,500	9
H.ii	15,268.18	11,301.64	12,000	10

5.4 Rain Gardens and Green Roofs

Figure 5.5 designates proposed rain gardens, a xeriscape and a green roof. The xeriscape is proposed in the existing raised bed north of Yoforia (Building A.) This garden is at a peak in elevation and receives no runoff. It makes no sense to put a rain garden here. Existing raised beds should be resurfaced or renovated. Low-maintenance plants that thrive in hot, dry, sunny conditions should be planted in these beds. The existing rosemary should be trimmed. Tall shrubs should be removed for visibility and replaced with short showy grasses and Brown-eyed Susan. Additional seasonal color could be added. Concrete platform should be removed.

The largest rain garden northwest of Building D is currently a rough rocky swale that could be retrofitted as a more artful rain garden. The smaller areas southwest of Building D all could have grill-covered drain runnels leading from downspouts to rain garden areas. Small overflow weirs in the rain gardens could spill from the rain gardens through curbs with more grill-covered runnels to the pervious parking. Although the rain gardens are part of the treatment chain, they are omitted from the following calculations to reduce complexity for this exercise. In a real world situation, their contribution would be included. One catchment faces pervious parking for the Hodgson building. The two adjacent catchments each have one of three downspouts that could spill via the treatment chain through the rain gardens into the parking area. Summing one-third of each of these catchments with the catchment that faces the parking yields 6,827 square feet of catchment that could be treated by the rain gardens and/or the parking area. The parking area can treat a WQ_v of 16,626 gallons, but is only required to treat a volume of 8,820 gallons for a 1.2-inch rain event. The WQ_v for the catchment served by the parking area is 4,852 gallons.

Treated volume = 4,852 + 8,820 gallons, yeilding 13,672 gallons of treated water. That is 2,954 gallons fewer than the available storage volume.

A strip of rain garden could replace the separated beds west of EarthFare (Building H.) The concrete covering some of the triangles would be removed to expose space for additional rain garden area. Curb cuts from the diagonal pervious parking would allow any excess water to flow into the rain garden. The current parking curb has outflow drains in the curb at its lowest corners that lead to the sidewalk below. These outlet pipes would be adapted within the rain garden to act as weirs for the same overflow purpose, but allowing the rain garden to take some of the excess rain load first. Of course this rain garden is second in this particular treatment train. The pervious parking above it makes the first venture at mitigating rainwater events. It is unlikely that very much rainwater will see this rain garden in a 1.2-inch rainfall event due to the large Water Quality Volume treated by the pervious parking.

With tight traffic and parking surrounding The Bottle Shop, (Building C,) no cistern could be placed above-ground nearby for harvest or artful application. The roof is flat and relatively unencumbered. For this reason, a green roof has been proposed for Building C, provided the building structure can support it. This will be a typical light-weight extensive green roof system using succulents, engineered growing medium, filter fabric, water-retaining drainage layer, root barrier and waterproof membrane. Plants well-suited for the Athens area include Sedum, Delosperma (Ice Plant), Euphorbia (Spurge) and Sempervivum (Hens and Chicks). This typical extensive green roof will not be able to retain 1.2 inches of rainfall, but this roof is the first control structure in the treatment train, and all downspouts for this roof overflow into the rear pervious parking. The next step is to find out how much roof water will be treated by the green roof by subtracting an adapted WQ_v using a runoff coefficient of 0.5, a typical coefficient [105] for a three-inch-deep extensive green roof (1,538 gallons) from the WQ_v of the currently impervious roof (2922 gallons). The Bottle Shop green roof will therefore retain 1,384 gallons (2,922 - 1,538) of water from a 1.2-inch rain event, while the overflow handled by the pervious parking will be 1,538 gallons. The parking lot can infiltrate up to 9,604 gallons of water, but only needs to handle 5,095

[105] (Ngan 2004) p. 22.

gallons from the pervious parking itself, and so can easily handle the additional 1,538 gallons from the roof, leaving an additional 2,971 gallons of infiltration volume to spare in a 1.2-inch rain event. The stormwater goal is met for roof and parking in this part of the site.

Green roofs and rain gardens have been shown in this section to play a vital role in mitigating stormwater by being part of the treatment train. Wherever practical, these kinds of design considerations should be applied in order to meet or exceed stormwater management aims. It should be stressed that these kinds of considerations are not always practical, especially in dense urban design.

Figure 5.5 - Rain gardens, a green roof and a xeriscape

5.5 Compare and Contrast Existing Pervious with Proposed Pervious Implementation

In this section the comparison is made between existing unpaved conditions and proposed changes. The existing conditions showed that about two-thirds of an acre remain unpaved out of five acres. (See Table 4.5.b.) In Table 5.5, existing unpaved and planned stormwater management improvements are summed to achieve a total of 3.26 acres, or 64% of the entire space now available for stormwater runoff management. (See Table 5.C.) The dramatic expected improvement in runoff is due to application of many small changes scattered throughout the site.

Table 5.C - Converted area for infiltration, delay and attenuation			
		sq ft	**acres**
Entire	Total space of parcels to edge of street	222,147	5.10
Unpaved	Total of existing unpaved areas	29,349	0.67
Catchment/Cistern	Including artful implementations	36,311	0.83
Rain Gardens	(Not already 'unpaved')	671	0.02
Green Roof		4,111	0.09
Pervious Parking	Navigable by cars *and* pedestrians	64,312	1.48
Pervious Sidewalk	And mostly non-motor-vehicular access	7,156	0.16
Sum of Converted		141,912	3.26
Percent total area of unpaved and converted to infiltration delay or attenuation			**64%**

5.6 Artful Water Features fed by Proposed Cisterns

While it is one thing to show numerically that the site has been improved for stormwater management purposes, the main goal now is to show that these improvements can be implemented artfully. The following images and graphics intend to show a clear path of water from catchment to conveyance to storage and/or use. (For locations listed below, refer to Figure 5.4)

- **Location 1** - Building A - (Yoforia Yogurt Bar)

Taking a cue from the Lady Bird Johnson Wildflower Center, a metal aqueduct held on metal poles conveys water to a six-foot tall, four-foot wide metal cistern that includes a recirculating water feature in an attached stucco alcove. The water runs down a textured wall, making a small trickling noise. The alcove is lit at night during business hours when it is running. Water is released slowly from the feature into a narrow grate-topped runnel that abuts the public sidewalk, travels around the cistern and empties into the infiltration bed below the patio. The overflow from the infiltration could also be exposed using the grating method. The path from roof to infiltration bed to municipal storm drain should be interesting enough to get passers-by curious about the path of water. Figure 5.6 diagrams artful stormwater treatment below. Figure 5.7 is a simple interpretation of what could be done for this installation.

