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Designing Water Conservation Landscapes Using Local Water Audit Data

Logan Oates
Utah State University

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DESIGNING WATER CONSERVATION LANDSCAPES
USING LOCAL WATER AUDIT DATA

by
Logan Oates

A report submitted in partial fulfillment of the requirements for the degree
of
MASTER OF LANDSCAPE ARCHITECTURE (PLAN B)

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UTAH STATE UNIVERSITY
Logan, Utah 2020
ABSTRACT

DESIGNING WATER CONSERVATION LANDSCAPES USING LOCAL WATER AUDIT DATA

By

Logan Oates, Master of Landscape Architecture Utah State University, 2020

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Department: Landscape Architecture and Environmental Planning

In 2016, Eagle Mountain City (EMC) entered into a collaborative agreement with Utah State University Extension to complete several water conservation projects. These projects include Water Checks, landscape water conservation publications, educational programs, and a water-wise landscape design for Eagle Mountain City Hall and a nearby roundabout.

The Water Check program is sponsored by Utah State University’s (USU) Center for Water Efficient Landscaping (CWEL) and offers residential water efficiency checks to EMC residents. Data collected from the Water Check program includes lot size, square feet (sf) of turfgrass, sprinkler types, sprinkler efficiency, and existing watering schedules.

This thesis examines the data collected in the water efficiency checks to assist in the design of the low water use demonstration garden at Eagle Mountain City Hall. Significant findings in the data collection that assisted in the EMC design include the percentage of turfgrass, head type sprinkler efficiency, and scheduling data. This
information was used in the EMC design to educate residents on water-wise landscaping pertinent to their locale.

The final product is an 18-page conceptual landscape plan for Eagle Mountain City Hall and the adjacent roundabout, as well as this written thesis, which explores the water audit data and discusses its application in the conceptual design. The conceptual design focuses on low water use plant design and efficient irrigation. A plant list handout was created and given to EMC for distribution at City Hall, which list consisted of an image of each plant, growth habits, hardiness zones, watering needs, and maintenance recommendations. This plant list is intended to be used by EMC residents to identify and select plants for their own homes.

(163 pages)
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Thank you to my parents for inspiring me and helping me along the way.

Logan Oates
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CHAPTER I

PROJECT NEED AND PURPOSE

On the west side of Utah Lake in Utah County, Utah (see Figure 1), Eagle Mountain City (EMC) sits 30 miles northwest from Provo and 40 miles southwest from Salt Lake City (Eagle Mountain City, 2020), acting as a bedroom community to both Salt Lake County and Utah County. It is the 3rd largest city in Utah according to landmass, totaling 50 square miles (Eagle Mountain City, 2020). The current population of EMC is approximately 40,000 as of 2020, growing from 250 in 1996 when it was first incorporated as a city (Eagle Mountain City, 2020). Current projections anticipate that the population will reach 120,000 by 2040 (Utah Governor’s Office of Management and Budget, 2012). The median age of EMC is 39.2, and the median household income is

Figure 1. Eagle Mountain Vicinity Map (Google, 2020)
$74,885. The median home price is $237,000, with an average of 4.2 persons per household. In EMC, 32.9% of the population holds a bachelor’s degree or higher (Eagle Mountain City, 2020).

Figure 2 illustrates EMC’s different communities. The Ranches (11) and City Center (17) are considered EMC’s two main communities due to their size, population, and amenities. Utah State University Extension has also installed weather stations at these two communities (Eagle Mountain City, 2020).

Figure 2. Eagle Mountain Communities (Real Estate Webmasters, 2020)
The Ranches is located toward the north side of EMC and includes The Ranches Golf Course, Porter’s Crossing Town Center, and 50 different neighborhoods (Wise Choice Real Estate, 2020). It is adjacent to Saratoga Springs, a city on the northern tip of Utah Lake. City Center is located to the south of The Ranches and west of Lake Mountain, at the heart of EMC. It currently includes 18 different neighborhoods and is the fastest growing region of EMC. City Hall is also centrally located within City Center.

City Center and The Ranches are different from each other in evapotranspiration (ET) and rainfall. Evapotranspiration (ET) is the amount of water that evaporates from the soil and plant leaves due to temperature, solar radiation, wind, and humidity (U.S. Geological Survey, n.d.). Reference evapotranspiration (ETo) refers to the evapotranspiration of turfgrass (Washington State University, 2016). In 2019, The Ranches accumulated 15.69 inches of rainfall, while City Center only received 13.92 inches. The Ranches ETo for the same year reached 38.28 inches, while City Center reached 45.23 inches (Eagle Mountain City, 2020). With 11% less rainfall and 18% more water demand, City Center requires more supplemental water than The Ranches and highlights the need for smart irrigation practices.

Situated outside the Wasatch Front watershed and separated from Utah Lake by Lake Mountain (see Figure 1), EMC cannot provide for its own culinary water. Instead, it relies on the Central Utah Project (CUP) for its water supply and has a contract with the Central Utah Water Conservancy District (CUWCD), headquartered in Orem, UT. Eagle Mountain City is at the end of CUWCD’s service line (see Figure 3).
With its rapid growth and lack of water, EMC is justifiably concerned about future water demand. The city desires to understand its own water needs and become a leader in water conservation throughout Utah (C. Pengra, personal communication, March 28, 2017). To achieve these goals, EMC partnered with Utah State University (USU) Extension in 2016 to complete several water conservation projects. These projects include Water Checks, landscape water conservation publications, educational programs, and a water-wise landscape design for Eagle Mountain City Hall and a nearby roundabout. The Water Check program offers EMC residents a free water audit. The product of the water audit is a customized irrigation schedule based on site-specific factors. The water audit checks sprinkler efficiencies, precipitation rates, soil type, and
root depth to formulate these schedules. Lot size, amount of lawn, hardscape, other-irrigated areas, and the existing watering schedule are also recorded in the audit.

This thesis seeks to understand the data collected through the Water Check program and use it to inform a low water use landscape design for Eagle Mountain City Hall and a nearby roundabout. The City Hall landscape is intended to educate residents about low water use landscaping. The roundabout is to serve as a template for other roundabouts and public spaces. The project is to be a model for other low water use landscape designs.

The final product is an 18-page conceptual landscape plan for Eagle Mountain City Hall and the roundabout (see Result A). The conceptual design focuses on low water use plant design and efficient irrigation. Another result of the project is an 8-page plant list handout to assist residents with plant identification (Wheaton, 2017). The handout contains an image of each plant used in the low water use landscape at City Hall and describes its growth habits, hardiness zones, watering needs, and maintenance recommendations (see Result B).
CHAPTER II

LITERATURE REVIEW

Chapter Two reviews the design and research methods of various conservation gardens and published theses to identify past methods of designing conservation gardens. These include the Jordan Valley Water Conservancy District’s (JVWCD) Conservation Garden Park in West Jordan, Utah, the Utah House at the Utah State University (USU) Botanical Center in Kaysville, Utah, and the thesis “Water-Wise Landscaping: A Guide on Residential Landscaping for Teton County, Idaho and the City of Driggs, Idaho,” written by Skyler Westergard and published by USU.

In 2000, the Jordan Valley Water Conservancy District (JVWCD) first came up with the idea to build Conservation Garden Park to educate residents regarding best practices for conserving water in their landscapes. District members visited San Diego’s Water Conservation Garden in El Cajon, California for both design inspiration and research. Landmark Design, a landscape architectural firm located in Salt Lake City, was contracted to design the first phases of the Conservation Garden Park. San Diego’s Water Conservation Garden served as the main source of inspiration for the design (S. Moser, personal communication, June 9, 2020). In fact, Deneen Powell Atelier, who designed portions of San Diego’s Water Conservation Gardens, was contracted to design future phases of JVWCD’s Conservation Garden Park (S. Moser, personal communication, June 9, 2020). These research and design methods proved to be successful. Conservation Garden Park has become one of the most visited and photographed conservation gardens.
in Utah. It continues to develop new programs and demonstration gardens that educate residents on water-wise practices.

This thesis also used conservation gardens to inspire the EMC landscape design. The conservation gardens used for this thesis include CUWCD’s Central Utah Gardens in Orem, Utah; Ashton Gardens Waterwise Garden at Thanksgiving Point in Lehi, Utah; JVWCD Conservation Garden Park in West Jordan, Utah; and the USU Botanical Center in Kaysville, Utah. Professional design firms were not used in the design process, but the thesis did recognize that the final drawings were conceptual. Eagle Mountain City was advised to seek professional services to develop final construction documents.

