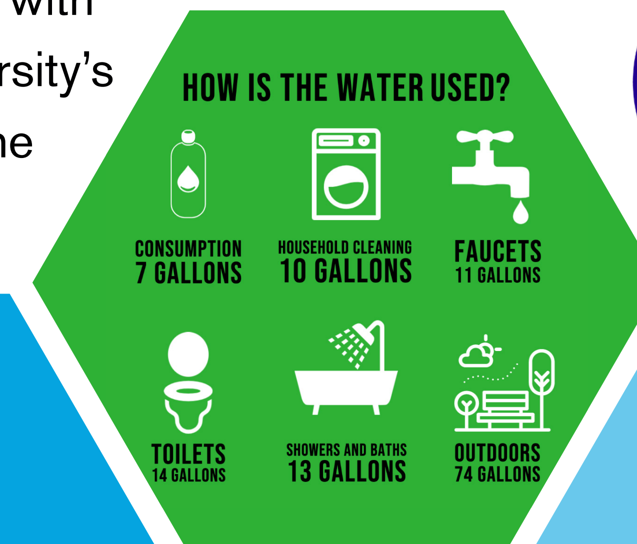
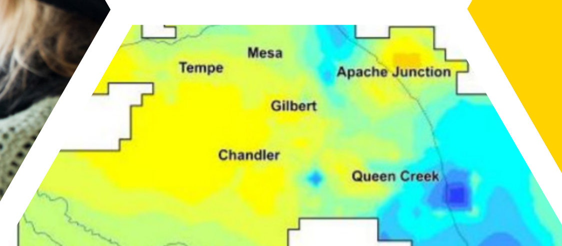
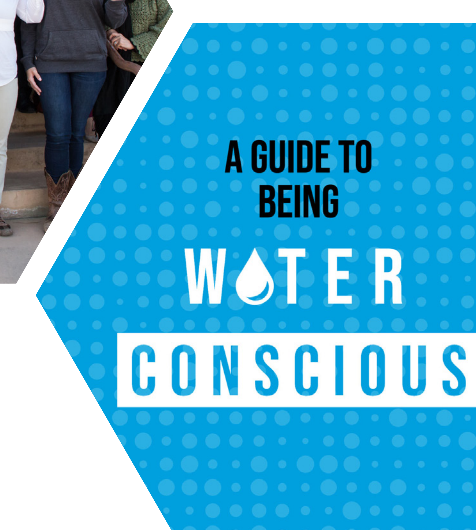
Planning for Scarcity: Water Conservation in Peoria, Arizona

A Spring 2020 Collaborative Project with Arizona State University's Project Cities & the City of Peoria

Sustainable Cities Network
Arizona State University
Project Cities







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On behalf of the Julie Ann Wrigley Global Futures Laboratory, the Global Institute of Sustainability and Innovation, and the School of Sustainability, we extend a heartfelt thank you to the City of Peoria for enthusiastically engaging with students and faculty throughout the semester. These projects provide valuable real-world experience for our students and we hope that their perspectives shine light on opportunities to continuously improve Peoria's future livelihood and community well-being.

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To access the original student reports, additional materials, and resources, visit:
links.asu.edu/PCPeoriaWaterConservation20S

ABOUT PROJECT CITIES

The ASU Project Cities program uses an innovative, new approach to traditional university-community partnerships. Through a curated relationship over the course of an academic year, selected Community Partners work with Project Cities faculty and students to co-create strategies for better environmental, economic, and social balance in the places we call home. Students from multiple disciplines research difficult challenges chosen by the city and propose innovative sustainable solutions in consultation with city staff. This is a win-win partnership, which also allows students to reinforce classroom learning and practice professional skills in a real-world client-based project. Project Cities is a member of Educational Partnerships for Innovation in Communities Network (EPIC-N), a growing coalition of more than 35 educational institutions partnering with local government agencies across the United States and around the world.

ABOUT SUSTAINABLE CITIES NETWORK

Project Cities is a program of ASU's Sustainable Cities Network. This network was founded in 2008 to support communities in sharing knowledge and coordinating efforts to understand and solve sustainability problems. It is designed to foster partnerships, identify best practices, provide training and information, and connect ASU's research to front-line challenges facing local communities. Network members come from Arizona cities, towns, counties, and Native American communities, and cover a broad range of professional disciplines. Together, these members work to create a more sustainable region and state. In 2012, the network was awarded the Pacific Southwest Region's 2012 Green Government Award by the U.S. EPA for its efforts. For more information, visit *sustainablecities.asu.edu.*

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ASU Sustainable Cities Network
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Sustainability through local action

ABOUT PEORIA

Ranked as the No. 1 place to live in Arizona by Money Magazine and the only Arizona city named as one of the best cities in the U.S. by Yahoo! Finance, the City of Peoria is currently home to more than 171,000 residents. The City enjoys a reputation as a family-oriented, active community with an exceptional quality of life. Peoria entertainment and recreational amenities include popular attractions such as Lake Pleasant, a large network of trails and open space, community parks, recreation centers, community theater, libraries, pools, and the spring training home for the San Diego Padres and the Seattle Mariners.

The City has demonstrated a strong commitment to sustainability, as evidenced by its directive to incorporate LEED building design standards, a council-adopted Sustainability Action Plan, and a dedicated full-time staff person to manage and coordinate organization-wide sustainability initiatives.

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PEORIA ★ ARIZONA ★

Peoria is the place
World class ▪ Sustainable ▪ Future Ready

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June 4, 2020

Dear Peoria community members,

It is with tremendous gratitude and excitement that we bring to your attention the results of the first year of our partnership with ASU's Project Cities program. This collaboration provided the opportunity to move beyond traditional resources, and explore all that is possible by working alongside faculty and students across several academic programs.

Project Cities is one of several partnerships we enjoy with ASU, and part of our ongoing strategy to learn from innovative community leaders as we address the complex challenges and opportunities we face as a fast-growing community. With a modest investment in this program, we received extensive research, creative recommendations, diverse perspectives, and innovative deliverables that take several key initiatives to the next level for us.