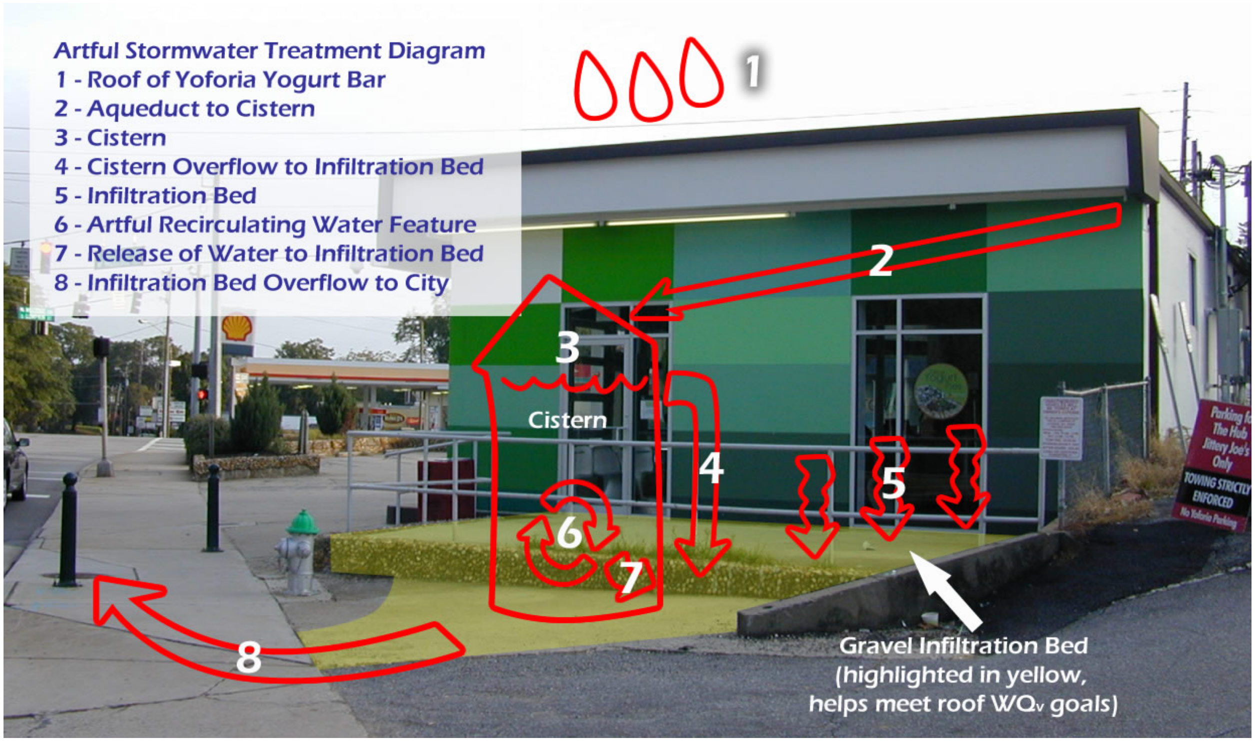

Figure 5.6 - Diagram of Yoforia Yogurt Bar stormwater treatment

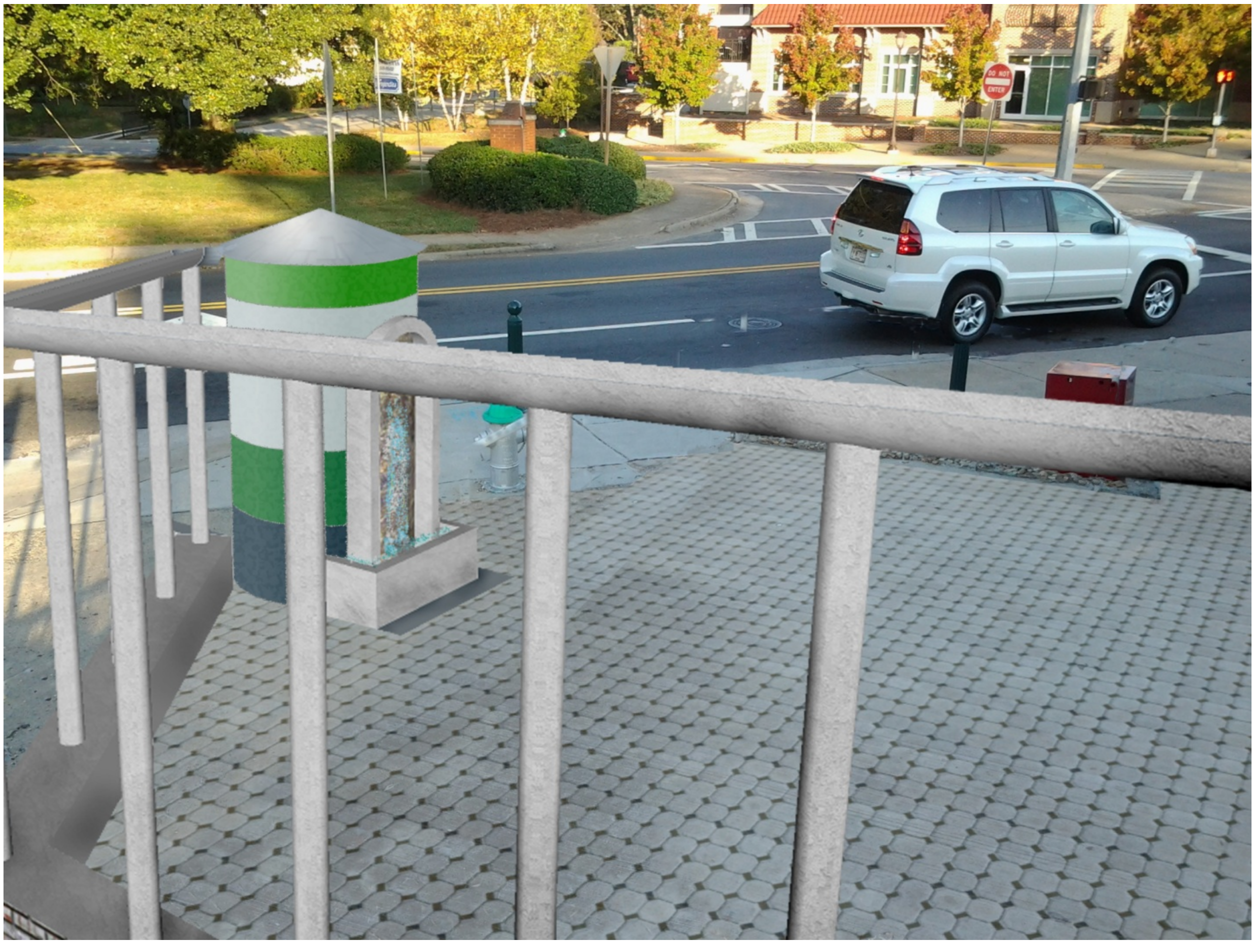

Figure 5.7 - Cistern at Yoforia, view of recirculating water feature

- **Location 2** - Building B - (Five & Ten)

Existing tanks should be consolidated to one larger metal tank, possibly painted to match the building colors. A planted geocell green wall should be planted with herbs and flowers, tilted at a slight angle to maximize sun. Additional herbs could be used by the restaurant. For color, edible flowers like pansies in winter and marigolds in summer could be introduced. Conveyance should be cleaned up so it is more distinctive. For this installation the pervious parking should have a base course depth of twelve inches. WQ_v volume = 1,197 gallons (roof) + 386 gallons (pervious parking) = 1,583 gallons. Available treatment volume in gallons: Pervious Parking (1,301 gallons) + Cistern (250 gallons) = 1,550 gallons. This comes close enough to the 1.2-inch WQ_v goal to be practical for this application. Figure 5.8 shows a diagram of treatment. Figure 5.9 shows a general suggestion of how it might look.

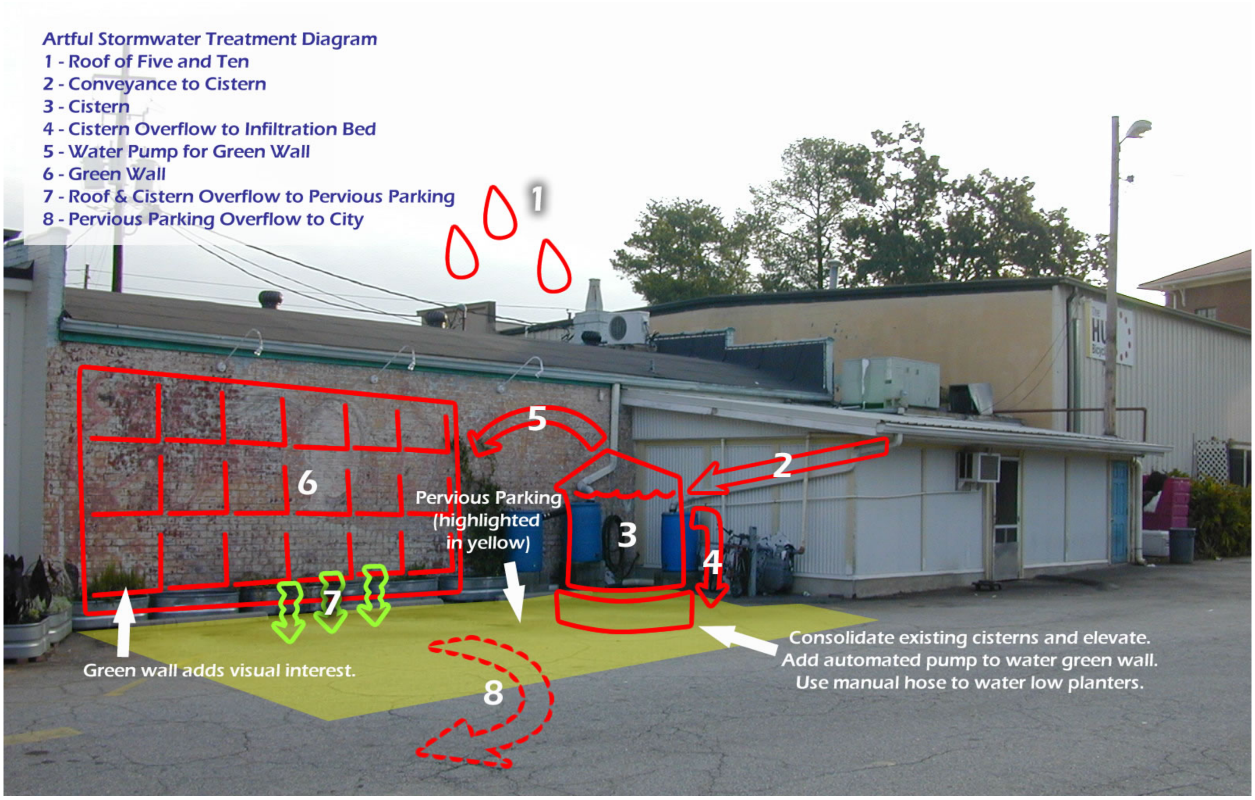

Figure 5.8 - Diagram of artful stormwater treatment for cistern and green wall next to Five & Ten