The Utah House at the USU Botanical Center began as a vision in 1996, growing into a grassroots movement run by volunteers. Initially, USU hosted a workshop where approximately 100 attendees shared thoughts regarding the best ways to construct both a demonstration house and a landscape focused on water conservation. Of the workshop attendees, over 50 volunteers formed groups to develop the project. These groups focused on marketing, landscape design, infrastructure, fundraising, and house design. An executive team was formed consisting of volunteers and USU personnel. These teams worked for a year to get the project off the ground (Utah State University Extension, 2017). This method also proved successful. The building methods used in the Utah House over two decades ago are still viewed as leading edge. Its well-maintained grounds attract many visitors and host weddings and other events throughout the year. Although this thesis did not rely on large numbers of volunteers to develop the EMC design, it did use
the collaboration of EMC council members, the mayor, and the thesis committee members.

In 2010, Skyler Westergard completed a thesis at Utah State University which involved the creation of a guide for water-wise landscaping for residents in Teton County, ID. The thesis cites books, Extension websites, and classes that teach the principles of water-wise landscaping (Westergard, 2010). The Utah State University Extension website and the University of Idaho Extension website were the two main sources used. The websites Xeriscape Colorado, High Country Gardens, and the Idaho Native Plant Society were other listed resources used for the water-wise guide (Westergard, 2010). This thesis also used Extension resources, websites, and literature to help with the EMC design. The Center for Water-Efficient Landscaping’s (CWEL) Water Check program was used for the water audit data, and the USU Botanical Center was used as inspiration for the design. Other websites such as Hunter Industries, the United States Departments of Agriculture, and the Saving Water Partnership were used to understand water-wise irrigation practices. The book *Combinations for Conservation*, published by the Center for Water-Efficient Landscaping (CWEL) at Utah State University, was used for the planting design.

These projects used existing conservation gardens, design professionals, collaborative workshops, books, classes, and websites as the primary drivers for design development. This thesis also uses existing demonstration gardens and literature as a precedent to guide the EMC design. The use of water audit data to drive the EMC design makes this thesis unique. The water audits were sponsored by CWEL and administered by Dr. Kelly Kopp,
USU PSC. Information regarding the audits, including the audit data itself, were provided by Dr. Kelly Kopp (K. Kopp, personal communication, June 12, 2020). One-hundred and twenty-two audits were provided that were conducted in EMC (Kopp, 2009). CHAPTER
III

METHODS

Defining the Project

Located at 1650 Stagecoach Run, Eagle Mountain City Hall is situated at the heart of City Center. Just northwest of City Hall, the roundabout is located at the intersection of Pony Express Parkway and Trail Head Road. Figure 4 shows the correlation of the two sites within the context of City Center (see Appendix A for existing site images).

Figure 4. City Hall and Roundabout Vicinity Map

Figure 5 shows an aerial view of City Hall and the roundabout prior to design, both of which have existing landscapes (see Appendix A for site images). The boundary of work for City Hall is indicated with a red dotted line and includes the entire landscaped area surrounding the building and the islands adjoining the parking lot. A four-foot park strip is included beyond the exterior curb of the parking area. The
roundabout totals 7,000 square feet (sf), while the City Hall landscape totals 23,000 sf, resulting in approximately 30,000 sf of landscaped area.

Figure 5. Aerial View of City Hall and Roundabout Prior to Design

The project scope and requirements were defined through meetings with EMC council members, Mayor Christopher Pengra, and USU team members. The expressed goal of the demonstration garden at City Hall was to educate residents about low water
use landscaping, while the roundabout aimed to serve as a template for future public spaces. The city stated that the main south entrance of City Hall was to act as the focus of the landscape design and conservation garden. Therefore, the main entrance would be installed first, and the remainder of the site would be completed in future phases (C. Pengra, personal communication, March 28, 2020).

Figure 6. Eagle Mountain City Hall Main Entrance

The entrance to the city office is located on the south side of the building (see Figure 5). This entrance area includes flag poles and a concrete patio gathering area (see Figure 6). The building's architecture is a Prairie style-influenced structure faced with
stone and stucco. Other entrances to the building include access to the library, public safety, and employee office space (see Figure 7).

Figure 7. City Hall Layout

Requested landscape elements for the main entrance included a gathering area with seating and standing space, walkways with benches throughout the conservation garden, and a dry creek serviced by greywater from the adjacent restroom sinks. The city asked that the remainder of the City Hall design include water-wise planting areas that matched the main entrance (C. Pengra, personal communication, March 28, 2020).

The roundabout was chosen because it welcomes visitors to City Hall after exiting Pony Express Parkway. Many roundabouts in EMC are landscaped only with traditional
turfgrass. However, the city requested that the City Hall roundabout landscape design include native trees, shrubs, and a berm for visual screening. This roundabout would serve as a template to be replicated in other roundabouts throughout the city (C. Pengra, personal communication, March 28, 2020).

To create a design that met EMC’s programmatic needs, research was conducted by studying various regional water conservation gardens, gathering water audit data provided by the Water Check program in EMC (Kopp, 2009), and studying the book *Combinations for Conservation* (Wheaton & Rupp, 2017). Regional conservation gardens were used to gather design inspiration and ideas to include in the EMC design. The water audit data guided the irrigation design and the amount of turfgrass used in the design. *Combinations for Conservation* was the primary resource used in selecting appropriate plant groupings for the planting plan. The following sections describe the findings and research associated with each of these sources.

**Review of Precedent Gardens**

Four conservation gardens were chosen as precedent sites. Private and public sites were chosen that were regionally located with objectives similar to EMC. The four gardens included the Central Utah Water Conservancy District’s (CUWCD) Central Utah Gardens in Orem, Utah; The Waterwise Garden at Thanksgiving Point’s Ashton Gardens in Lehi, Utah; the Jordan Valley Water Conservancy District’s (JVWCD) Conservation Garden Park in West Jordan, Utah; and the USU Botanical Center in Kaysville, Utah. Research conducted about each site included an investigation of website offerings, an in-person visit to the gardens, and photos taken on-site.
Central Utah Water Conservancy District’s Central Utah Gardens

Figure 8. Central Utah Gardens in Orem, UT (Central Utah Water Conservancy District, 2020)

Central Utah Gardens are operated by the CUWCD. The Central Utah Water Conservancy District was created in 1967 as the repayment agency to complete the Central Utah Project (CUP). The Central Utah Project was initiated to collect water from the Uinta Mountains and deliver it to the Wasatch Front in response to years of drought and increased water demands (Central Utah Water Conservancy District, 2020).

Figure 9 shows the CUWCD distribution area within Utah. As can be seen, its limits extend east to Vernal, southwest to Spanish Fork, and north into the Salt Lake Valley. Eagle Mountain City lies on the western edge of CUWCD’s distribution area. Within the service area, CUWCD operates dams, hydropower, pipelines, and treatment facilities (Central Utah Water Conservancy District, 2020).

The Central Utah Water Conservancy District offers classes, school curriculum, rebates, and conservation support to the community. A variety of classes are offered to adults, youth, and children and are held throughout the state. Examples of classes include Fall Gardening, Sprinkler Crash Course, Design Workshop, and Localscapes University.
 Rebates are available for water-efficient sprinkler components such as smart controllers and water-efficient nozzles. The district also provides complimentary residential water audits, similar to the Water Checks performed in EMC (Central Utah Water Conservancy District, 2020).

Figure 9. CUWCD Distribution Map (Central Utah Water Conservancy District, 2020)

Central Utah Gardens were located at 355 West University Parkway in Orem. (In 2019, CUWCD relocated, and the Central Utah Gardens are no longer accessible to the public (Pugmire, 2019)). The Central Utah Gardens offer visitors a chance to stroll through well-maintained gardens teeming with water-wise plants. The gardens also contain residential landscape demonstration gardens and interactive irrigation education (see Figure 10). These demonstration gardens highlight the proper layout & relative
amount of lawn, water-wise plant selection, and other low water use principles. Interactive buttons on the irrigation sign pop-up various sprinkler heads to teach proper sprinkler head layout.

Figure 10. Central Utah Garden Site Images

When compared with the other conservation gardens, Central Utah Gardens is relatively small, but it is well-maintained and designed. Successful elements of Central Utah Gardens that were considered in EMC’s design include interactive irrigation demonstrations, plant identification markers, gathering areas, pergola structures, and an amphitheater (see Figure 10) (see Appendix B for site images).
Waterwise Garden at Thanksgiving Point’s Ashton Gardens

Also located in Utah County, Thanksgiving Point is a non-profit farm, garden, and museum complex located at 3003 North Thanksgiving Way in Lehi, UT near the “point of the mountain.” Thanksgiving Point’s Ashton Gardens is the closest conservation garden to EMC.