These include our efforts around water conservation, transit, placemaking, smart cities, and the possibilities around our Skunk Creek corridor near the P83 Entertainment District. Many of these efforts entailed public participation, and you may have participated by speaking to students at one of several Peoria events they attended, or by sharing your personal insight through a survey. By engaging students and faculty on these subjects, we have advanced our understanding and positions on each topic much more quickly than we could have without their assistance.

The project results provided us with invaluable insights into many of our most important opportunities and we are proud to see the students' deliverables advancing. We hold our partnership with ASU and Project Cities in high esteem and look forward to continuing this work on additional projects in the coming year.

Sincerely,

Cathy Carlat, Mayor

Jeff Tyne, City Manager

Peoria, Arizona

Rio Vista Recreation Center

Demographics

total population: **172,259**

median age: **39.5**

highly skilled and educated workforce of 85,252

11,997 veterans live in Peoria

73% of residents are homeowners

median property value: **$230,400**

31% of residents hold a Bachelor's degree or higher

median household income: **$73,039**

Schools

#3 of 131 Best School Districts for Athletes in Arizona

#5 of 40 Best School Districts in Phoenix Metro Area

#7 of 130 Best School Districts in Arizona

The Peoria Unified School District is one of the largest employers in the West Valley. The district consistently receives high ratings and offers signature programs such as the Career and Technical Education programs.

Peoria is also home to Huntington University, a liberal arts college offering digital media education in animation, broadcasting, film, graphic design and other digital media arts.

Leading industries

Peoria, Arizona is not just a scenic suburb of Phoenix, but also a thriving economic development hub with an educated workforce and high-end residential living. There are 22,470 employers and more than 75,000 people employed within Peoria. Leading industries include health care and social assistance, retail trade, and finance and insurance. Highest-paying industries include utilities, manufacturing and public administration. Beyond these industries, Peoria works actively to attract businesses from aerospace and defense, film and digital media, technology and innovation, hospitality and tourism, and research and development. Peoria is the place for business owners, developers and investors.

Health Care & Social Work
10,905 employees

Retail Trade
10,628 employees

Finance & Insurance
6,574 employees

History

Founded in 1886 by Midwestern settlers, Peoria is nestled in the Salt River Valley and extends North into the foothills around Lake Pleasant. Beginning as a small agricultural town, the economy received a major boost when a railroad spur line was built along Grand Avenue. The construction of the Roosevelt Dam in 1910 secured a reliable water supply, attracting more settlers to the area and business endeavors to the town center. Peoria's economy continued to have an agricultural focus for decades. Continually growing, Peoria assumed city status in 1971 with a population of 4,792. It has since grown into a city with a population over 172,000, and is renowned for its high quality of life and recreational amenities.

Sustainability

Peoria has demonstrated leadership in municipal sustainability efforts through a wide range of actions. Listed below are some of the City's sustainability accomplishments.

- Incorporation of LEED building design standards
- Appointment of a full-time city staff member who manages and coordinates sustainability initiatives
- Sustainable urban planning practices including open space planning and water management principles
- Sustain and Gain: Facebook page and brochures keep residents up to date on city sustainability efforts and ways to get involved
- Water Conservation Program: free public classes, public outreach at city events, and water rebate incentives for residents
- Council-Adopted Sustainability Action Plan: this strategic planning document, in its second iteration, ensures city departments are developing sustainability-oriented goals, tracking success metrics, and encouraging cross-communication in the preparation of Sustainability Update presentations made to the Peoria City Council on an annual basis
- Sustainable University: courses and workshops to empower residents to make small changes that make Peoria a better place to live. Topics covered include residential solar, gardening, composting and recycling

Awards and recognition

- Received three Crescordia awards by Arizona Forward at the annual Environmental Excellence Awards in 2016
- 12th City for Green Space in the U.S. in 2019 *(Wallethub)*
- Top 15 Safest Cities in the U.S. 2017-2019 *(Wallethub)*
- 6th Wealthiest ZIP Code in 2020 *(Phoenix Business Journal)*
- Top 50 Hottest Hoods in 2018 *(Phoenix Business Journal)*
- 10th Best City to Raise a Family in 2018 *(Wallethub)*
- Top 100 Golf Course in U.S. 2017-2019 *(Golf Digest)*

Lake Pleasant

- **1886** – Peoria founded by William J. Murphy
- **1889** – First school district formed
- **1919** – Chamber of Commerce organized
- **1954** – Peoria incorporated
- **1971** – Assumed city status with a population of 4,792
- **1977** – Brewers spring training begins at Greenway Sports Complex
- **1986** – Centennial celebration
- **1994** – Peoria Sports Complex opened
- **2007** – Theater for the Performing Arts and Rio Vista Recreation Center opened
- **2012** – 20-year extension spring training agreement with San Diego Padres and Seattle Mariners
- **2017** – Selected as site of new $70M health clinic for Maricopa County Integrated Health System
- **2020**

Livability

Peoria is renowned as a great place to raise a family and start a career. A plethora of local amenities and attractions contribute to Peoria's livability. Beyond the tourist attractions of Spring Training and Lake Pleasant, the City offers many community facilities and recreational opportunities for all ages and interests such as an extensive public park system and annual community events. Peoria's dedication toward livability is also evident in the City's latest General Plan which addresses sustainable water use, housing, public services and more.

Ranked as the No. 1 place to live in Arizona and one of the best cities in the United States.

-Money Magazine and Yahoo! Finance

Peoria Sports Complex

Peoria strives to uphold these six major livability priorities in order to maintain an exceptional quality of life for its citizens.