Figure 5.9 - Cistern and green wall next to Five & Ten

- **Location 3** - Building B - (Jittery Joe's/Hub Bicycle)

Air conditioners already exist on the ledge south of this building. There is plenty of additional space for a cistern of sufficient size to collect 1.2 inches of rain on this ledge. For the back half of the Hub Bicycle building catchment, a WQ_v of 1,968 gallons would satisfy the stormwater goal. A six-foot-wide, nine-foot-tall 2,100-gallon cistern could be elevated a couple feet from the slab to lend additional hydrostatic pressure for the water feature. A small flow-form water feature within the Jittery Joe's outdoor seating area could be enabled by the cistern's hydrostatic pressure alone. Water that has passed through this water feature could be returned back toward the cisterns and directed to the ginger bed and subsequently the pervious parking below the ledge. When the tank is empty, the water feature stops. The ginger could be interplanted with clumps of irises, rushes and inkberry hollies. The area includes multiple dumpsters and bins. Water feature installation and placement would have to consider traffic from Jittery Joe's staff, as they haul recycling and trash through the existing gate. This implementation would not necessarily show a clear path of water to the Jittery Joe's customers, but the use from the cisterns to the existing bed below the ledge would be clear. There is already coordination in this area between multiple businesses with regards to trash and recycling handling. The next step of coordination for use of water for various purposes could be established, making the path of water certainly clear to those who work in these neighboring buildings. Figure 5.10 shows a diagram depicting the treatment train for the water coming from this catchment. Water travels from roof to cistern to water feature to ginger bed to pervious parking and meets stormwater goals. Figure 5.11 depicts what a flowform might look like from the seating area of the outdoor cafe space next to Jittery Joe's. Figure 5.12 shows an example of how the cistern treatment might change to two cisterns of smaller size if the larger specified size were not readily available. Multiple shorter cisterns in series could also be raised higher to increase hydrostatic pressure.

Figure 5.10 - Artful stormwater treatment diagram for Jitter Joe's water feature

Figure 5.11 - Flowform waterfall at Jittery Joe's, powered by hydrostatic pressure

Figure 5.12 - Elevated cisterns behind Jittery Joe's for water feature in outdoor seating area

- **Location 4** - Building F - (Bottle Shop Extenstion)

The north catchments of the roofs on Building F have no gutters. Instead, they just pour onto the pavement. This water could be captured and conveyed via new gutters to a storage tank on the terrace east of Building F and used to water the existing vegetation. The WQ_v of 723 gallons could be contained by two 400-gallon cisterns. The cisterns need to be squat because the lowest gutter is not very far from the ground, and the terrace is already fairly high. Finding a commercially-available 800-gallon cistern below five feet tall is not easy, so multiple smaller cisterns in series might be a practical consideration. Water would be set to drain slowly through trickle hoses over a period of a couple days throughout the terrace vegetation. Cisterns could be painted bold colors. Again, this implementation should be obvious to anyone looking, but as for artfulness, it may not be a good example. Terrace vegetation should be weeded, trimmed and replanted as necessary to give the space a well-kept appearance. Large trees should be removed from the terrace so that their roots do not destroy the existing retaining wall of Hodgson Terrace. (See Figure 5.13.) Figure 5.14 is an example of how this area might look after a cistern system is installed.

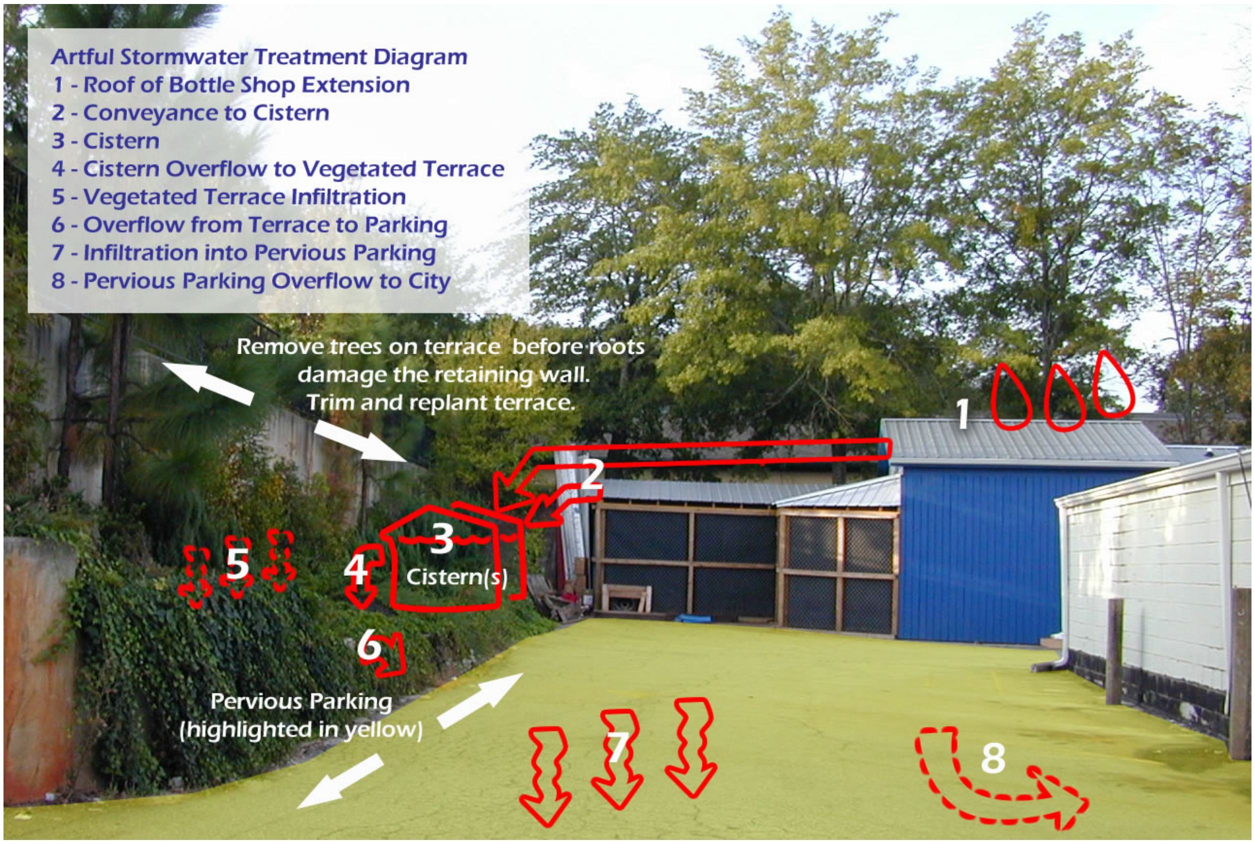

Figure 5.13 - Bottle Shop Extension stormwater treatment diagram

Figure 5.14 - Bottle Shop Extension rainwater stored by cisterns for use on terrace

● **Location 6 -** Building D **-** (Hodgeson Mixed-Use Building)

There is a thirty-foot diameter hemi-circle of cement below the stairs in front of this building adjacent to the public sidewalk that has absolutely no purpose. Nobody congregates there. It faces north east and is not easily accessible in terms of conveyance from Building D, nor is release to the municipal storm drains easily accessible. The two center-most downspouts on the northeast side of Building D convey water from Catchment D.i. (See Fiure 5.3.) These downspouts also take a third of the water from Catchment D.ii and its mirror equivalent catchment on the other side of D.i. Therefore, WQ_v will be Catchment D.i volume (2,180 gallons) + 2/3 of catchment D.ii volume (287 galllons) + catchment volume of the new reservoir (154 gallons) = 3,251 gallons. To fully contain this WQ_v, the reservoir would have to be 24 inches tall, giving us a reservoir treatment volume also of 3,251 gallons. However, this is not a comfortable seating height. Part of placemaking is the consideration for elements in the design that would cause people to want to stay. A comfortable adult seat height is eighteen inches, but that may be too comfortable — enough to encourage overnight "stays". It would also reduce the reservoir size to 2,438 gallons. A reservoir depth of 20 inches would create a relatively comfortable seating ledge for most adults, though feet would dangle. It would treat 2,709 of 3,272 gallons of the preferred WQ_v. Considering that this is still above Athens' true 85th percentile, the tradeoff seems reasonable. [106] Therefore, the reservoir would be 20 inches tall with a lip large enough to sit on or lean against comfortably.