Figure 11. Ashton Garden Map (Thanksgiving Point, 2020)

Ashton Gardens was designed by Leonard Grassli of MGB+A (MGB+A, n.d.) in 1997 and hosts 15 themed gardens on 50 acres (Thanksgiving Point, 2020). Gardens include The Grand Allee, Secret Garden, Italian Garden, Rose Garden, Light of the World Garden, Waterwise Garden, and Mountain Garden (see Figure 11). Ashton Gardens also hosts events and offers gardening classes, a retail greenhouse, a gift shop, and a café.

Ashton Gardens’ Waterwise Garden was the primary purpose of the visit, though each themed garden was visited. The Waterwise Garden was designed and built by USU Extension in 2016 (M. Caron, personal communication, June 6, 2020). A concrete staircase scales the hillside garden, while crushed stone walkways switch back and forth up the hillside (see Figure 12). The Waterwise Garden highlights low water use plants and plants that attract butterflies. Each plant species is specified with a plant marker (see Figure 12), and different styles of plant markers were used throughout the garden. There are periodic benches positioned along the crushed stone switchbacks to allow visitors to sit and rest. Much of the garden includes pine trees with a mulched undercover. The hillside feels very natural and provides the illusion of seclusion, as if one were hiking a mountain trail. Other garden features include a shade structure with seating, paver
walkways, steel edging, and a variety of water-wise flowering plants (see Appendix C for all site images).

Figure 12. Waterwise Garden Staircase Images

Compared with the other precedent gardens, Thanksgiving Point’s Waterwise Garden felt the most natural. Mulched beds with pine trees, crushed stone walkways with steel edging, wooden benches, plant markers, and plants that attract butterflies are some of the elements that were considered in the EMC design.

**Jordan Valley Water Conservancy District’s Conservation Garden Park**

Created in 1951 under the Water Conservancy Act (Jordan Valley Water Conservancy District, 2020), the Jordan Valley Water Conservancy District is one of
Utah’s largest water districts. It distributes water throughout the Salt Lake Valley and operates the Jordan Valley Water Treatment Plant, which is the largest conventional treatment plant in Utah (Jordan Valley Water Conservancy District, 2020).

Figure 13. Conservation Garden Park Map (Jordan Valley Water Conservancy District, 2017)

Located at 8275 South 1300 West in West Jordan, Utah, the Conservation Garden Park was conceptualized in 2000. It was built to educate homeowners regarding best practices for water conservation within the local landscape. As culinary water makes up 60% of the water used in the landscape, the district considers water conservation to be an additional cost-effective water supply (S. Moser, personal communication, June 9, 2020).
San Diego’s Water Conservation Garden inspired the original Conservation Garden Park design. Since that original design installation, other phases were added to the gardens. The gardens sit on 2.5 acres and see approximately 15,000 regular visitors each year. An additional 25,000 people visit for school tours, conferences, classes, and events (S. Moser, personal communication, June 9, 2020).

Conservation Garden Park is organized into themed pathways consisting of an irrigation path, maintenance path, design path, planting path, and example landscapes (see Figure 13). Each route includes both adult and child-friendly demonstrative and interactive learning stations related to each theme.

Of all the precedent sites, Conservation Garden Park included the largest variety of landscape design examples, irrigation education, and online resources. Drip irrigation education, sprinkler head design, alternative turf displays, scheduling information, soil characteristics, and installation guides were just some of the irrigation demonstrations found in the park (see Figure 14).

Conservation Garden Park highlighted a variety of landscape materials choices, plant arrangements, design elements, and design styles. Among others, paver styles, shade structure, mulch options, wall styles, and seating options were featured with side-by-side options (see Figure 14). The gardens also provided an excellent balance of shade, seating, and education, while the building offered plenty of interior space to cool off and learn (see Appendix D for site images). Conservation Garden Park elements considered in the EMC design include interactive irrigation elements, crushed gravel paths, seating areas, material comparisons, and plant markers.
The Conservation Garden Park’s website also contained valuable information used to assess water audit data and help in the EMC design, including ready-made landscape plans, videos, blogs, and a list of landscape professionals (Jordan Valley Water Conservancy District, 2017). One blog article addressing common landscape errors was
particularly helpful in comparing water audit data with recommended standards (Jordan Valley Water Conservancy District, 2017). The article emphasized preferred shapes for turfgrass areas, how to use hardscapes and gravel pathways effectively, and which drip irrigation components work best (Jordan Valley Water Conservancy District, 2017). According to the article, the turfgrass area should be a central open shape, which is easier to water for efficiency, and no turfgrass area should be narrower than 8’ wide. For low water use landscapes, turf areas should make up around 30% of the entire landscape. The remaining 70% should consist of planter beds, gravel pathways, permeable paver patios, and garden space. Also, drip components with low precipitation rates should be used in the planter beds (Jordan Valley Water Conservancy District, 2017). Another article highlighted reasons not to use weed barrier. According to the article, weed barrier is ineffective after a season or two, prohibits organic matter from entering the soil, and chokes plants as they grow (Lorenc, 2017). These tips were used in the water check data assessment and the final EMC design.

Figure 15. Correctly Shaped Turfgrass Area (Jordan Valley Water Conservancy District, 2017)
Utah State University Botanical Center

Figure 16. Botanical Center Location Map (Utah State University Extension, 2020)

Located adjacent to Interstate 15 in Kaysville at 725 Sego Lily Drive, the USU Botanical Center is comprised of a collection of gardens and research facilities that help to educate the public and further knowledge within the landscape profession (see Figure 16). Landscape classes, baby animal days, family nights, and farmer’s markets are some
of the events hosted at the Botanical Center (Utah State University Extension, 2020).

Some gardens of interest in the EMC design include the Urban Farm Demonstration Garden, the Rasmussen Teaching Garden, the Utah House, and the William A. Varga Arboretum (see Appendix E for site images). Other notable venues and gardens include the Wetland Discovery Point, Kaysville Ponds and Nature Trails, the Stokes Ornamental Grass & Iris Garden, and the Garden View Pavilion (Utah State University Extension, 2020).

Figure 17. Urban Farm Demonstration Garden (Utah State University Extension, 2020)

The Urban Farm Demonstration Garden was built in 2015 to display fruits and vegetables that grow well in Utah (Utah State University Extension, 2020). It highlights raised garden beds, traditional in-ground gardens, orchards, and berry gardens (see Figure 17). This garden also demonstrates water-wise irrigation methods.

The Rasmussen Teaching Garden features a plant design combining color, texture, and water conservation that served as an example for the EMC design (see Figure
The Teaching Garden is used for USU’s horticulture classes and includes paths, benches, and pergola shade structures (Utah State University Extension, 2020).

Figure 18. Rasmussen Teaching Garden (Utah State University Extension, 2020)

Starting in 1996, the Utah House was designed by collaborative volunteer groups to promote energy-efficient building techniques, sustainable landscaping, and best methods to maintain a healthy environment (Utah State University Extension, 2017). Its landscaping highlights an arbor structure built with reclaimed wood from the Great Salt Lake, and it also includes compost bins for gardening. Adaptive plants, which do not require fertilizers to thrive, are used as well (see Figure 19). Part of the turf is irrigated.
with sub-surface drip irrigation, and rainwater harvesting is utilized for supplemental water. Organic matter was added to the soil to enhance water retention, and garden boxes were built for wheelchair accessibility. Hydro-zoning, or grouping plants together with the same water requirement, was also used. Utah House elements that were considered in the EMC design were rainwater harvesting, plant hydro-zoning and wheelchair accessibility (Utah State University Extension, 2017).

*Combinations for Conservation*

Published in 2017 by CWEL, *Combinations for Conservation* assists in choosing planting combinations for the Intermountain West. Rather than focusing on individual plants, *Combinations for Conservation* focuses on groupings of plants that work best together. Chosen plant combinations not only work well together ecologically but also aesthetically and functionally. The purpose of each plant grouping is to offer combinations that are “functional, attractive, and desirable, yet are also water-wise” (Wheaton & Rupp, 2017). The book is organized into sections detailing lawns, perennials, ornamental grasses, shrubs and evergreens, deciduous trees, and park strips.
Combinations for Conservation outlines each plant’s flowering seasons, water requirements, hardiness zones, growth habits, planting recommendations, and maintenance requirements. Images of each planting combination, with closeups of individual plants, are included, making it easy to browse. With hundreds of plant combinations, the book offers a plethora of combinations of all plant types (see Figure 21). All the plants used for the EMC design were chosen from Combinations for Conservation. The plant list handout was also derived from the information found in Combinations for Conservation (Wheaton & Rupp, 2017).