- **Arts, Cultural and Recreational Enrichment**
- **Economic Prosperity**
- **Smart Growth**
- **Superior Public Services**
- **Healthy Neighborhoods**
- **Integrated Transportation**

Community facilities

- Peoria Community Center
- Rio Vista Recreation Center
- Peoria Sports Complex
- Peoria Center for the Performing Arts
- 36 neighborhood parks
- 2 libraries
- 3 swimming pools
- 6 golf courses
- 9 lighted multi-purpose ball fields
- 15 tennis courts

Lake Pleasant

Urban ecology, ecotourism and recreation

Skunk Creek

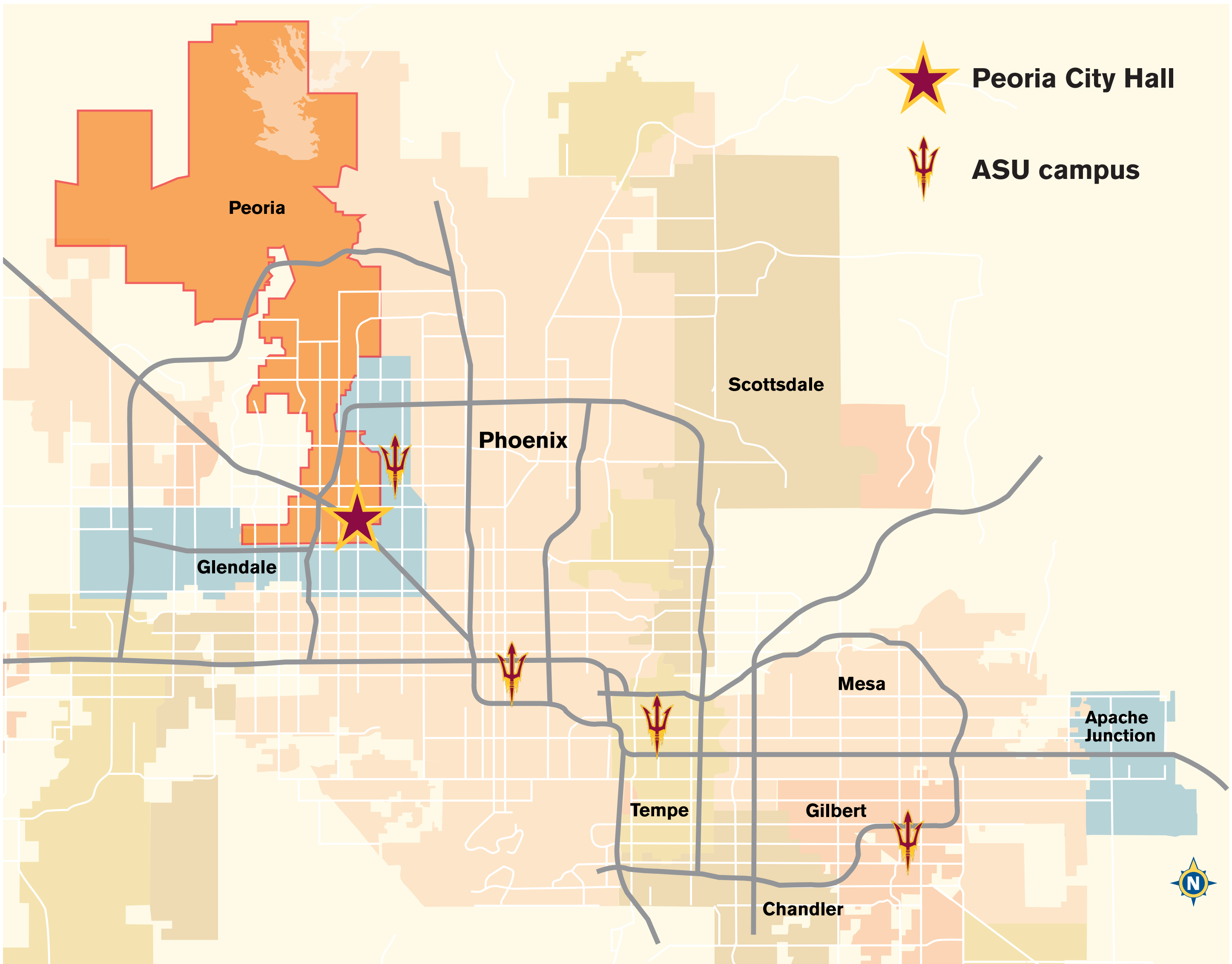
Peoria is surrounded by the natural beauty of the Sonoran Desert and is home to Lake Pleasant, a 23,000-acre park and major recreational asset to the North Valley. The transient Agua Fria River and New River flow through Peoria, as do a multitude of washes and creeks. Most notable perhaps is Skunk Creek — known for the recreational trails running alongside it — which forges a connection between Peoria and Glendale. Northern Peoria is home to beautiful mountains and buttes including Sunrise Mountain, Calderwood Butte and Cholla Mountain.

Boasting over 300 days of sunshine annually, Peoria's ecotourism opportunities are a steady industry for residents and visitors. The City features over 60 miles of trails for walking, biking and horseback riding, as well as 570 total acres of accessible park land.

Lake Pleasant Regional Park contains a full-service marina, providing opportunities for water-oriented recreation such as kayaking, water skiing and even scuba diving. Visitors can also go horseback riding, take gliding lessons, hike, camp and more.

Pleasant Harbor

MAP OF PEORIA & GREATER PHOENIX, ARIZONA



The following report summarizes and draws highlights from work and research conducted by students in ERM 494/598 Water Resource Management, and capstone student Denise Delgado in STC 593 Social Technologies Applied Project, for the Spring 2020 partnership between ASU's Project Cities and the City of Peoria.

To access the original student reports, additional materials, and resources, visit:

links.asu.edu/PCPeoriaWaterConservation20S

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EXECUTIVE SUMMARY

The City of Peoria exists in a unique semi-arid desert region, with water bodies such as Lake Pleasant, the Agua Fria River, and the New River all lying within its borders. The city's water comes from multiple sources and is distributed through the ubiquitous canal networks that traverse the Phoenix Metropolitan Area. Peoria's proximity to natural bodies of water, however, does not guarantee protection against climate change effects, such as drought. It is imperative for arid communities like Peoria to strategically plan and prevent future water shortages by strengthening water conservation efforts and developing mitigation plans in preparation for potential drought conditions. The City of Peoria has demonstrated its leadership and dedication to sustainable water management practices through municipal efforts such as the residential water rebate program, Sustainable University classes and workshops, and the development and updates of the City's 2017 Water Conservation and Shortage Response Plan.