The two downspouts could be set to pour into basins, similar to what was seen in the Cedar River Watershed Education Center. (See items marked "1" in Figure 15.5.) These basins would then pour into grated runnels across the stairs to an extended scupper that pours out from the center top of the landing above the stairs. A poured-in-place reservoir could be set in the hemiscircle below and faced with brick or stone. While water still sits in the reservoir, it could be pumped back up the slope to connect to existing vegetation drip lines. The cistern would be topped with a steel grill, just above the overflow level. Rounded river rocks would cover the grill, giving the scupper's contents a reasonable and striking landing surface. The water quickly finds its way below the rocks, keeping the top of the reservoir free of standing water, but releases water at the cistern base slowly via pumped infiltration and stormwater delay.

The water would then serve the needs of the plants on the slope and delay stormwater for most rainfall events for catchments facing the street. The density of this area makes it difficult to incorporate a more efficient stormwater treatment. While it might seem appropriate to create infiltration under the pavers in the walkway against the building facing Milledge Terrace, this area is actually the roof of the underground parking area. For this retrofit, it was deemed more appropriate to leave this walkway alone. Catchment has been treated to the most practical consideration for the density of this urban space. Figure 5.15 diagrams the artful stormwater treatment of this installation. Figures 5.16 and 5.17 are examples of how this sort of installation might look.

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[106] This is still technically above Athens' true 85th percentile rainfall event based on data from 2000 to 2011, 0.85 inches, which would yield a WQv of 2,303 gallons in this instance.

Figure 5.15 - Hodgson Terrace Location 6 stormwater treatment diagram

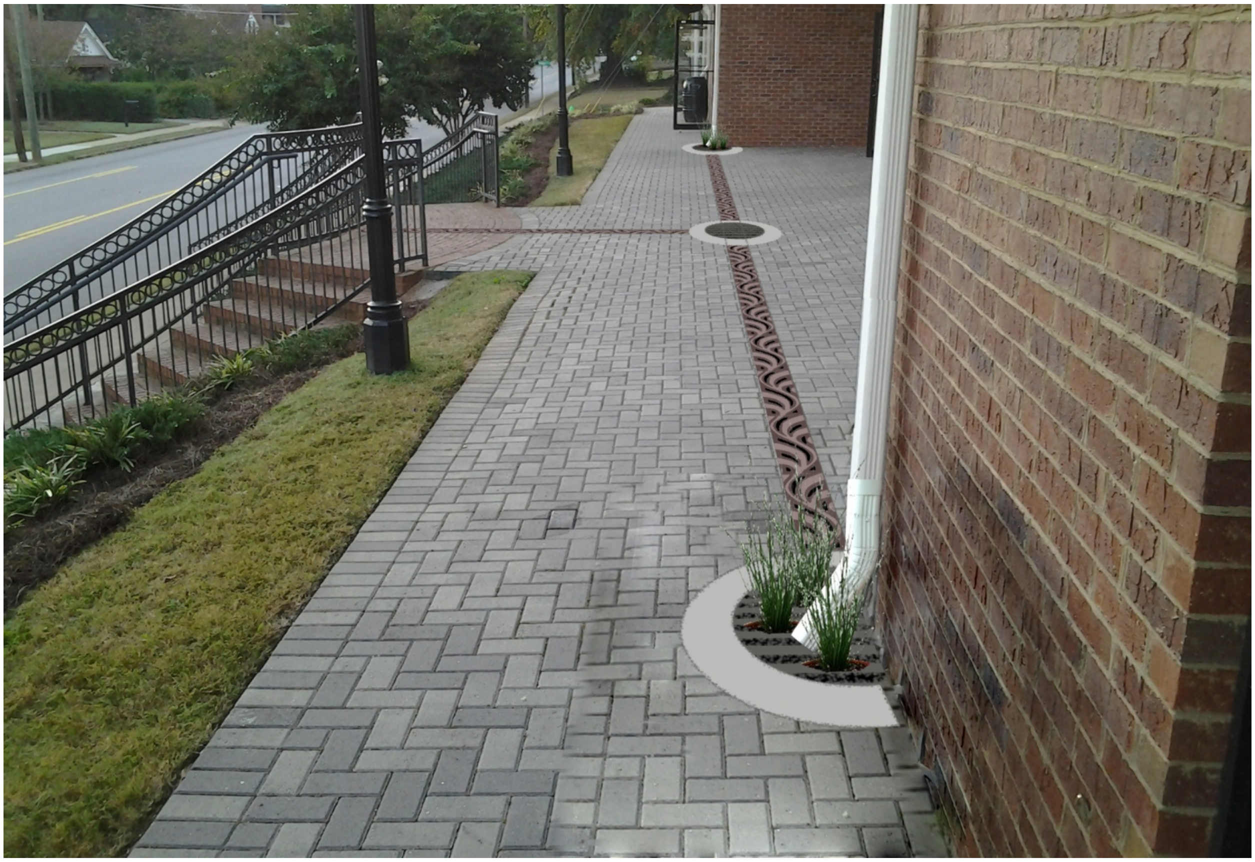

Figure 5.16 - Articulated drainage at front of Hodgson Terrace leading to hemicircular basin below

Figure 5.17 - Hemicircular basin with delayed drainage to street and drip irrigation to slope

- **Locations 5 and 7** - Building D - (Hodgson Terrace - Mixed-Use Building)

Catchment D.ii is representative of the catchment surface served by Locations 5 and 7. For a 1.2-inch WQ_v, each of four outermost rain barrels would have to capture about 145 gallons of rain water. Under these circumstances, fifty-five-gallon rain barrels are not well suited for the two downspouts that are there. Larger cisterns would be inappropriate because this is a mixed-use site with businesses on the ground floor. However, existing rain barrels could be adapted so that they have a delay drain connected to a drip tube that distributes water evenly to the grass or groundcover on the slope across the walk. Overflow would go through a runnel to the planted side of the walk. These barrels are best suited for mitigating a 1/4-inch rain event in Athens, rather than a 1.2-inch rain event, but any mitigation is better than none, and they are already part of the scene. This implementation merely makes them more useful than they are now.

Figure 5.18 - Drain-delay rain barrels with overflow and drip hose connection

- **Location 8** - The public alley - (between building E, the Royal Peasant and building G, the Five Points Yoga Center)

The east end of the alley is now blocked to all but pedestrian traffic. To serve a better purpose, the alley should be closed to all vehicular traffic. The existing sidewalk and road should be removed. Bollards should be placed at the front of the alley between Buildings E and G. The existing alley apron would be turned into standard curb. A permeable paver sidewalk should stretch from one side of the alley to the other. Several benches and picnic tables should be interspersed along the alley. A below-grade aquablock 1,600-gallon cistern is proposed for the space between these two buildings. Five catchment surfaces from buildings surrounding the alley would serve the cistern with a combined catchment area of about 2,218 square feet, yielding a WQ_v of 1,576 gallons. The cistern would feed a very shallow, uncovered recirculating rill that runs axially through the sidewalk center from the peak elevation of the sidewalk down to the cistern between the two buildings. The rill would be textured in such a way that water would make a trickling noise as it flows from the peak elevation back to the cistern. The value of 150 gallons per day release rate could be arbitrarily assigned, giving this installation 238 Available Water Days. A 1.2-inch rain event would yield about 11 Available Water Days. Some of the water could be used to drip-irrigate proposed seasonal flower beds. The overflow outlet would be expressed as a grated runnel [107] leading down the remaining distance to the proposed curb where it would finally meet the city stormwater drain. The treatment train for this installation would recirculate, delay and infiltrate as much as 1,600 gallons during a single 1.2- inch rain event. Figure 5.19 diagrams the stormwater treatment of this public alley. Figures 5.20 and 5.21 detail examples of what this kind of installation might look like.

[107] For the purpose of Location 8, the *rill* is defined as the open-faced channel leading from the peak elevation down to the cistern. The *runnel* is defined as the grated channel leading from the cistern to the sidewalk curb.