Figure 21. Combinations for Conservation Sample Pages (Utah State University Extension, 2019)
Water Audit Data

Eagle Mountain City water audit data comes from the Center for Water Efficient Landscaping’s (CWEL) Water Check program (Kopp, 2009). The Center for Water Efficient Landscaping was created in 1999 to help promote water-efficient practices in Utah (Utah State University Extension, 2019). The Water Check program tests the efficiency of residents’ sprinkler systems and delivers a customized schedule based on the findings. The Water Check program is a free service available to counties throughout Utah (Utah State University Extension, 2020).

In total, 122 water audits were provided for EMC during 2009 and 2015. Site information and sprinkler data were collected for each audit. Recorded site information included the lot size, square feet (sf) of non-irrigated surfaces, sf of turfgrass, sf of other irrigated areas, soil type, and root depth. Gathered sprinkler data included head type, water pressure, distribution uniformity, precipitation rate, controller type, and the homeowners’ existing watering schedule. However, the data gathered varied year to year, and if sprinkler systems didn’t have enough pressure to operate correctly, they were not tested at all.

Auditors recorded the information on paper forms. The data from each paper form was entered into an Excel database to be assessed. Personal information was not collected. The following sections discuss the findings of each category as they pertain to the EMC design.
Lot Data

Water auditors used a measuring wheel to assess the total lot size and various subtotals of non-irrigated areas, turfgrass areas, and other irrigated areas (K. Kopp, personal communication, June 12, 2020). Non-irrigated areas included the building footprint, driveways, sidewalks, and other paved pathways. Other irrigated areas consisted of planter beds and garden areas. Plant types were not recorded.

Of the 122 audits, lot size averaged 13,037 sf, or .3 acres. Non-irrigated areas averaged 5,591 sf per lot. The average turfgrass area totaled 5,099 sf, and other irrigated areas averaged 1,122 sf. Figure 22 illustrates the percentage of lot distribution for each category.

Figure 22. Average Lot Distribution
Figure 23 shows the distribution of irrigated areas between turfgrass and other irrigated areas. Turfgrass area accounted for 82% of the total landscaped area. However, the Jordan Valley Water Conservancy District recommends not only that turfgrass area make up just 20% to 35% of the total landscaped area, but that those turfgrass areas be a central open shape larger than 8’ wide (Jordan Valley Water Conservancy District, 2017). Considerations were made to follow the recommended levels of turfgrass area for the EMC design.

Figure 23. Distribution of Irrigated Areas

**Soil Type**

Auditors determined soil type by rubbing soil samples between their fingers. Sandy soils feel grittier, while clay soils tend to feel smoother. Although this method
seems somewhat subjective, a trained auditor can obtain accurate estimates thereby. Of the 122 tested sites, 14% of soils were classified as clay, 10% loam, 62% clay loam, and 14% sandy loam (see Figure 24). Soil samples were also taken at Eagle Mountain City Hall and tested at USU’s more in-depth soil testing facilities. The soil collected at City Hall was classified as clay loam (see Appendix F).

Figure 24. Soil Type Percentages

Determining soil type is important because soil types have different infiltration rates. The USDA defines infiltration rate as the speed at which water enters the soil (United States Department of Agriculture, 2008). Clay and loam soils have lower infiltration rates than sandy soils (see Figure 25). Organic matter can be added to soil to
increase its infiltration rate, as was done at the Utah House (Utah State University Extension, 2017).

When water is applied faster than it can enter the soil, it runs off. The Jordan Valley Water Conservancy District recommends using in-line or point-source drip irrigation with low application rates for planter beds, so that the soil has sufficient time to absorb the applied water (Jordan Valley Water Conservancy District, 2017). In-line drip irrigation uses drip tube with built-in emitters spaced out every 12 to 18 inches, while point-source drip irrigation uses an emitter installed at the base of each plant. Low flow emitters range from .5 to 2 gallons per minute. Since Eagle Mountain City Hall is comprised of clay loam soils, it was important to include drip irrigation and sprinkler nozzles with low application rates in the EMC design. The following section discusses the application rate of each head type tested in the audits.

Figure 25. Soil Infiltration Rates (United States Department of Agriculture, 2008)

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Steady Infiltration Rate (in/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>&gt; 0.8</td>
</tr>
<tr>
<td>Loams</td>
<td>0.2 - 0.4</td>
</tr>
<tr>
<td>Clays</td>
<td>0.04 - 0.2</td>
</tr>
</tbody>
</table>

Precipitation Rate

Hunter Industries defines precipitation rate (PR) as how fast water from a sprinkler system is applied to an area (Hunter Industries Incorporated, 1997).
Precipitation rates are measured in inches per hour (in/hr). As part of the water audit, auditors measured PR by distributing catch cans throughout the test area and running each sprinkler zone for several minutes. They would then measure the volume of water in each can (see Figure 26). The formula for calculating PR is shown below (City of Bozeman, n.d.).

Precipitation Rate Formula for Catch Can Tests

\[
\text{Precipitation Rate (in/hr)} = \frac{3.66 \times \text{average catch can volume (mL)}}{\text{Run time} \times 16}
\]

Figure 26. CWEL Catch Can Test (Utah State University Extension, 2020)

Water check auditors conducted one catch can test for each head type, if possible. A maximum of 3 catch can tests were performed at each location. Auditors only performed the test for grass areas—no information was recorded for the remaining zones. Head types were recorded as sprays, rotors, or a mixture of sprays and rotors. Spray heads distribute water in a fan shape, while rotors shoot water in a single rotating stream.
Sprays are typically designed for smaller areas with a higher PR, while rotors are designed for larger areas with a lower PR.

Figure 27. Spray and Rotor Head Comparison (Lowe’s, 2020) (Amazon, 2020)

For all audited zones, spray zones averaged a PR of 1.66 in/hr. Rotor zones averaged a PR of .75 in/hr, and mixed zones averaged 1.08 in/hr (see Figure 28). With a PR 55% lower than sprays, rotors were determined more suitable for EMC soils where possible. However, while rotors have a lower PR than sprays, they still apply water faster.

Figure 28. Average Precipitation Rate by Head Type
than clay loam soils can absorb (see Figure 25 and Figure 28). The scheduling section will discuss smart irrigation practices to abate this potential problem.

**Distribution Uniformity**

Distribution uniformity (DU) relates to how evenly water is distributed by sprinklers within an irrigation zone. In an ideal world, a sprinkler system that distributes water evenly over a designated area would have a DU of 1. In reality, an average sprinkler system has a DU between .55 and .75 (City of Bozeman, n.d.). Auditors calculated DU using the results from the catch can test—after recording the average volume of the lowest quarter of catch cans (Vlq), auditors divided this number by the average volume of all the catch cans combined (Vavg) (City of Bozeman, n.d.). This formula is illustrated below.

**Formula to Calculate DU**

\[
\text{Distribution Uniformity} = \frac{V_{lq}}{V_{avg}}
\]

**Figure 29. Average DU by Head Type**
Following these calculations, the average DU for spray zones came to .47, while the average DU for rotor zones was .58. The average DU for mixed zones was .51 (see Figure 29). These numbers show that rotor zones distributed water 23% more uniformly than spray zones, and reiterates the importance of designing an open turfgrass area irrigated with rotors for the EMC design.

**Scheduling**

Water auditors recorded homeowners' existing watering schedules for 2009 and 2010 only. They included the number of watering days per week, the number of cycles per day, and the total run time in minutes per week for each head type (sprays or rotors). Start times were not recorded, and only 23 audits with complete data were accomplished during these years.

Of these audits, spray zones ran for an average of 135 minutes, while rotor zones ran for 173 minutes. Calculating how many inches of water used by each head type is achieved by converting the total minutes into hours and multiplying by the corresponding PR (in/hr). This is achieved by dividing the total number of minutes per week by 60 and multiplying the average precipitation rate of each head type. The corresponding formula is shown below.

**Inches Water Used Each Week**

\[
\text{Min per Week} / 60 \times \text{Precipitation Rate (in/hr)} = \text{Inches per Week}
\]

- Sprays = \(135 / 60 \times 1.66 = 3.7\text{ in}\)
- Rotors = \(173 / 60 \times .75 = 2.2\text{ in}\)
These results show that homeowners used 40% less water when using rotor heads as compared with spray heads (see Figure 30). The fact that rotors have a lower PR and higher DU may contribute to this significant difference.

Figure 30. Average Inches of Water Used per Week by Head Type

![Average Inches of Water Used / Week by Head Type](image)

The City Center weather station in EMC measured an average ETo of 1.38 inches per week during the 2018 and 2019 irrigation seasons (April 15 – October 15), which are the only years that the weather station has been active (Eagle Mountain City, 2020). This means that the turfgrass needed an average of 1.38 inches of water per week to remain healthy, not considering rainfall. Figure 31 illustrates how much each head type used compared to ETo. This shows that spray zones used on average 2.7 times more water than what the turfgrass needed, while rotor zones used 1.6 times more water than needed.