In the Spring 2020 semester, 7 undergraduate and graduate students in 2 classes took on the challenge of developing tangible ways for Peoria to maximize its water conservation efforts, as a continuation of the Water Conservation project initiated in the Fall 2019 semester for Peoria's partnership with ASU Project Cities. Both projects incorporated extensive research and interviews, as well as consultation with city staff on Peoria's needs and current efforts.

ERM 494/598: Six students from the Ira A. Fulton Schools of Engineering and Polytechnic School participated in Larry Olson's **ERM 494/598: Water Resource Management** class. Students split into two groups to tackle their main objectives. Group 1 analyzed Peoria's existing water sources to determine key points to implement the City's Drought Management Plan. Group 2 focused on outlining actionable water conservation tactics to assist Peoria in minimizing its risks of drought. Both groups conducted their research in a forward-thinking manner, creating plans and solutions that would retain value and stay implementable as Peoria continues to grow and develop. Students conducted case studies of similar arid communities in Arizona and Texas to help determine relevant water conservation actions, including suggestions of tax credits, expanded greywater use, xeriscaping plans, and stormwater management. The student team's lead author, Emily Hinkle, conducted additional solo research and analysis on greywater use, growth analysis, and xeriscaping, and also produced the report's key recommendations.

STC 593: Capstone student Denise Delgado participated in Majia Nadesan's **STC 593: Social Technologies Applied Project**, focusing on how to tailor public messaging campaigns to increase water conservation behaviors amongst Peoria residents. Peoria's existing water conservation digital assets were also evaluated by industry experts and specific suggestions for improving the relevant web pages are outlined in the report. By developing a sample digital media campaign, including the use of graphics developed in the Fall 2019 edition of the project, and determining guidelines for effective water conservation messaging strategies, this project aims to identify key digital communication methods that increases Peoria residents' awareness and convinces them to change their water use behaviors, as part of the effort to mitigate drought in the community. By using systematic methods to test and evaluate both existing and proposed digital media, the project provides Peoria with actionable suggestions that can be implemented in public water conservation communications, and ultimately leave a lasting impact on the community's water knowledge and behaviors.

Water conservation, especially in arid regions, is an ongoing issue. To be effective, conservation methods and protocols should be reevaluated and updated often. The student research displayed in the following summary report and recommendations aims to assist Peoria in this necessary process. By studying Peoria's existing protocols and messaging, students have compiled feasible suggestions to assist the city in their continual efforts to conserve water as part of securing a sustainable future for the city's residents and visitors.

GOALS & RECOMMENDATIONS

The purpose of this combined report is to provide the City of Peoria with feasible recommendations that can help improve the city's resiliency to drought, through water conservation, drought management, and public messaging initiatives.

Figure 1 *Jay Davies, Peoria Chief of Staff, speaks to students at the spring semester Peoria Kickoff Event in February 2020*

Figure 2 *Capstone student Denise Delgado and professor Majia Nadesan discuss communication strategies with Jen Stein, the City of Peoria's Director of Communications*

KEY STUDENT RECOMMENDATIONS

Recommendations for drought management strategies

Perform a vulnerability assessment for the water supply to assist with conserving water now and provide information needed to create a framework for water resource planning as the City grows and develops. Monitoring and periodically reperforming the assessment may also be helpful as conservation measures, changing regulations, and climate change, among other things, can continually affect the water supply vulnerability (pp.26-34).

Consider upgrading water reclamation facilities to further treat wastewater to safe drinking water standards. Peoria could look to the City of Scottsdale for process ideas, as they currently treat wastewater to potable reuse standards before reinjecting it into the aquifer (pp.26-34).

Consider the following questions regarding the enactment and enforcement of the Drought Management Plan should it become necessary (pp.35-39).

1. How are the mandates going to be enforced?
2. If the mandates are going to be enforced with fines, how will that be done operationally?
3. How will the mandates and enforcements work from a policy standpoint?
4. How will people respond to the mandates and enforcements?

Refer to Figures 13-17 in the Present Trigger Points section and Drought Management Action Ideas section for suggested mitigation strategies to enact in response to the various drought levels (pp.40-46).

Consider policies that limit new expansion and development plans should a Stage One Drought be declared. When developing, do so slowly in stages, and monitor water levels throughout development to avoid over-extending the water supply (pp.35-54).

Aim for the majority of new residential developments to be low-medium density and, where possible, the mixed use areas to be low density to reduce the future demand for water (pp.49-51).

KEY STUDENT RECOMMENDATIONS

Recommendations for drought management strategies (cont'd)
Reduce the gap between the water supply and water demand by investigating sustainable ways to augment the water supply and seek conservation measures to reduce water demand (pp.52-54).
Where possible, replace water-intensive city landscaping with xeriscaping, and when possible use xeriscaping for any new landscaping, such as new commercial or residential developments (pp.54-56).
Promote rainwater harvesting by offering educational workshops, incentives, and rebates for installing rainwater harvesting systems for homes and businesses. Also consider relevant local ordinances such as requiring the use of rainwater for at least half of new landscaping maintenance, or that new commercial buildings meet a portion of their water needs with harvested rainwater (pp.56-68).
Capture and treat stormwater for use in the municipal water system. Utilize curb cuts and basins along roadways to capture stormwater, both preventing runoff and filtering the water through existing landscaping (pp.56-68).
Provide information to residents regarding the benefits of greywater systems, state rebates, and tax credits for installing greywater systems. Additional incentives and workshops may further encourage the installation of greywater harvesting systems in new and existing developments. Local ordinances, similar to the stub-out ordinance in Tucson, may also drive further greywater harvesting (pp.69-73).
Attract sustainable home developers to the community, and encourage developers to reduce their water usage during construction by offering incentives for using less water intensive construction materials and methods (pp.74-77).
Adopt water efficiency standards for new homes and buildings, such as requiring EPA WaterSense or LEED certified water-efficient fixtures in new construction and remodeling projects to decrease water consumption and increase water savings. Incentives or rebates for Energy Star or WaterSense Certified fixtures and appliances may also boost installation rates in homes (pp.74-77).