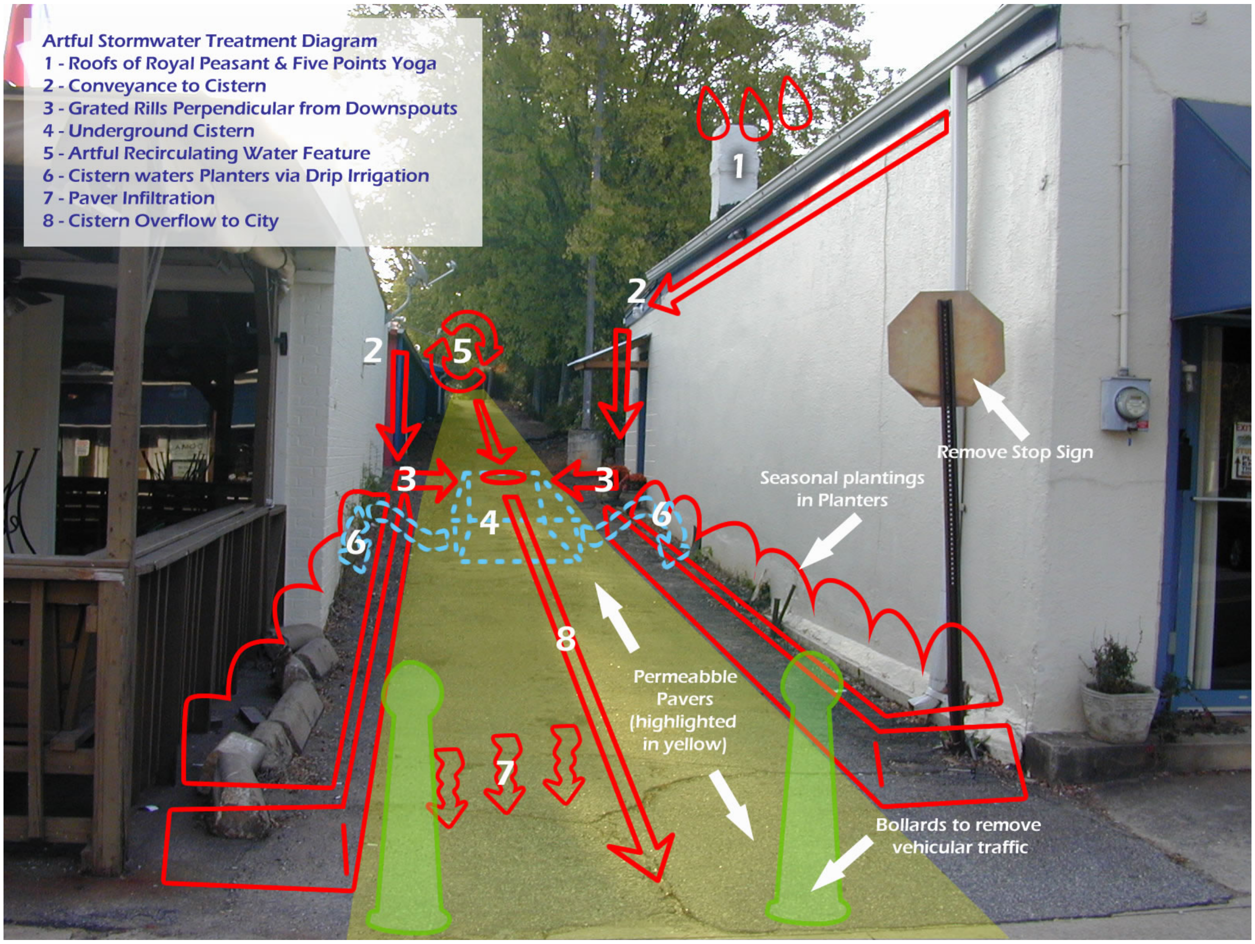

Figure 5.19 - Stormwater treatment diagram for the public alley

Figure 5.20 - Public alley rill, starting at peak elevation of path

Figure 5.21 - Public alley rill, runnel, bollards, overflow, aquablock and cistern cut-away view

- **Location 9** - Building H - (Earthfare/Add Drug)

The scupper at Location 9 is one of four scuppers for a catchment area of 3,488 square feet. One-fourth of the total WQ_v for this catchment would be 620 gallons, so a reasonably-sized reservoir would be a 650-gallon underground aquablock cistern. The scupper would be extended as a decorative fish head pouring water into a small water wheel kinetic sculpture during rain. The water would be funneled from there into a rain chain that leads to a 3-foot diameter flush-curbed grating either decoratively faced or covered with river rocks that sits directly above the cistern. The underdrain would tie first to existing pervious parking and subsequently through to municipal drainage. This is a kinetic sculpture and rain chain drawing attention to the path of water from the roof to the below-ground cistern. Figure 5.22 diagrams the stormwater treatment of this artful water feature. Figure 5.23 is an example of what the design might look like.

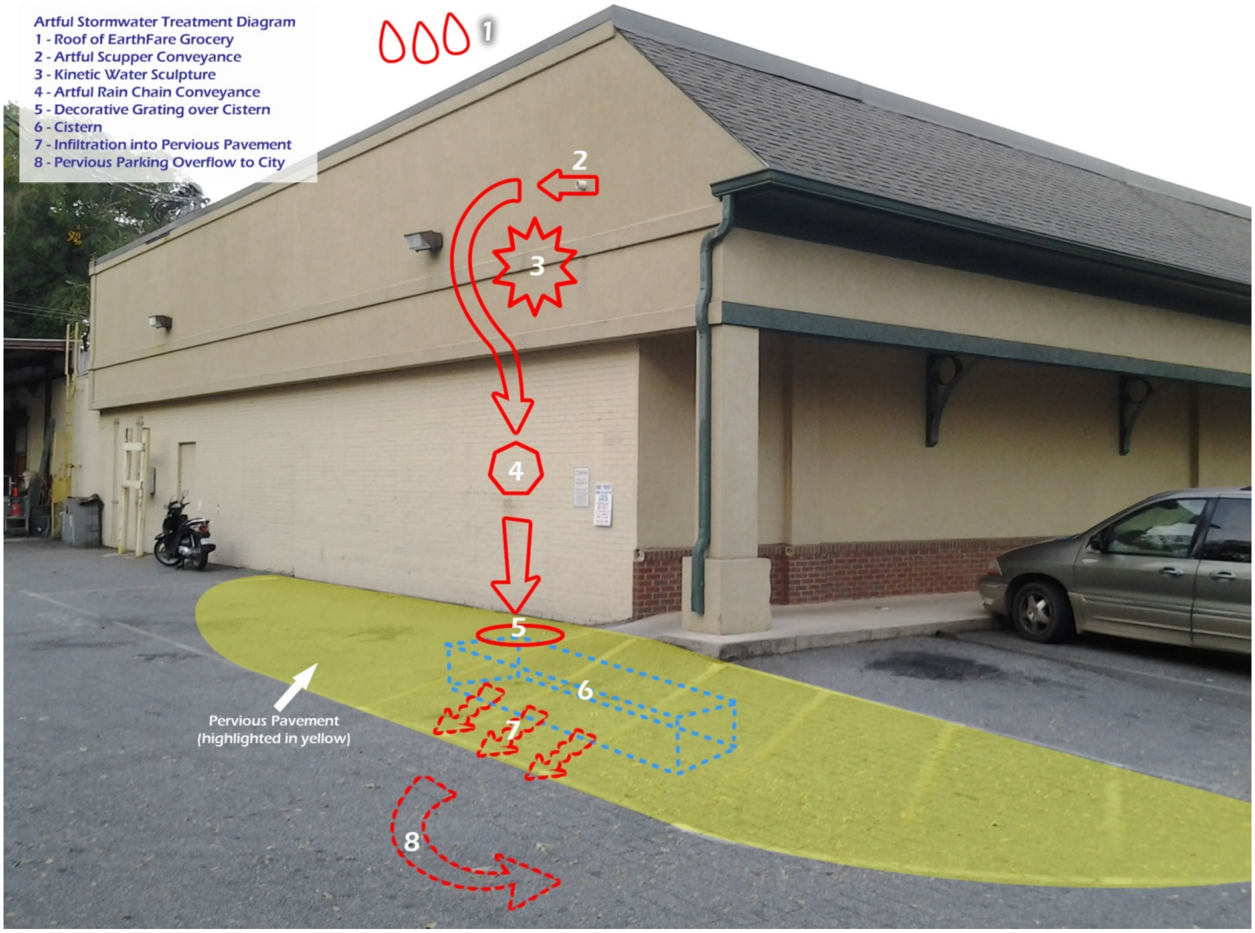

Figure 5.22 - Diagram of stormwater treatment for kinetic water sculpture at EarthFare

Figure 5.23 - Fanciful rain chain with kinetic water sculpture as part of cistern delay system

<u>5.7 Comments and Observations</u>

Street-side rain gardens were not possible with this site given the existing density of traffic and buildings. Sidewalks on the west side of our site (South Lumpkin Street) have no grass strips as they are. Sidewalks on the east side of the site (Milledge Avenue) have only narrow grass strips. These strips could be turned into areas for small street trees that take advantage of a structured soil environment spanning under the sidewalk in this area, but might decrease vehicular visibility.