Irrigation efficiency (IE) refers to the ratio between how much water a plant needs compared to how much is applied by a sprinkler system (Machibya et al., 2004). It is
measured by dividing the turfgrass water requirement (ETo) by the amount applied by the sprinkler system, as seen below.

Irrigation Efficiency Formula

Irrigation Efficiency (IE) = Turfgrass Eto / Applied Water

Sprays IE = \frac{1.45}{3.7} = 39\%

Rotors IE = \frac{1.45}{2.2} = 66\%

Figure 31. Weekly Water Use Compared to ETo

This calculation shows that spray zones had an average IE of 39% while rotor zones had an IE of 66%. Note that tall fescue is used to calculate ETo (Regents of the University of California, 2020). Turfgrass variety was not recorded during any of the EMC water audits.
Water auditors also recorded the number of days per week homeowners ran each zone. While the Jordan Valley Water Conservancy District recommends watering turfgrass in clay soils just 2 to 3 times per week during the summer (Jordan Valley Water Conservancy District, 2020) (see Figure 32), EMC homeowners watered their turfgrass 4 times per week on average with spray zones and 3.25 times per week with rotor zones. The Saving Water Partnership teaches that deep and infrequent watering promotes deep roots, which require less watering (Saving Water Partnership, n.d.). It may be because of rotors’ lower PR that EMC residents were able to water less frequently with rotor zones compared to spray zones.

Figure 32. JVWCD Watering Guide (Jordan Valley Water Conservancy District, 2020)
The Jordan Valley Water Conservancy District also recommends using the cycle and soak method, which splits up run times and watering at intervals throughout the night, thereby allowing water to soak into the soil between cycles. The water audit data revealed that only 1/3 of EMC residents use the cycle soak method.

Utah Water Savers, a statewide rebate program, teaches that using a smart controller can save water by automatically adjusting watering schedules based on weather conditions (Utah Water Savers, 2020). Some smart controllers use on-site weather instruments to collect data, while others rely on off-site sources. Water auditors recorded which sprinkler controller homeowners used, though this information did not always reveal whether the controller possessed smart watering capabilities. Since EMC is comprised of various microclimates that vary significantly, as previously discussed, recommending a smart controller would be an important part of the EMC design.

Design Process

The design process consisted of a site analysis phase, a conceptual design phase, and a conceptual construction documentation phase. The process resulted in the final conceptual plan set and plant list for EMC (Wheaton, 2017).

Site analysis was dedicated to research of the site and understanding the design requirements. It included client consultations, site measurements, a soil analysis, and creation of the base map. Throughout this phase, the thesis committee and I met with EMC representatives to better understand their vision for the low water use demonstration garden. The following bullet points list the major elements requested by the city.
• A gathering area for groups of 10-20 people with possible seating in front of the south entrance.

• A demonstration garden with low water use plants circling the south entrance.

• Gravel walkways through the demonstration garden.

• Benches along gravel walkways.

• Greywater-harvesting dry creek connected to the indoor restroom sinks adjacent to the south entrance.

• Employee seating east of the building.

• Similar low water use plants in park strips and parking islands.

The city provided site drawings of the building for the base map (see Appendix G); however, I came to realize that the drawings were inaccurate, so I took independent site measurements and adjusted the base map accordingly. I also gathered soil samples throughout the site to test at the Utah State University Analytical Laboratories (see Appendix F). It was during this phase that I researched and visited the precedent conservation gardens.

The goal of the conceptual design phase was to establish the main layout of the design before moving on to the construction document details. I drafted several design alternatives, which were reviewed by the thesis committee. After a series of revisions, two design concepts were presented to the city (see Appendix H and Appendix I). Concept 1 maintained the existing flagpole location and provided a shaded gathering area east of the entrance (see Figure 33). Concept 2 created one large gathering area centered
at the entrance and moved the flagpoles to the east. This modification provided more room for a demonstration garden and walking paths (see Figure 34). Both concepts included the greywater dry creek, open turfgrass areas, and seating throughout. I presented the design concepts at Eagle Mountain City Hall in person. City representatives chose to move forward with Concept 2.
Figure 34. Concept Option 2
The conceptual construction document stage consisted of developing the layout plan, planting plan, and irrigation plan, as follows.

**Layout Plans**

The layout plan shows the conceptual design excluding plants and irrigation. Rather, it illustrates the layout of the planter beds, turfgrass area, pathways, benches, edging, and other landscape elements (see Figure 35). It specifies which type of mulch to use, which gravel to use for pathways, and which existing trees to protect.

A balance of 30% turfgrass was maintained for the main demonstration garden per JVWCD’s recommendations. The remaining 70% of landscaped area consists of planter beds, gravel pathways, and seating areas. Steel edging was chosen, thereby replicating the clean edging of the USU Waterwise Garden at Thanksgiving Point. Wasatch Chat, a local crushed gravel observed in several of the precedent conservation gardens, was chosen for the walkways. A mixture of bark mulched areas and rock mulched areas were specified to provide variety and offer a visual comparison. Weed barrier was specified not to be used, consistent with JVWCD’s recommendations. Stone seating walls were recommended to match the existing building façade. The center of the gathering area was designed with a focal art piece, while the existing flagpoles were to be moved to the east. A concept of the greywater dry creek was included as well. The roundabout was shown with a cross-section of the berm (see Results A).
Planting Plan

The book *Combinations for Conservation* guided the planting plan. Through several collaborative revisions with the committee, a planting plan was created that highlighted native and adaptive plant combinations (see Figure 37). These combinations focused on creating an aesthetic mixture of color and texture, similar to that found at the Rasmussen Teaching Garden at the USU Botanical Center. Hydro-zoning as utilized at the Utah House, was used by choosing plants with similar water requirements for each area. Plants that attract butterflies, similar to those found in the Waterwise Garden at Thanksgiving point, were included as well. Tall fescue and western wheatgrass were chosen as an alternative to Kentucky bluegrass for the turfgrass areas. Once the planting plan was complete, the plant list handout was created (Wheaton, 2017) (see Results B).
Irrigation Plan

The water audit data guided the irrigation design (see Figure 38). Per JVWCD’s recommendations, turfgrass areas were designed to be central open areas large enough to accommodate the efficient use of rotor heads. Also per JVWCD’s recommendations, point-source drip irrigation was specified for the shrub and tree areas. Turfgrass was not specified within the park strip, as strips were less than 8 feet wide and wouldn’t provide for efficient irrigation or maintenance (Jordan Valley Water Conservancy District, 2017). Educational irrigation elements were suggested to the city but were not approved. A smart controller that can connect to EMC local weather stations and automatically adjust watering times, including appropriate cycle soak, was specified.
CHAPTER IV

RESULTS

Final Product

The completed conceptual design set was an 18-sheet document including a cover sheet, three layout sheets, twelve planting sheets, and two irrigation sheets. The document was printed on 24” by 36” sheets. The plan set document and plant list handout were provided to the city (Wheaton, 2017) (see Result A and Result B). These plan sets are conceptual in nature and were not produced by a professional design firm. Eagle Mountain City was advised to seek professional services to develop final construction documents.
A. Conceptual Plan Set
EAGLE MOUNTAIN CITY HALL
CONCEPTUAL PLANS FOR LOW WATER USE LANDSCAPE IMPROVEMENTS

1. Plans are provided on a conceptual design only. A licensed contractor should be hired to convert the design into a construction document before work can begin.

2. The design is the responsibility of the designer and is not the responsibility of the City. The designer must comply with City regulations.

3. The design is not responsible for any objections to plans, plant material, or further design work. The design is to be reviewed by the City, and the designer must make changes as necessary.