KEY STUDENT RECOMMENDATIONS

Recommendations for water messaging

Refine the current City of Peoria website to potentially increase the number of people signing up for water rebates online. It is specifically recommended to:

- Distance font sizes more dramatically, and remove the use of all caps.
- Add Call-to-Action (CTA) buttons in place of hyperlinks to encourage engagement.
- Further organize and reduce the web pages' text content to reduce site navigation.
- Streamline the pages by removing unnecessary elements such as font size buttons, using relevant graphics only when needed, and utilizing helpful icons throughout the site.
- Further details of suggested website changes and feedback are available in Appendix A of the original student content (pp.92, 98-103, 118).

Create an inspiring water conservation social media campaign that is visually striking and consistently themed, using videos, infographics, photos, or links to other materials. Sample digital content suggestions can be found in Figures 7-11 as well as Appendix B in the original student content (pp.91-97, 106-113, 118).

Adopt innovative new marketing tactics to further enhance social media content. Utilizing new strategies, such as augmented reality, is ideal for creating awareness and educating residents about water conservation (pp.92-98, 113-118).

FACULTY
LARRY OLSON

ERM 494/598: WATER RESOURCE MANAGEMENT
IRA A. FULTON SCHOOLS OF ENGINEERING
POLYTECHNIC SCHOOL

Drought Contingency Planning

Management strategies for municipal drought mitigation and response

ACKNOWLEDGMENTS

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GLOSSARY OF TERMS

For the purpose of this report, these relevant terms are defined as follows:

100-Year assured supply
Water supply planned to last 100 years, also known as the 100-year Designation of Assured Water Supply, which is approved and issued by the Arizona Department of Water Resources (ADWR).

Capacity
The full availability of the water supply

Conservation
A long-term reduction in water use through improved efficiency and reduced demand

Direct potable reuse
The treatment, distribution, and delivery of reclaimed water, or highly treated sewer treatment plant effluent water, through the city's pipes and water system without an environmental buffer

Drought
Prolonged period of unusually dry weather and reduced precipitation

Drought Contingency Plan (DCP)
The law signed on May 20th, 2019 by the seven Colorado River Basin states, the U.S. Department of the Interior, and the Bureau of Reclamation

Drought Management Plan (DMP)
The 2017 City of Peoria Drought Management Plan

Indirect potable reuse
The use of an environmental buffer, such as an aquifer, for the water before it is treated and used in a city's drinking water system

Interdependencies
Reliance of the water resources upon each other and mutual impacts

Municipal and industrial (M&I) water
Colorado river water delivered by the Central Arizona Project (CAP) for uses other than agriculture

Non-Indian Agriculture (NIA) water
Colorado river water delivered by CAP originally to agricultural water users in Maricopa, Pinal, and Pima counties

Reclaimed water
Former wastewater treated to be used for non-potable purposes

Editor's Note
Recycled water is a large category of water, and can include non-potable and potable reclaimed waters. For the purposes of this report, recycled water specifically refers to water that has been treated to drinking standards, though state law currently precludes delivering this water to residents for the purpose of consumption.

Recycled water
Reclaimed water further treated to safe drinking water standards (except for when in reference to specific greywater permits)

Snowpack
The accumulation of snowfall over the winter, especially at the high elevations in the watershed

Sustainable
Water supply planned to last into perpetuity, forever

Temporary demand reduction
The temporary reduction in water use and demand that occurs during drought management

Tertiary effluent
Former wastewater that has passed through the primary, secondary, and tertiary stages of cleansing

Trigger points
The predetermined water level benchmarks in Lake Mead at which water shortages are declared according to the DCP

Vulnerability
The state of being at risk or exposed to harm by external factors

Wastewater
Used water that has been contaminated from human use, sewer inflow to the city's water reclamation plant(s)

Water resources
The individual supplies of water to the city

Water resource management
The act of planning, acquiring, distributing, and managing water resources

Water shortage
An actual reduction in the supply of water, can be caused by drought

Water supply portfolio
The combination of water resources that comprise the city's supply of water

PROJECT SUMMARY

This document is the result of the collaboration between the City of Peoria, the Arizona State University's Sustainable Cities Network, and the Ira A. Fulton Schools of Engineering at Arizona State University-Polytechnic Campus. The three primary goals of this project are 1) to assist the City of Peoria in refining guidance around when and how to execute their Drought Management Plan should a water shortage be declared, 2) to determine if the projected water supplies can match the projected future growth of the City in a sustainable manner, and 3) to suggest water conservation measures for the present and future.

There are many factors to be considered when studying water resource management and evaluating how to be responsible in the present and prepare for the future. The research for this project began with a study of Peoria's water supply portfolio's resources and limitations. In this study, the vulnerabilities, capacity, and interdependencies of Peoria's water resources were evaluated. The City of Peoria is doing a remarkable job managing their complex water supply portfolio, and it has been a wonderful opportunity to partner with them to learn more about municipal water management and to leverage our research process to present information and ideas to consider. This report will present the Drought Contingency Plan in comparison with Peoria's Drought Management Plan to determine the trigger points and analyze the potential impacts.

With an understanding of the present and potential future water needs and limitations, Peoria's projected growth and corresponding water needs will be examined. This will not be a complete study as there are many factors to be considered and varying metrics that can be applied. This report is meant to provide a general overview and present ideas for sustainable water resource management and growth.

This report also presents ideas for water conservation measures that Peoria can implement now and consider as the City grows. This will not be an exhaustive study as there are many methods and forms of technology to assist in water conservation with varying degrees of feasibility and costs. The measures included are ones that, based on the research conducted for this project, may be viable options for Peoria to consider. With these measures, the pros and cons, estimates of cost, and case studies are presented.

This report concludes with recommended strategies that the City of Peoria may consider adopting based on the research, analysis, and findings of this project. It is a privilege to have the opportunity to partner with the City of Peoria to help create a sustainable water future for the City.