That there are five municipal storm drains on Lumpkin between Earthfare (Building H) and the Five Points intersection is an indication of just how much runoff the streets handle from the surrounding community and this site in particular. The Five and Ten (south west corner of Building B) used to flood during restaurant hours on a regular basis before two additional storm drains were installed several years ago. In other words, our site is like a giant chess board slanted toward the west (Lumpkin Street.) Most of the water from these properties pours into these storm drains. There is only one storm drain east on Milledge Avenue. A water balance study showing how much water has been averted or delayed from the stormwater system by implementing artful urban rainwater harvesting techniques would be a good next thesis. However it is possible to sum the considered water quality volumes and compare with proposed water storage volume in pervious paved areas, green roof and cistern applications. Table 5.C shows the entire impervious gallons not treated as 137,002 gallons. The proposed changes to the site would add an additional 114,404 gallons of storage volume, which might alleviate as much as 84% of the previously untreated volume.

Table 5.D - Treatment Volume, Before and After					
		sq ft	**acres**	**WQ_v**	**$Storage_v$**
Entire	Total space of parcels	222147	5.10	*(gallons)*	*(gallons)*
Unpaved	Where runoff coefficient = 0.17 (grass slope)	29349	0.67	-	3,732.06
Impervious	Entire - Unpaved (Before Changes)	192798	4.43	137,002.11	-
Pervious	Parking and Sidewalk After Changes	71468	1.64	-	95,730.51
Green Roof	(Where runoff coefficient = 0.5)	4111.497	0.09	-	1,383.93
Other Roofs	(Where runoff coefficient = 0.95)	61178.46	1.40	-	2,288.07
Cisterns	Total Volume of Cisterns/Reservoirs	-	-	-	11,269.00
	114,403.57/137,002.11 = **84%**			**137,002.11**	**114,403.57**

As Echols and Pennypacker point out for 10th @ Hoyt, [108] it is difficult to articulate hidden amenities such as underground cisterns or gravel infiltration beds. That observation is affirmed in proposed examples for this site as well. Where education is a priority, signage could depict and explain the value of managing non-point source runoff at multiple levels, beginning with delay and infiltration as close to the point of precipitation as possible.

There is an element of worn shabbiness about these urban alleys, parking and downspout areas. This does not suggest abuse of amenities, but rather that there is very high vehicular and pedestrian traffic. Five Points is a popular place to be. Currently, no organization is framing the "cues to care" suggested by Jane Nassauer in her article *Messy Ecosystems, Orderly Frames.* [109] Business owners don't own the buildings, and building owners want to invest as little as possible in infrastructure, let alone art. Amenities like curbs, raised beds and water features need attention and management that business owners

[108] (Echols and Pennypacker 2006)
[109] (Nassauer 1995)

and visitors are not paid to maintain. Three excellent local organizations that might help mobilize and manage the look of this urban setting are Friends of Five Points, BikeAthens and USGBC-Georgia, Athens Branch. Business owners, building owners, neighbors and local organizations like the above can coordinate in a joint stakeholder effort. Given the popularity of Five Points with out-of-city visitors and the economy they bring, a special purpose local-option sales tax (SPLOST) might be voted upon for renovation and maintenance of the Five Points alley artful urban rainwater harvesting, picnic tables and other amenities for this site.

Different permeable paving materials and layouts vary in their degree of legibility with regards to articulating the path of rainwater in the landscape. Permeable pavers for this exercise were chosen for their distinctive patterns and for their obvious and visibly-open joints. To further distinguish from impermeable surfaces, concrete margins help define and highlight the areas of permeability and the infiltration they imply.

Chapter 6

CONCLUSION

6.1 Success in Artful Urban Rainwater Harvesting

The goal of this thesis has been to present examples and methods for achieving rainwater harvesting that not only attains the goal of stormwater runoff mitigation, but also does so in an artful way that articulates the path from catchment to conveyance to storage and use. In section 5.5, the numeric values show that adapting multiple small non-point runoff sources over multiple parcels can have a cumulative positive effect that dramatically reduces or delays stormwater runoff for the wider area. In section 5.6, artful examples are applied.

6.2 Lessons Learned from the Five Points Design

Three locations were identified for placement of cistern-driven artworks. These kinds of artworks benefit urban areas like Five Points by providing attractive places for people to congregate, developing a sense of place and civic identity, helping encourage tourism, fostering local businesses and displaying general good will to out-of-town visitors. Even better, they educate visitors about the path and expression of water in the urban landscape.

The density of this site limited the number of cistern-driven artworks for a few reasons. First, only a few conveyance-and-catchment combinations were large enough to supply a reasonable amount of water for a satisfactory display. Second, finding a place to put a cistern can be tricky in dense urban environments. Third, cisterns can exist where people may not ordinarily congregate, making the path of rainwater harvesting unclear, as is the case for the Jittery Joe's flowform water feature. There was one location at the back of Add Drugs/EarthFare parking lot that could have been a great place for a cistern water feature, but because nobody goes there except to exit the premises, its artfulness would have gone unappreciated.

There are many small catchments with dispersed conveyances in urban and suburban Athens with multiple distributed downspouts per catchment. If the 50th percentile rain event (0.2 inches in Athens) had been adopted as it had been in Portland, Oregon, a rain barrel would be appropriate for treatment. However, at the 85th percentile for Athens (0.85 inches) the WQ_v coming from most downspouts will always far exceed a fifty-five-gallon rain barrel. That said, any mitigation is better than none, and the appearance of at least trying to do so educates others about its importance in the urban landscape.

Rain barrels available on the market today are ugly, poorly designed and ill-constructed. The rain barrels currently at Hodgson Terrace have spigots halfway up the barrel, leaving at least half the water dead in the barrel at all times. There is no knowing if anyone actually uses the barrels for anything other than to promote a sense of ecological "greenness" to the community using the building. The barrels have no visible overflow and poor screening. With proper design and artful application, rain barrels could be as welcome and understood a sight as a park bench or a picnic table.

A drain-delay-enabled rain barrel can be as simple as drilling a single one-quarter-inch hole in the very bottom of a rain barrel. A *well-designed* drain-delay-enabled rain barrel might have an artful hydrostatic water feature built into its base that articulates its function in an obvious and fun manner. For instance, a spinning water wheel or a water jet could be powered by hydrostatic pressure in the barrel as the water exits out of the base of the barrel before it waters the surrounding vegetation. This type of barrel could serve its purpose without additional human intervention.

Street-side rain gardens that take advantage of curb cuts at the street could not work in the density of this urban site. The sidewalk is already too narrow to include a rain garden strip. Also, that there are four municipal stormwater drains on Lumpkin Street so close together suggests that water even from a less-than-average rainfall event might make most any small attempted rain garden inadequate. Rain gardens, swales, check dams and other well-known earthworks methods for stormwater management are rarely applied where concrete and asphalt already cover the majority of the landscape. It would be an excellent exercise to find out what could be accomplished with just a little less urban density.

The one method that accomplished the most in terms of stormwater management on this site was the use of permeable pavers, primarily because much of the impervious area was parking lot or sidewalk. Once again, within a less dense landscape, additional methods for stormwater management might have been able to include more cost-effective and ecologically efficient approaches involving less-processed materials, recycled materials, simple earthworks and copious plantings.

For sites with larger pervious parking areas, permeable pavers could be arranged in mosaic patterns or via a computer-generated template organizing the paver colors to show a face or a scene, furthering the mission of artfulness in the installation. For example a ripple pattern could mimic water when viewed from a distance or from some height. A scene of vegetables might work for a large grocery parking lot. The parking areas of this site seem a bit tight for this to work, but the possibility for further artfulness through mosaic patterns or computer-templated images exists.

6.3 Additional Considerations

Design elements used in urban amenties are often driven by economic factors. In other words, when cost exceeds short-term return on investment, the likelihood of artful construction drops. A formula for reliably indicating the likely increased worth of properties surrounding retrofitted or newly-installed artful urban amenities - including artful urban rainwater harvesting - could be useful for convincing local citizens and organizations of the worthiness of a project. Research to date suggests that property values increase within a multi-variable amalgamation of urban amenities, but that an economic forecasting formula for suggesting general value increase of properties does not yet seem to be available. Further, it may not be possible to extrapolate separately the worth of a single urban amenity outside the context of its correlative amenities (theatres, shops, parks, courtyards, public services, mass transit, etc.) This kind of study might make a great thesis for someone coming from the field of economics.

Neighborhoods change flavor as new people move in and out. It might be interesting to determine if amenities such as artful urban rainwater harvesting combined with other successful amenities actually play a part in reducing crime in urban situations.

Many urban water features that are well-received in Europe would likely, in the US, first have to pass muster with a series of lawyers that might quell designs that included parking lots, flights of stairs or courtyards with open rills or other "hazards" anywhere except at the very margins of a design. Articulated water features are still seen as a liability, where children and elderly alike might trip, fall or hurt themselves and blame it on the design. Improper consideration for the American Disabilities Act in any installed design may also fall under the category of litigious concerns.