4. All necessary permitting will be the responsibility of the acting contractor.

5. All installation and maintenance is the responsibility of the city and it contractor.
B. Plant Handout
### Eagle Mountain Demonstration Garden Plant List

#### SHRUBS

<table>
<thead>
<tr>
<th>Shrubs</th>
<th>Height x Width</th>
<th>Sun</th>
<th>USDA Zone</th>
<th>Water Zone</th>
<th>Wildlife Value</th>
<th>Salt Tolerance</th>
<th>Deer Resistant</th>
<th>Foliage Value</th>
<th>Firewise Value</th>
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<td>Powis Castle Artemisia</td>
<td>30&quot; x 30&quot;</td>
<td>Full</td>
<td>4-9</td>
<td>Low</td>
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<tr>
<td><em>Artemisia x &quot;Powis Castle&quot;</em></td>
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<tr>
<td>Blue Mist Spirea</td>
<td>2-4&quot; x 2-4&quot;</td>
<td>Full</td>
<td>5-9</td>
<td>Low</td>
<td>0</td>
<td>0</td>
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<tr>
<td><em>Caryopteris clandonensis</em></td>
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<tr>
<td>Fernbush</td>
<td>3-6&quot; x 3-6&quot;</td>
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<td>4-8</td>
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<td><em>Chromeocharia millefolium</em></td>
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<tr>
<td>Grow-Low Fragrant Sumac</td>
<td>2-3&quot; x 6-8&quot;</td>
<td>Full</td>
<td>4-8</td>
<td>Low</td>
<td>0</td>
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<tr>
<td><em>Rhus aromatica &quot;Grow-Low&quot;</em></td>
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<tr>
<td>Autumn Amber Fragrant Sumac</td>
<td>10-14&quot; x 6-8&quot;</td>
<td>Full</td>
<td>4-9</td>
<td>Low</td>
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<tr>
<td><em>Rhus typhoides &quot;Autumn Amber&quot;</em></td>
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</tbody>
</table>

- **Pleasing mounded silvery gray foliage makes a nice contrast against colorful perennials. Fragrant.**
- **Maintenance:** Cut back to about 1/3 to rejuvenate the foliage in the spring.

- **Mounded shrub covered in a profusion of blue flowers late summer. Very attractive to bees.**
- **Maintenance:** Low-maintenance shrub. Can be cut back to 1/3 to rejuvenate and keep compact size every few years, but not necessary. Seedheads offer winter interest.

- **An attractive, rounded shrub with finely divided foliage and showy white flowers in midsummer. A tough, adaptive Western native.**
- **Maintenance:** Low-maintenance shrub. Can be cut back to 1/3 to rejuvenate and keep compact size every few years, but not necessary. Seedheads offer winter interest.

- **Woody groundcover shrub with bright green leaves and vibrant red fall color.**
- **Maintenance:** Low-maintenance shrub. Can be pruned back to keep within a planter area, but not necessary. Naturally low growing.

- **Very low growing woody groundcover with yellow to deep amber fall color.**
- **Maintenance:** Low-maintenance shrub. Can be pruned back to keep within a planter area, but not necessary. Naturally low growing.
WALL GERMANDER

**Teucrium chamaedrys**

- Height: 12-18" x 18"  
- Full sun  
- USDA Zone: 5-9  
- Salt Tolerance: Low  
- Depth Preference: Shallow

Low growing mound evergreen shrub with small, dark green leaves. Pink flowers emerge from tip of stem adding a hint of color in the summer. **Maintenance**: Shear back flowers as necessary. Can be used to create a formal look if desired. Low-maintenance shrub. Do not prune back to ground.

---

**TREES**

**HOT WINGS TATARIAN MAPLE**

**Acer tataricum 'Hot Wings'**

- Height: 15-18" x 15-18"  
- Full sun  
- USDA Zone: 4-10  
- Salt Tolerance: Low  
- Depth Preference: Shallow

Brilliant red samaras look like flaming flowers all summer long. Attractive, sturdy tree with showy fall color. Ideal for home landscapes where a smaller tree is desired. **Maintenance**: Prune in early spring to remove dead or crossing branches and to create desired shape.

---

**PURPLE SMOKEBUSH**

**Cotinus coggygria**

- Height: 8-15" x 8-15"  
- Full sun  
- USDA Zone: 5-8  
- Salt Tolerance: Low

A small tree or large shrub, smoke bush is named after the plume seedheads produced in the fall. Large, waxy leaves. Leaf colors vary by cultivar. **Maintenance**: Prune in early spring to remove dead or crossing branches and to create desired shape.

---

**RUSSIAN HAWTHORN**

**Crataegus azarolus**

- Height: 10-20" x 12-30"  
- Full sun  
- USDA Zone: 4-9  
- Salt Tolerance: Low

This small tree is smothered with flowers in the spring, followed by red fruit and golden fall color. **Maintenance**: Prune in early spring to remove dead or crossing branches and to create desired shape.

---

**COCKSPUR HAWTHORN**

**Crataegus crus-galli inermis**

- Height: 20-30" x 20-30"  
- Full sun  
- USDA Zone: 4-8  
- Salt Tolerance: Low

Small tree with attractive fall color and persistent winter fruit that attract birds. Fruit can be messy don't plant over sidewalks. Make sure to find a thornless variety. **C. phaenopyrum**, C. x leucanthemum, C. mollis, and C. x flabelliformis are alternative selections. All are hosts for apple-cider rust. **Maintenance**: Prune in early spring to remove dead or crossing branches and to create desired shape.
<table>
<thead>
<tr>
<th>Height x Width</th>
<th>Sun</th>
<th>USDA Zone</th>
<th>Water Zone</th>
<th>Wildlife Value</th>
<th>Salt Tolerance</th>
<th>Deer Resistance</th>
<th>Pollinator Friendly</th>
</tr>
</thead>
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<tr>
<td><strong>EMPEROR</strong> (Gleditsia triacanthos 'Imperial')</td>
<td>30-35 x 30-35</td>
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<td>5-6</td>
<td>☀</td>
<td>☀</td>
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</tr>
<tr>
<td>A good shade tree that is tolerant of cold, drought, salt and alkaline soils. Make sure to get a thornless and fruitless variety. Yellow fall color. <strong>Maintenance</strong>: Prune in early spring to remove dead or crossing branches and to create desired shape.</td>
<td></td>
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</tr>
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<table>
<thead>
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<th>Height x Width</th>
<th>Sun</th>
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<th>Wildlife Value</th>
<th>Salt Tolerance</th>
<th>Deer Resistance</th>
<th>Pollinator Friendly</th>
</tr>
</thead>
<tbody>
<tr>
<td>KENTUCKY COFFEE TREE (Gymnocladus dioica)</td>
<td>60-70' x 40-50'</td>
<td>☁</td>
<td>3-8</td>
<td>☀</td>
<td>☀</td>
<td>☀</td>
<td>☀</td>
</tr>
<tr>
<td>A large oval-shaped landscape tree with dark blue-green foliage. Pods can be somewhat messy, but are not too abundant. Fruitless varieties are available. <strong>Maintenance</strong>: Prune in early spring to remove dead or crossing branches and to create desired shape.</td>
<td></td>
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</tbody>
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<table>
<thead>
<tr>
<th>Height x Width</th>
<th>Sun</th>
<th>USDA Zone</th>
<th>Water Zone</th>
<th>Wildlife Value</th>
<th>Salt Tolerance</th>
<th>Deer Resistance</th>
<th>Pollinator Friendly</th>
</tr>
</thead>
<tbody>
<tr>
<td>'WOODWARD' COLUMNAR JUNIPER (Juniperus scopulorum)</td>
<td>20' x 4'</td>
<td>☁</td>
<td>3-9</td>
<td>☀</td>
<td>☀</td>
<td>☀</td>
<td>☀</td>
</tr>
<tr>
<td>Woodward columnar juniper is a narrow, upright and compact selection with a bright green color. A newer selection. <strong>Maintenance</strong>: Low maintenance evergreen. Prune out dead or broken branches.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<table>
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<tr>
<th>Height x Width</th>
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<th>USDA Zone</th>
<th>Water Zone</th>
<th>Wildlife Value</th>
<th>Salt Tolerance</th>
<th>Deer Resistance</th>
<th>Pollinator Friendly</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOLDEN RAIN TREE (Koehneonia paniculata)</td>
<td>20-30' x 25-35'</td>
<td>☁</td>
<td>5-9</td>
<td>☀</td>
<td>☀</td>
<td>☀</td>
<td>☀</td>
</tr>
<tr>
<td>Small to medium sized tree ideal for parkstrips and parks. Unusual lantern-shaped seed pods provide summer interest when little else is blooming. <strong>Maintenance</strong>: Prune in early spring to remove dead or crossing branches and to create desired shape. Remove any suckers.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Height x Width</th>
<th>Sun</th>
<th>USDA Zone</th>
<th>Water Zone</th>
<th>Wildlife Value</th>
<th>Salt Tolerance</th>
<th>Deer Resistance</th>
<th>Pollinator Friendly</th>
</tr>
</thead>
<tbody>
<tr>
<td>WEEPING WHITE SPRUCE (Picea glauca pendula)</td>
<td>30' x 30'</td>
<td>☁</td>
<td>2-8</td>
<td>☀</td>
<td>☀</td>
<td>☀</td>
<td>☀</td>
</tr>
<tr>
<td>Densely packed needles hang down from pendulous branches. Narrow and tall, weeping white spruce makes an interesting specimen plant. <strong>Maintenance</strong>: Low maintenance evergreen. Prune out dead or broken branches.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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### BLUE SPRUCE
*Picea pungens*

<table>
<thead>
<tr>
<th>Height &amp; Width</th>
<th>Sun</th>
<th>Utah Zone</th>
<th>Water Zone</th>
<th>Wildlife Value</th>
<th>Salt / Tolerance</th>
<th>Deer</th>
<th>Firewise</th>
<th>Foliage Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>30' - 60'</td>
<td>full part shade</td>
<td>3 - 8</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>high</td>
<td>high</td>
<td>cones</td>
</tr>
</tbody>
</table>

Blue needles of the blue spruce add a distinctive look to any landscape. Available in a variety of sizes and shapes, blue spruce prefer full sun and well-drained soil. **Maintenance:** Low maintenance evergreen. Prune out dead or broken branches.