Figure 3 *Lake Pleasant, a popular recreation spot in Central Arizona, is also an important water storage reservoir for the region*

INTRODUCTION

The Environmental and Resource Management (ERM) 494/598 class on "Water Resource Management" was given two primary tasks which were taken on by two groups of students within the class. The objective of Group 1 was to analyze the City of Peoria's current water sources and model scenarios which would help indicate the trigger points of when and how to implement the City's Drought Management Plan. Group 2 was given the task of planning for the future by determining if the water supplies can match the projected future growth of the City in a sustainable manner and presenting water conservation ideas for future development.

This project sought to assist the City of Peoria in water conservation and future planning. This report presents ideas and information that may be helpful as they evaluate their water resources and plan to grow. It will be exciting to see how the City continues to chart the course of being a sustainable water leader in Arizona and beyond.

RESEARCH METHODS

The project's research goals included evaluation of Peoria's water resources and vulnerabilities at present and in the context of future growth, external risk factors to Peoria's water supply, the projected future growth and water needs of the City, and water conservation strategies to conserve water now and in the future. Additionally, students aimed to clarify the trigger points at which water shortages would be declared according to the Drought Management Plan and develop strategies to have in place to conserve water, combat the effects of the water shortage, and plan for future growth considering this risk.

The research for this project was conducted through meetings with City of Peoria officials; city, state, and federal documents; academic reports; interest articles on water conservation and sustainability; and case studies of other cities and communities that have adopted water conservation measures. This spectrum and diversity of research sources provides a well-rounded perspective for water conservation and planning. Where applicable, sources are cited to support the insights and recommendations formed through this research.

Figure 4 *ASU students and faculty, Peoria city staff, and Project Cities staff show their Sun Devil pride at the close of the Spring 2020 Peoria Kickoff Event*

FINDINGS AND ANALYSIS

City of Peoria background

History and current state

The City of Peoria was incorporated in Maricopa County in the state of Arizona in 1954, however, the first pioneers arrived in Peoria in the 1880s to pursue agriculture. In those early days, floods regularly washed out the canal diversion dam causing the pioneers to trek six miles to the Grand Canal to fill barrels with water for domestic use and stock watering. The City of Peoria received its name from the early settlers who came from Peoria, Illinois (J. Davies, personal communication, February 05, 2020; City of Peoria, n.d.).

The City of Peoria is now a thriving community situated in the northwest region of the Phoenix Metropolitan Area. As of 2016, Peoria boasted a population of 164,173, with an area of 179 square miles located only thirty minutes from downtown Phoenix (City of Peoria, n.d.). Known as the City of Roses, Peoria offers a high quality of life (J. Davies, personal communication, February 05, 2020). Especially notable attractions in Peoria include the Lake Pleasant Regional Park which offers opportunities for outdoor activities such as boating, fishing, and camping, as well as 570 parks and more than 60 miles of trails for hiking, biking, and horseback riding throughout the City (City of Peoria, n.d.). For entertainment, the City of Peoria offers activities such as Spring Training baseball, community theatre and an art museum, a year-round calendar of festivals and special events, and the P83 Entertainment District which provides a wide range of dining, shopping, and entertainment options (City of Peoria, n.d.).

Figure 5A *Fishing at Lake Pleasant*

Figure 5B *Baseball at the Peoria Sports Complex*

Figure 5C *Enjoying the outdoors at Discovery Trail*

Figure 5 *Many of Peoria's diverse recreational activities take advantage of the region's warm weather and outdoor amenities such as trail networks*

Water resources

The City of Peoria's total water supply for 2018 was 34,046 acre-feet (Powers, 2019). One acre-foot of water equals 325,851 gallons and at one foot deep, would approximately cover an entire football field (Powers, 2019). For reference, the average home in Peoria uses 0.34 acre-feet (110,789 gallons) of water per year (Powers, 2019).

The City of Peoria has a diverse water supply portfolio. Peoria is supplied with water from the Central Arizona Project , Salt River Project, Reclaimed Water, Gila River Indian Community, groundwater, and long-term storage credits (Powers, 2019). Figure 6 below shows the composition of water sources in Peoria's 100-year designation of assured water supply. This is the amount of water that the City of Peoria has to work with at present.

Editor's Note
In the long-term, Peoria may also gain access to White Mountain Apache Tribe water. Currently however, there is a pending settlement that pushes access to this water out several years.

City of Peoria water portfolio*

Source	***Acre-feet***	***Percent***
Central Arizona Project (CAP)	25,236	37%
Salt River Project (SRP)	25,201	36%
Reclaimed water	7,889	11%
Gila River Indian Community	7,000	10%
Groundwater	3,114	5%
Long-term storage credits	677	1%
Total acre-feet	69,117	100%
Total used	34,046	49%
Balance remaining	**35,071**	**51%**

**Availability and variety of sources under 2010 Designation of Assured Water Supply*

Figure 6 *Composition of Peoria's water portfolio, by Cape Powers, 2019*

Editor's Note
The Gila River Indian Community water also reaches Peoria through the CAP system, and has the same M&I priority as CAP water.

Central Arizona Project

The Central Arizona Project (CAP) provides the largest share of replenishable surface water in Peoria's water supply portfolio through the canals that channel water from the Colorado River, store it in Lake Pleasant, and release it to the City through additional canals (City of Peoria, 2017). Peoria holds a Municipal and Industrial (M&I) subcontract for 25,236 acre-feet of water per year (City of Peoria, 2017). On the plus side, Peoria is not currently using its full supply and there are no legal restrictions on where this water can be used within the city water service area (City of Peoria, 2017). However, there are vulnerabilities associated with this specific water resource.