Because parking lots and roofs make up the bulk of dense current urban surfaces - both pervious and impervious, the heat island effect caused by these surfaces is compounded by the fact that the bulk of these surfaces absorb too much sunlight. Broader adoption of legislation for high albedo pavement materials, roofing and other surfaces for all new and rebuilt structures could substantially reduce the heat island effect in any city, consequently reducing summer power drain caused by additional need for air conditioning.

Athens-Clarke County Unified Government charges a stormwater utility fee[110] dependent upon the amount of impervious surface on a parcel of land, including roofs and parking lot. Commercial lots are charged almost twice what residential owners pay per ERU of impervious surface. The monthly stormwater fee for EarthFare/Add Drug building and parking lot is $100.77 compared to a residential homeowner who pays around $3.50 per month. (See Table 6.A) According to athensclarkecounty.com, Monthly Stormwater Fee = (ERU x Base Rate) + (ERU x Quantity Rate) + (ERU x Quality Rate x ID Factor).

Table 6.A - Stormwater utility fee					
base rate	quantity rate	quality rate	id factor (commercial)	id factor (residential)	
2.07	0.86	0.56	1.9	1	
	sq ft	**ERU**	**Fee**		
EarthFare impervious	66,310	25.23	**$100.78**		
typical residential	2,626	1	**$3.49**		
EarthFare improved	26,600	10.12	**$40.43**		
1 ERU = 2,628 sq ft, the average homeowner impervious area per parcel					

Credits for increased permeability in parking and delay in catchment could seriously reduce the monthly stormwater utility fees for parcel owners in dense urban settings like Five Points.

110 (Athens-Clarke County Unified Government 2012) This is the URL for the stormwater utility fee calculation.

Artful urban rainwater harvesting can be achieved in dense urban settings. The proposed installations for this site include a number of artful examples that could spur interest in the general public with regards to appropriate and attractive stormwater management techniques. Sixty-four percent of the impervious area of this site has been turned into pervious surface for either infiltration or delay. Where possible, a treatment train of multiple control structures has been applied. When looking at preferred water quality volume for the impervious area prior to the proposed changes, (see Table 5.C,) and comparing it with the storage volume available after the proposed changes to the site, the proposed storage volume may treat as much as 84% of water quality volume of what was once mostly impervious surface.

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APPENDIX A

Table 7.A gives the Excel spreadsheet formulas used to derive columnar data based on inches of rainfall on specific dates. Table 7.B is 30 Year Averages for each city as provided by NOAA. [111] Tables 7.C through 7.F are examples of more data derived from these columns of data from Table 7.A.

Table 7.A - Key to recreating Active Art Days spreadsheet			
Column	**Column Name**	**Description**	**Calculation**
A	**Date**	12 years (4383 rows) of data.	
B	**PRCP**	Precipitation in millimeters*	
C	**Inches**	Precipitation in inches	(Column B * 0.00393701 inches/mm)
D	**Qharv**	Quantity of harvest	(rfcast*column C*rcoef*cf)
E	**Prior Storage**	Leftover storage from yesterday**	IF(AND(I(current_row)=1, freeze="Yes"),0,IF(D(current_row-1)+E(current_row-1)-F(current_row-1)>cap,cap,IF(D(current_row-1)+E(current_row-1)-F(current_row-1)<0,0,D(current_row-1)+E(current_row-1)-F(current_row-1))))
F	**Cistern Releas**	Amount released today by cistern	IF(AND(I(current_row)=1, freeze="Yes"),0,IF(E(current_row)>0,IF(D(current_row)+E(current_row)-r_rate>0,r_rate,D(current_row)+E(current_row)),0))
G	**Overflow**	The volume of cistern overflow	IF(AND(I(current_row)=1, freeze="Yes"),D(current_row),IF(D(current_row)-F(current_row)+E(current_row)>cap,D(current_row)-F(current_row)+E(current_row)-cap,0))
H	**TDR**	Total daily release	F(current_row)+G(current_row)
I	**Winter**		IF(OR(DATE(YEAR(A(current_row)), athens_lfm, athens_lfd) > A4395, DATE(YEAR(A(current_row)), athens_ffm, athens_ffd) < A(current_row)), 1, 0)
J	**AAD**		IF(OR(AND(I(current_row)=1, freeze="Yes"),E(current_row)<=F(current_row)),0,IF(D(current_row)+E(current_row)>c_portion,1,0))
Named variables			
	rcast	Roof Catchment Area	
	rcoef	Runoff Coefficient	
	cap	Cistern Capacity	
	r_rate_override	Override calculated release	If this value is filled it, it overrides "r_rate"
	freeze	Use Freeze Dates	"Yes" or "No"
	c_portion	Recirculation shutoff volume	
	r_rate	Rate of Cistern Release	IF(r_rate_override<>"",r_rate_override,VLOOKUP(cap,(two columns:ten rows),2)) (See Table 6.c, page 41)
	cf	Conversion factor (gallons/cf)	0.623333333
	prior	Storage at End of 1999 (gallons)	Assumed "0.0" for first row Prior Storage (1/1/2000)
	athens_lfm	Athens last frost month	03
	athens_lfd	Athens last frost day	28
	athens_ffm	Athens first frost month	11
	athens_ffd	Athens first frost day	07
* (NOAA 2012)			
** This is the only column that makes use of data from the previous row. Prior storage on 1/1/2000 is "0".			
As an example, F(current_row) might be "F3454". If this is the case in the calculation,			
F(current_row-1) would be "F3453" since prior storage is about previous day's storage.			

[111] (NOAA 2012)

Table 7.B - Monthly Rainfall Normals 2010				
	Athens	**Portland**	**Austin**	**Cedar Lake**
Jan	4.05	4.88	2.22	13.00
Feb	4.48	3.66	2.02	8.60
Mar	4.43	3.68	2.76	9.94
Apr	3.15	2.73	2.09	8.29
May	3.00	2.47	4.44	6.88
Jun	4.18	1.7	4.33	5.62
Jul	4.47	0.65	1.88	2.53
Aug	3.53	0.67	2.35	2.56
Sep	3.94	1.47	2.99	4.60
Oct	3.55	3	3.88	8.86
Nov	3.82	5.63	2.96	15.34
Dec	3.73	5.49	2.4	11.17
measurements in inches				
Source:	http://gis.ncdc.noaa.gov/map/cdo/			

Table 7.C - Monthly Rainfall Average 2000 - 2011				
	Athens	**Portland**	**Austin**	**Cedar Lake**
Jan	3.43	5.01	2.65	7.66
Feb	3.73	2.77	1.68	6.94
Mar	4.84	3.67	3.16	5.34
Apr	2.53	2.73	1.86	3.12
May	3.05	2.54	3.08	3.90
Jun	3.82	1.46	3.94	5.44
Jul	4.23	0.41	2.21	8.34
Aug	3.37	0.65	2.10	13.02
Sep	4.10	1.36	3.25	11.76
Oct	2.99	2.69	3.24	10.95
Nov	3.81	5.12	3.86	8.20
Dec	3.96	5.71	2.21	10.72
measurement in inches				
Derived from table 7.D below				