### PINYON PINE
*Pinus edulis*

<table>
<thead>
<tr>
<th>Height &amp; Width</th>
<th>Sun</th>
<th>Utah Zone</th>
<th>Water Zone</th>
<th>Wildlife Value</th>
<th>Salt / Tolerance</th>
<th>Deer</th>
<th>Firewise</th>
<th>Foliage Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>20' - 35'</td>
<td>full part shade</td>
<td>4 - 8</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>high</td>
<td>high</td>
<td>cones</td>
</tr>
</tbody>
</table>

This slow growing native pine is very drought tolerant and has a nice blue-green needle. Edible pine nuts. **Maintenance:** Low maintenance evergreen. Prune out dead or broken branches.

### GAMBEL OAK
*Quercus gambelii*

<table>
<thead>
<tr>
<th>Height &amp; Width</th>
<th>Sun</th>
<th>Utah Zone</th>
<th>Water Zone</th>
<th>Wildlife Value</th>
<th>Salt / Tolerance</th>
<th>Deer</th>
<th>Firewise</th>
<th>Foliage Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>20' - 30'</td>
<td>full part shade</td>
<td>4 - 8</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>high</td>
<td>high</td>
<td>leaves</td>
</tr>
</tbody>
</table>

Grows in dense clumps or stands and spreads through root sprouts. Good for slopes and tough, dry sites. **Maintenance:** Prune in early spring to remove dead or crossing branches and to create desired shape.

### BUR OAK
*Quercus macrocarpa*

<table>
<thead>
<tr>
<th>Height &amp; Width</th>
<th>Sun</th>
<th>Utah Zone</th>
<th>Water Zone</th>
<th>Wildlife Value</th>
<th>Salt / Tolerance</th>
<th>Deer</th>
<th>Firewise</th>
<th>Foliage Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>70' - 100'</td>
<td>full part shade</td>
<td>3 - 8</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>high</td>
<td>high</td>
<td>leaves</td>
</tr>
</tbody>
</table>

Very large deciduous tree with interesting fringed acorns. Well adapted to alkaline soils and drought conditions. **Maintenance:** Prune in early spring to remove dead or crossing branches and to create desired shape.

### YELLOWHORN
*Xanthoceras sorbifolium 'Pygmy'*

<table>
<thead>
<tr>
<th>Height &amp; Width</th>
<th>Sun</th>
<th>Utah Zone</th>
<th>Water Zone</th>
<th>Wildlife Value</th>
<th>Salt / Tolerance</th>
<th>Deer</th>
<th>Firewise</th>
<th>Foliage Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>18' - 22'</td>
<td>full part shade</td>
<td>5 - 8</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>low</td>
<td>high</td>
<td>leaves</td>
</tr>
</tbody>
</table>

Small, vase-shaped tree with masses of white flowers in spring. Interesting seedpods. **Maintenance:** Prune in early spring to remove dead or crossing branches and to create desired shape. Makes a nice multi-stemmed tree.
### PERENNIALS

#### FIRE CHALICE
Euphohium (Sauschonaria) garrettii

- **Height x Width:** 4-6" x 18-24"  
- **Sun:** full sun  
- ** USDA Zone:** 3-8  
- **Wildlife Value:** low  
- **Salt Tolerance:** low  
- **Pollinator:** friendly  

- Spreading groundcover with masses of orange-scarlet flowers in summer. Hummingbird magnet.
- **Maintenance:** Cut back to base in late fall or early spring.

#### WHIRLING BUTTERFLIES
Gaura lindheimeri

- **Height x Width:** 24-30" x 24-36"  
- **Sun:** full sun  
- ** USDA Zone:** 5-10  
- **Wildlife Value:** low  
- **Salt Tolerance:** low  
- **Pollinator:** friendly  

- Tough plant with white to pink flowers on long, wiry stem. White selections are generally harder than the pink forms. **Maintenance:** Cut back to base in late fall or early spring.

#### VARIEGATED IRIS
Iris pallida

- **Height x Width:** 24-30" x 12"  
- **Sun:** full sun  
- ** USDA Zone:** 4-9  
- **Wildlife Value:** low  
- **Salt Tolerance:** low  
- **Pollinator:** friendly  

- Grown as much for its striped, sword-like leaves and architectural form as it is for its pale purple, fragrant flowers. **Maintenance:** Remove spent flowers after blooming. Cut back foliage to a couple of inches in late fall or early spring.

#### LAVENDER
Lavandula spp.

- **Height x Width:** varies  
- **Sun:** full sun  
- ** USDA Zone:** 5-10  
- **Wildlife Value:** low  
- **Salt Tolerance:** low  
- **Pollinator:** friendly  

- Mounded silvery-gray foliage with long fragrant blooms. A variety of sizes and colors that vary from dark purple to white. **Maintenance:** Shear back flower stalks to mound shrub after blooming. Do not cut back foliage.

#### DESERT FOUR O' CLOCK
Mirabilis multiflora

- **Height x Width:** 12-24" x 4-6"  
- **Sun:** full sun  
- ** USDA Zone:** 4-6  
- **Wildlife Value:** low  
- **Salt Tolerance:** low  
- **Pollinator:** friendly  

- Low-growing, colorful perennial spreads from taproot and dies back completely at the end of the season. Masses of magenta blooms all summer. **Maintenance:** Cut back to base after first frost. Shear to get going in the spring.
### CATMINT

**Nepeta spp.**

- **Height x Width:** 18-36" x 12-36"
- **Sun:** full
- ** USDA Zone:** 3-9
- **Water Zone:** low
- **Wildlife Value:** low
- **Salt Tolerance:** low
- **Pollinator Preference:** 

A rugged, easy to grow perennial with fragrant gray-green foliage and lavender flowers that can bloom all season with regular shearing. **Maintenance:** Shear flowers after blooming throughout the season. Cut back to base in late fall or early spring.

### NARROW-LEAF EVENING PRIMROSE

**Oenothera biennis**

- **Height x Width:** 12" x 15-18"
- **Sun:** full
- ** USDA Zone:** 4-8
- **Water Zone:** low
- **Wildlife Value:** low
- **Salt Tolerance:** low
- **Pollinator Preference:** 

Dependable, low-water, low-maintenance perennial with lemon-yellow flowers that bloom all summer. Silver-blue, linear foliage. **Maintenance:** Deadhead flowers throughout the season. Pinch stem tips in the spring to create branching. May need occasional thinning to keep in plants, but otherwise low maintenance.

### PALMER'S PENSTEMON

**Penstemon palmeri**

- **Height x Width:** 48-90" x 12-30"
- **Sun:** full
- ** USDA Zone:** 4-9
- **Water Zone:** low
- **Wildlife Value:** low
- **Salt Tolerance:** low
- **Pollinator Preference:** 

A gorgeous wildflower for difficult sites. Tall spikes of fragrant, pink, tubular flowers reach 6' tall. Blue-green serrated foliage. **Maintenance:** Cut flower spikes to base after blooming. Evergreen foliage fairly low-maintenance.

### PINELEAF PENSTEMON

**Penstemon pinifolius**

- **Height x Width:** 12-18" x 18-24"
- **Sun:** full
- ** USDA Zone:** 4-9
- **Water Zone:** low
- **Wildlife Value:** low
- **Salt Tolerance:** low
- **Pollinator Preference:** 

Mounded evergreen foliage is covered with red, trumpet-shaped flowers for most of the summer. **Maintenance:** Shear back flower stalks to mounded shrub after blooming. Evergreen foliage does not need to be cut back.