CAP brings water from the Colorado River to much of central and southern Arizona (CAP-Background & History, n.d.). The 336-mile system delivers water to 80% of Arizona's population, and is the largest renewable water supply in the state (CAP – Background & History, n.d.). This is a massive responsibility exacerbated by the fact that CAP is impacted by fluctuations in the Colorado River system and interstate and international agreements (CAP- Colorado River Shortages, n.d.). For over 16 years, the Colorado River system has experienced widespread drought conditions (CAP-Colorado River Shortages, n.d.). These conditions have resulted in declining water levels at Lake Mead, the primary storage reservoir for the Lower Basin States including Arizona, and it is projected that this is likely to continue into the foreseeable future (CAP-Colorado River Shortages, n.d.). Despite the continuing drought conditions, the Colorado River is overallocated (Powers, 2019). **Central Arizona's rights** to water from the Colorado River are "junior" to those of other states, meaning that other states have priority to receiving Colorado River water (Powers, 2019). As of 2019, Arizona had an allocation of 2.8 million acre-feet of Colorado River water, and CAP's allocation was 1.6 million acre-feet (Powers, 2019). In the event of a water shortage, these allocations would be cut resulting in **water shortages** for Arizona, CAP, and possibly Peoria (Powers, 2019). Water shortages will be discussed further throughout this report.

Editor's Note
It should be noted that not all of Arizona's Colorado River water rights are "junior" to other states, just those used by CAP to deliver water to central Arizona.

Editor's Note

Whether or not Peoria experiences water resource cuts depends on the extent of the shortage. For example, there could be severe cuts to water allowed to flow through the CAP system, yet Peoria would still receive all of its water allocation.

Salt River Project

The Salt River Project (SRP) is one of the oldest water resources for Peoria, drawing water from the Salt and Verde River systems (City of Peoria, 2017). Peoria is entitled to 25,201 acre-feet per year of SRP Water (City of Peoria, 2017). Peoria is not currently using the full allotment, but a challenge with SRP water is that it can only be used on SRP Project land (City of Peoria, 2017). In Peoria, much of this land is south of Skunk Creek and is traditionally agricultural land that receives irrigation (City of Peoria, 2017). Development on this land would result in the conversion of the water from agricultural irrigation to municipal use (City of Peoria, 2017). However, this water can not be considered as a water source for development in other parts of the City as it cannot be transferred from the land.

The Salt River Project (SRP) delivers approximately 1 million acre-feet of water annually to the Phoenix Metro area despite climate variability through their complex water supply system of reservoirs, groundwater pumping, and conveyance (Carpe Diem West Academy, n.d.). Like CAP, SRP has also combatted sustained drought since 1995 (Carpe Diem West Academy, n.d.). The SRP reservoirs which supply the Phoenix metro area receive most of their water through snowmelt from the Salt and Verde River watershed which is roughly a 13,000 square mile area in Central Arizona (Phillips, Reinink, Skarupa, Ester III, & Skindlov, 2009). This is a vulnerability as precipitation in the watershed is seasonal and varies each year (Phillips, Reinink, Skarupa, Ester III, & Skindlov, 2009). Under certain conditions, SRP can receive water from the Colorado River via a water exchange agreement with CAP, but as mentioned earlier, there is already strain on the Colorado River (Phillips, Reinink, Skarupa, Ester III, & Skindlov, 2009). Other challenges include the shifts in demand patterns as agricultural land is converted to urban use and the forecasting of continued severe droughts (Phillips, Reinink, Skarupa, Ester III, & Skindlov, 2009). Figure 7 on the following page illustrates the Salt and Verde River Watershed and the SRP Service Area.

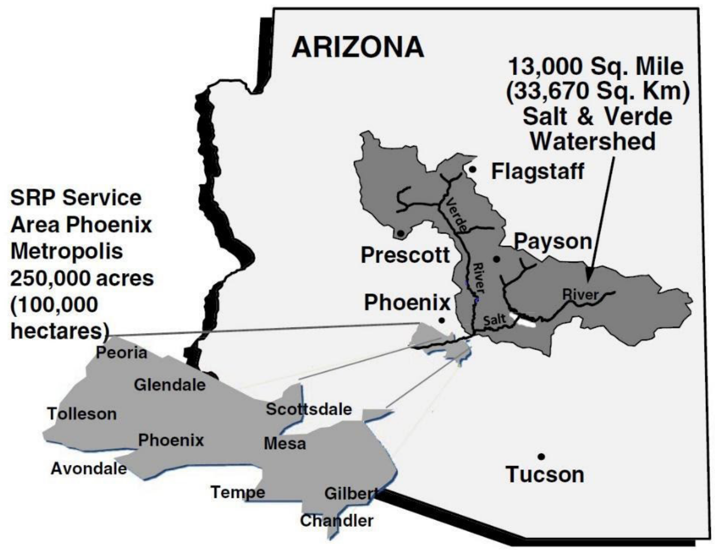


Figure 7 *Salt River and Verde River watersheds, juxtaposed with the SRP service area, by Phillips, Reinink, Skarupa, Ester III, & Skindlov, 2009*

Gila River Indian Community and White Mountain Apache Tribe Water

These two sources of water are leased by the City of Peoria and come via the CAP canal (City of Peoria, 2017). Peoria leases 7,000 acre-feet of water per year from the Gila River Indian Community and 1,249 acre-feet of water from the White Mountain Apache Tribe (City of Peoria, 2017). Each of these leases extend through the next 100 years (City of Peoria, 2017). However, there is a note with the water leased from the White Mountain Apache Tribe, as this water has a lower priority, it could be reduced if a shortage is declared on the Colorado River (City of Peoria, 2017). In addition, though the congressionally approved water settlement with the White Mountain Apache Tribe has been enacted, it is not yet effective (Buschatzke, 2020).

Reclaimed water

The City of Peoria is credited with producing 33,369 acre-feet of reclaimed water per year (City of Peoria, 2017). This is a valuable water resource as it is the only water supply that Peoria owns outright (City of Peoria, 2017). Reclaimed water helps augment the water supply and is used for non-potable applications, such as landscape watering, golf course and park irrigation, aquifer recharge, and infiltration basin storage (City of Peoria, 2017).