Table 7.D - Monthly total rainfall 2000 - 2011

Month	Athens	Portland	Austin	Cedar Lake
Jan-00	4.48	5.67	2.85	7.60
Feb-00	1.99	4.50	1.76	8.91
Mar-00	3.41	3.20	1.15	8.63
Apr-00	1.70	1.82	2.40	9.91
May-00	2.16	2.71	3.25	8.78
Jun-00	1.98	1.19	5.27	6.23
Jul-00	3.36	0.15	1.87	1.57
Aug-00	3.68	0.12	0.13	7.99
Sep-00	4.81	1.67	1.76	7.61
Oct-00	0.23	3.25	6.04	7.29
Nov-00	4.20	2.46	7.95	7.24
Dec-00	3.46	3.47	2.88	6.59
Jan-01	2.75	1.48	2.72	7.55
Feb-01	3.04	1.30	1.41	9.60
Mar-01	8.58	3.11	5.51	9.70
Apr-01	1.83	2.86	0.50	7.76
May-01	3.04	0.91	3.27	3.31
Jun-01	5.15	1.79	0.85	1.76
Jul-01	10.38	0.95	0.34	4.23
Aug-01	0.85	0.74	9.48	11.39
Sep-01	1.57	0.70	1.71	17.66
Oct-01	0.42	3.13	2.46	10.20
Nov-01	0.65	6.88	10.00	15.47
Dec-01	1.50	6.62	4.63	11.99
Jan-02	4.52	6.22	1.69	11.29
Feb-02	2.25	3.55	0.66	4.39
Mar-02	6.53	3.40	1.25	5.24
Apr-02	1.64	2.34	0.76	4.91
May-02	3.18	1.87	1.25	1.61
Jun-02	4.78	1.57	5.64	2.14
Jul-02	2.26	0.19	4.94	2.55
Aug-02	0.14	0.04	2.35	7.83
Sep-02	7.46	1.54	3.24	8.13
Oct-02	3.30	0.63	6.68	13.06
Nov-02	4.82	1.91	3.04	12.15
Dec-02	5.45	8.00	4.53	15.13
Jan-03	1.74	7.64	1.70	9.19
Feb-03	4.54	2.37	3.86	4.29
Mar-03	5.67	5.75	0.55	3.31
Apr-03	2.50	4.37	0.11	0.57
May-03	7.98	1.49	1.37	0.86
Jun-03	5.98	0.31	4.55	7.87
Jul-03	8.28	0.00	1.41	13.44
Aug-03	3.42	0.19	2.94	12.43
Sep-03	1.69	0.85	2.08	10.29
Oct-03	2.07	3.02	1.03	11.68
Nov-03	3.94	4.09	1.32	9.04
Dec-03	2.29	7.46	0.50	5.54
Jan-04	2.53	4.62	4.11	3.57
Feb-04	4.29	3.96	3.73	6.24
Mar-04	1.06	1.53	2.31	5.79
Apr-04	0.87	1.01	3.97	1.54
May-04	1.32	1.78	3.34	9.28
Jun-04	3.69	1.12	11.41	7.59
Jul-04	1.85	0.04	0.83	5.30
Aug-04	3.87	2.68	1.91	10.22
Sep-04	11.84	1.03	1.57	9.71
Oct-04	0.98	3.36	4.62	10.40
Nov-04	7.95	2.38	14.10	1.14
Dec-04	2.80	3.91	0.33	8.52
Jan-05	2.59	1.96	2.24	7.31
Feb-05	4.89	1.30	2.22	5.50
Mar-05	6.85	3.77	4.31	4.81
Apr-05	5.87	3.50	0.72	3.75
May-05	2.67	4.35	3.14	1.87
Jun-05	10.25	2.21	0.89	6.47
Jul-05	9.35	0.41	2.75	10.79
Aug-05	5.48	1.05	2.44	10.52
Sep-05	0.17	1.70	1.44	13.01
Oct-05	2.97	3.39	1.78	28.95
Nov-05	2.78	4.98	0.33	5.44
Dec-05	4.56	7.52	0.09	6.07
Jan-06	4.26	10.93	1.80	5.61
Feb-06	4.71	2.15	0.90	8.42
Mar-06	2.53	2.96	7.54	2.32
Apr-06	2.35	2.46	2.89	1.14
May-06	2.17	3.00	5.29	1.55

Table 7.D, continued

Month	Athens	Portland	Auston	Cedar Lake
Jun-06	1.93	0.92	3.18	5.78
Jul-06	3.67	0.47	0.48	8.76
Aug-06	5.76	0.10	0.22	28.54
Sep-06	2.22	0.87	3.00	18.46
Oct-06	3.52	1.39	3.93	4.18
Nov-06	3.18	11.93	1.29	12.93
Dec-06	3.91	5.86	4.20	15.85
Jan-07	3.48	2.72	6.92	5.22
Feb-07	2.92	3.47	0.14	4.48
Mar-07	3.89	3.21	5.94	5.03
Apr-07	1.64	2.02	2.24	1.78
May-07	1.56	1.45	7.01	2.26
Jun-07	2.17	1.09	5.41	8.22
Jul-07	3.48	0.56	9.83	7.52
Aug-07	1.72	0.46	2.50	12.03
Sep-07	0.53	2.05	3.97	10.12
Oct-07	2.35	3.26	1.13	12.43
Nov-07	2.35	4.25	1.16	10.92
Dec-07	5.42	7.57	0.67	10.87
Jan-08	2.61	4.71	0.83	7.80
Feb-08	3.56	2.19	0.51	6.82
Mar-08	3.48	3.71	2.87	7.03
Apr-08	3.00	2.08	3.52	1.81
May-08	2.24	2.03	1.70	7.38
Jun-08	1.22	1.00	0.74	3.22
Jul-08	3.95	0.30	0.38	7.57
Aug-08	2.79	1.23	2.39	16.32
Sep-08	2.13	0.48	0.02	16.68
Oct-08	5.13	1.74	2.01	9.25
Nov-08	2.63	4.15	0.72	6.47
Dec-08	3.66	3.52	0.41	13.78
Jan-09	2.70	4.50	0.74	7.67
Feb-09	3.67	1.36	1.47	4.13
Mar-09	7.05	3.36	3.04	2.82
Apr-09	4.47	2.31	2.84	0.32
May-09	3.58	3.27	1.77	4.48
Jun-09	1.67	1.31	1.35	2.69
Jul-09	1.33	0.34	0.25	14.98
Aug-09	2.70	0.76	0.77	14.67
Sep-09	9.86	1.41	6.87	9.50
Oct-09	9.14	3.04	6.87	6.76
Nov-09	5.17	5.14	2.80	5.92
Dec-09	8.87	3.76	2.61	10.76
Jan-10	6.20	4.95	3.29	8.65
Feb-10	4.21	2.76	3.07	12.46
Mar-10	2.33	3.59	3.32	5.03
Apr-10	1.87	2.93	2.13	0.64
May-10	5.89	4.69	1.88	4.38
Jun-10	4.55	4.28	5.93	6.82
Jul-10	1.40	0.59	3.38	13.94
Aug-10	7.62	0.24	0.00	11.16
Sep-10	5.35	3.36	13.20	14.50
Oct-10	1.42	3.88	0.08	15.08
Nov-10	4.91	6.64	0.68	8.76
Dec-10	1.92	8.35	0.79	18.60
Jan-11	3.32	4.73	2.92	10.50
Feb-11	4.72	4.29	0.48	8.07
Mar-11	6.64	6.44	0.09	4.40
Apr-11	2.62	5.04	0.27	3.35
May-11	0.82	2.93	3.65	1.06
Jun-11	2.44	0.73	2.01	6.52
Jul-11	1.46	0.96	0.05	9.41
Aug-11	2.44	0.17	0.00	13.18
Sep-11	1.56	0.61	0.18	5.45
Oct-11	4.36	2.14	2.19	2.19
Nov-11	3.08	6.57	2.92	2.92
Dec-11	3.68	2.51	4.93	4.93
Totals	**526.32**	**409.30**	**398.85**	**1,144.93**

measurements in inches

Source

Derived from daily rainfall spreadsheets

Table 7.E - Yearly rainfall 2000 - 2011				
	Athens	**Portland**	**Austin**	**Cedar Lake**
2000	35.45	30.24	37.30	88.34
2001	39.75	30.47	42.89	110.62
2002	46.33	31.27	36.04	88.43
2003	50.10	37.54	21.43	88.50
2004	43.05	27.69	52.28	79.30
2005	58.45	36.15	22.36	104.48
2006	40.22	43.04	34.72	113.52
2007	31.50	32.10	46.94	90.88
2008	36.40	27.14	16.09	104.15
2009	60.23	30.56	31.40	84.70
2010	47.69	46.24	37.76	120.02
2011	37.15	37.12	19.69	71.97
Totals	**526.32**	**409.55**	**398.89**	**1,144.93**
Averages	43.86	34.13	33.24	95.41
Max	60.23	46.24	52.28	120.02
Min	31.50	27.14	16.09	71.97
measurements in inches				
Source				
Derived from daily rainfall spreadsheets				

Table 7.F - Average rainfall in inches for days with rain, Athens, Georgia						
Days with rain in twelve years			1,276.00	days		
Total days in twelve years			4,383.00	days		
Total winterizable days in 12 years			1,683.00	days		
Total winterizable days per year			140.25	days/year		
Total non-winterizable days per year			225.00	days/year		
Average rainfall in inches for days with rain			0.41	inches		
Maximum rain fall in twelve years			6.22	inches		
Average days of rain per year			106.33	days/year		
		days/year			Consistency Check	
	total days	59.42	713	days >0, ≤.25	55.88%	55.88%
Total days with rain > .25	563.00	17.25	207	days > .25, ≤.5	16.22%	72.10%
Total days with rain > .5	356.00	17.08	205	days > .5, ≤1.0	16.07%	88.17%
Total days with rain > 1.0	151.00	9.92	119	days > 1.0, ≤2.0	9.33%	97.49%
Total days with rain > 2.0	32.00	1.50	18	days >2.0, ≤3.0	1.41%	98.90%
Total days with rain > 3.0	14.00	1.00	12	days > 3.0, ≤4.0	0.94%	99.84%
Total days with rain > 4.0	2.00	0.17	2	days > 4.0	0.16%	100.00%
Consistency check		**106.33**	**1,276.00**			