### MEXICAN HAT

**Rutidosis columnifera**

- **Height x Width:** 24-30" x 18-24"
- **Sun:** full
- ** USDA Zone:** 4-9
- **Water Zone:** low
- **Wildlife Value:** low
- **Salt Tolerance:** low
- **Pollinator Preference:** 

Low yellow petals droop from black cones. Airy foliage. **Maintenance:** Cut back to base late fall or early spring.
**DORR’S SAGE**

Salvia dorril

Semi-evergreen mound-like shrub with aromatic foliage and spikes of purple and blue flowers in spring. **Maintenance:** Cut flower spikes to base after blooming. Evergreen foliage fairly low-maintenance. Cut back any dead or broken branches.

**MOJAVE SAGE**

Salvia parryi

Intensely aromatic, silvery evergreen foliage forms a compact mound. Fat spikes of purple-blue flowers attract bees and hummingbirds. **Maintenance:** Cut flower spikes to base after blooming. Evergreen foliage fairly low-maintenance. Cut back any dead or broken branches.

**SUNDANCER DAISY**

Tetramerus (Hymenoxis) acutellus

Small, ever-blooming perennial with light mounds of small, grass-like leaves and yellow, daisy-like flowers on slender stems. **Maintenance:** Shear flower stalks late fall. Deadhead as desired throughout the season. Evergreen foliage fairly low-maintenance.

**ORNAMENTAL GRASSES**

**ATLAS FESCUE**

Festuca maeiae

arching, bright green leaves form an attractive mound. Semi-evergreen with kahki inflorescences. **Maintenance:** Low maintenance semi-evergreen grass does not need to be cut back to base. Pull out any dead flowers in the spring as growth begins.

**RUBY MUHLY GRASS**

Muhlenbergia reverchonii

Showy pink flowering plumes cover this ornamental grass late summer to fall. Cold-hardy and tolerant of clay soils. **Maintenance:** Low maintenance semi-evergreen grass does not need to be cut back to base. Pull out any dead flowers in the spring as growth begins.
### LITTLE BLUESTEM
*Schizachyrium scoparium*

- **Height & Growth**: 24-36” x 15-18”
- **Sun**: full/part shade
- **Zones**: 3-8
- **Wildlife Value**: med
- **Salt Tolerance**: med

Upright bluish green foliage turns to shades of red changing to deep purple in the fall. Shimmering seed heads remain throughout the winter. Adaptable to poor, dry soils.

**Maintenance**: Cut to the base late fall or early spring.

### ALKALI SACATON
*Sporobolus airoides*

- **Height & Growth**: 24-36” x 24-36”
- **Sun**: full/part shade
- **Zones**: 5-8
- **Wildlife Value**: high
- **Salt Tolerance**: med

Airy grass native to salty, rocky, high-clay soils. Very tough, yet very beautiful.

**Maintenance**: Cut to the base late fall or early spring.
CHAPTER V

DISCUSSION

Insights

The water audit data offered a glimpse into the watering habits of EMC residents and the average distribution of landscape types for a typical residential home. It showed that EMC residents generally had over two times the amount of turfgrass area than was recommended for a water-wise landscape. The data also highlighted that residents used rotor heads more efficiently than they did spray heads. It showed that residents used significantly more water than was needed for the turfgrass. The data illustrated that lower infiltration rates, lower precipitation rates, and the use of cycle soak method may allow for more efficient water use in EMC. These numbers strengthened other water-wise design concepts, such as the importance of a central open turfgrass area, the use of low precipitation drip components, and the use of smart irrigation controllers. These insights were useful during the design of the EMC low water use demonstration garden, as they not only highlighted which aspects of low water use landscaping were most pertinent to EMC residents, they also allowed designers to better explain their design decisions.

The end result was a landscape design that is beautiful, functional, and educational. Research from other conservation gardens and the book *Combinations for Conservation* helped create an aesthetically pleasing low water use planting design by combining varying forms, textures, and colors. Using recommendations from water conservancy districts helped create a functional design that uses less water than a
traditional landscape and will educate EMC residents on low water use landscaping. Open turfgrass areas were designed as functional play areas and to irrigate efficiently. The demonstration garden area was designed to feel inviting to residents, to provide shade and seating for visitors, and to help visitors identify low water use plants for their own homes. Gathering areas were designed to accommodate larger groups visiting Eagle Mountain City Hall. Through this design, EMC residents can visit City Hall and learn how they can save water and money by applying the low water use landscaping principles seen at Eagle Mountain City Hall. If applied, these principles could significantly reduce residents’ landscape water usage. Furthermore, the landscape design can have a positive effect on the cultural landscaping habits of EMC and its residents by providing a template for future public space, businesses, and residential homes.

Challenges

The Water Check program was designed to create custom irrigation schedules for homeowners, not to provide design data. Consequently, information that may have been useful for design purposes, such as plant types, drip components, and the layout of turfgrass areas, was not collected. Extracting data was also challenging. Records were handwritten, forms got wet, and there was no extractable database.

Extracted information was also limited to residents who requested an audit, which demographic may not be representative of the entire EMC population. It is likely that those requesting a water audit would be more motivated to conserve water through their landscaping. The type of data collected varied year to year, which also made some data insignificant and incomparable. In addition, while several zones were tested per home,
not all were consistently tested, resulting in a possibly inaccurate representation of all zones. Recorded schedules were only accurate at the time when the audit was completed and may have differed throughout the growing season. Although these challenges existed, the data still proved useful and consistent with industry standards.

**Further Research**

Water audit data revealed that EMC homeowners had more than the recommended amount of turfgrass in their yards. A future research topic could examine why homeowners choose to use so much turfgrass in their landscapes. Another topic for further analysis is the cost difference between installing a low water use landscape compared to a traditional landscape. If water-wise landscapes were discovered to be cost-prohibitive, research could then focus on cost-effective methods to install such landscapes. Other research could examine the cost and return on investment (ROI) for different water-wise retrofits for existing landscapes. This data could inform recommendations regarding which water-wise practices homeowners would most likely accept.

The water audit data also showed that simple irrigation practices such as head type, the use of cycle soak, and utilizing smart controllers may decrease water use. Differing irrigation retrofits could be examined to better understand which changes would result in the biggest water savings. Further research could examine which modifications have the quickest return on investment.

**Conclusion**
The objective of this thesis was to find out if local water audit data could be useful to a low water use demonstration garden design. The water audit data proved useful in understanding local residents’ watering habits and landscaping trends. These habits and trends shed light on which design elements would be the most significant in reducing water use in the landscape. Some elements that were found to be important were using less turfgrass, the use of rotor sprinkler heads, and the use of smart irrigation controllers for best practice scheduling.

Another objective of the thesis was to discover whether the water audit data research method could be used by landscape professionals in future low water use landscape design. In cases where obtaining specific watering habits of local residents is required, using local water audit data would be a good source to obtain the data. Otherwise, most of the information found in the EMC water audit data seemed to follow industry standard norms that could be found more easily through traditional methods of research such as existing conservation garden visits, books, websites, and other professional literature. Apart from using the water audit data, other potential research topics were discovered that could be significantly useful to the landscape profession.

The thesis produced a successful low water use landscape design for Eagle Mountain City Hall, as well as a plant list handout which could ultimately help EMC reduce their water use and cultivate a culture of low water use landscaping.
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https://www.eaglemountain.com/communities.php
APPENDICES
A. Eagle Mountain City Hall Site Images
B. Central Utah Gardens Site Images
C. Ashton Gardens Site Images
D. Conservation Garden Park Site Images
E. Utah State University Botanical Center Site Images
F. Eagle Mountain City Hall Soil Report

![Soil Test Report and Fertilizer Recommendation](image)

Date Received: 3/30/2017
Date Completed: 4/7/2017

Name: ADREA WHEATON
Address: 4520 OLD MAIN HILL
LOGAN UT 84321

Lab Number: 1701-0452
Identification: EM-IAN
Crop to be Grown: Garden

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<td>Nitrate-Nitrogen - N</td>
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<td>Zinc - Zn</td>
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<td>Manganese - Mn</td>
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Notes:
*SEE GARDEN, LAWN, AND FRUIT GUIDES*

For further assistance, please see your County Agent -- Helen Mumtz - 752-6263
For further information and publications of interest, see the
USU Analytical Lab webpage or Utah State University Extension

Methods: Used by UHPLC; pH (0.01 M NaOH + KCl) = SAR; by dilution half; K by Luggin, soil solution leachate extract; K by AA;
P by spectrophotometry; T by EEM; Fe by redox + methionine; Mo-N by CaHPO₄; Cu by DTPA + 50%; Mn by CaHPO₄ + 50%; S by BaSO₄. Results only reflect the sample received and may not be indicative of actual field conditions.
G. City Hall Civil Site Plan
H. Concept Option 1
I. Concept Option 2