Groundwater and recovered water

The City of Peoria has over 40 wells to pump groundwater and 399,463 acre-feet of groundwater available for withdrawal over 100 years without being considered depleted (City of Peoria, 2017). However, Peoria is not actively using this resource, but saving it for the future and for security against shortages (City of Peoria, 2017). The City of Peoria has groundwater withdrawal and recovery wells where the groundwater is recharged with CAP and reclaimed water via infiltration basins, vadose zone recharge wells, and deep injection technology (City of Peoria, 2017). At present, Peoria has only pumped recovered water from the City's wells (City of Peoria, 2017). A challenge that the City of Peoria faces is that long-term use of groundwater is not considered sustainable. Because like a bank account, when it is depleted, it is depleted. In addition, the Arizona Department of Water Resources' projected water level changes within the Phoenix area show groundwater levels decreasing between 2002-2030 (Arizona Department of Water Resources, 2012). Figure 8 below illustrates this decline, and shows Peoria is located in one of the areas projected to experience a more dramatic decline in groundwater levels.

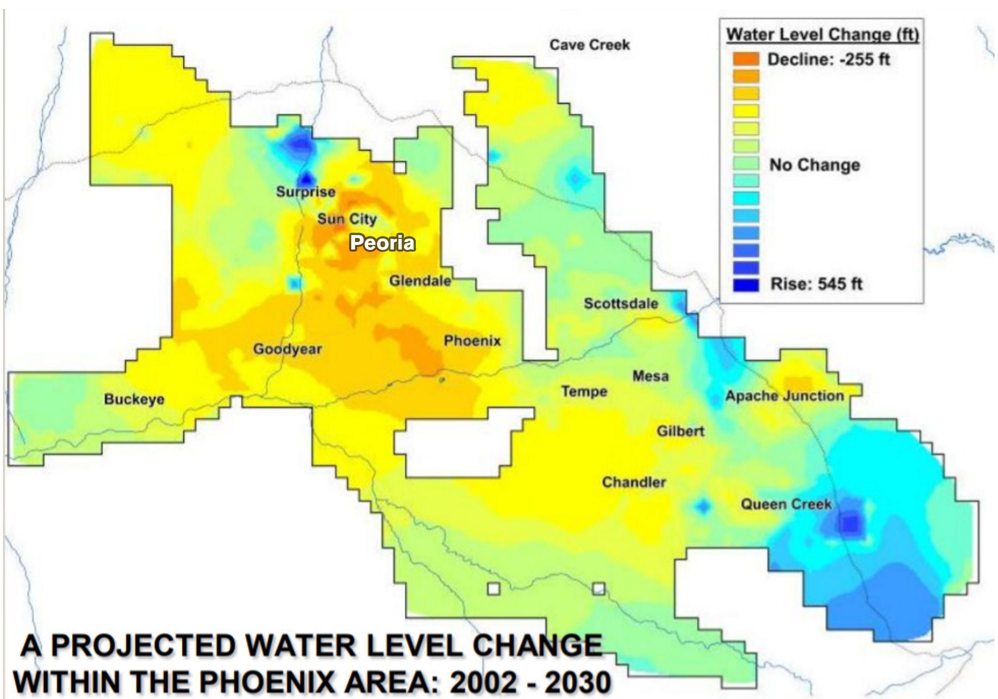


Figure 8 *Water level change map, indicating declines across the Phoenix Metropolitan Area, by Arizona Department of Water Resources*

Vulnerability assessment: Exposure, sensitivity, and adaptive capacity

The City of Peoria may want to consider performing a vulnerability assessment for their water supply portfolio to assist in conserving water now and to provide the information needed to create a framework for water resource planning as the City grows and develops. The three components of a vulnerability assessment are exposure, sensitivity, and adaptive capacity (Carpe Diem West Academy, n.d.).

- **Exposure** refers to how much a system experiences climate changes (e.g. impact pathways, items to manage for, and environmental conditions);
- **Sensitivity** refers to how much a system adapts in response to the changing climate (e.g. the size of the expected change, the size of the impact, and system buffers);
- **Adaptive capacity** refers to the degree to which a system can adjust to changes (e.g. flexibility of policies, pricing, and practices; jurisdiction over changes; and time needed to implement changes) (Carpe Diem West Academy, n.d.).

An important component of performing a vulnerability assessment is to identify situations where there is exposure, high sensitivity, and low adaptive capacity (Carpe Diem West Academy, n.d.). These are the situations that must be the focus in planning and decision-making as they are the most vulnerable (Carpe Diem West Academy, n.d.). Vulnerability should be monitored and reassessed periodically as it can change due to water conservation measures, changing regulations, the implementation of preparedness actions, and climate change (Carpe Diem West Academy, n.d.). The following sections provide a brief assessment of each of those elements that were examined, to provide an insightful, though not comprehensive, overview of the vulnerabilities in Peoria's water portfolio.

Exposure assessment

Through CAP, leased Gila River Indian Community Water, and leased White Mountain Apache Tribe water, the City of Peoria relies heavily on the Colorado River, which is the source of each of these water resources (City of Peoria, 2017). The greatest contributor to the flow of the Colorado River is snowfall in the Colorado Rockies, which subsequently drains into the River (City of Peoria, 2017). SRP receives its water through the precipitation that occurs in the high elevations of northeastern Arizona (City of Peoria, 2017).

SRP also has wells which can supplement the surface water supply with groundwater in the event of a water shortage (City of Peoria, 2017). Combined, these water resources account for roughly 85% of Peoria's water supply. Two of the biggest environmental risks to these water resources are drought and wildfire. Decreased snowfall and precipitation reduces the amount of water and flow in the rivers. Wildfires can dramatically affect watersheds and impact the water quantity and quality (EPA, 2019). After wildfires, water levels can increase and cause flooding, but contamination from ash, erosion, nutrients, and other contaminants can create challenges for drinking-water utilities and municipal water providers (EPA, 2019). Municipal water supply managers need to be concerned about the changes in the magnitude, frequency, and timing of extreme water discharge and sediment and know if their water treatment plants and storage systems are built to accommodate them (EPA, 2019). Due to projected climate changes, water managers should prepare for the effects of prolonged drought and greater wildfires on the water supplies (Wilkening, 2020).

Groundwater is another water source for Peoria (City of Peoria, 2017). One of the biggest challenges associated with groundwater is that it is a finite resource (Tenney, 2020). Though natural replenishment occurs through rain, rivers, and lakes, the effect is minimal and with increasing drought and decreased rainfall, it will lessen further (Tenney, 2020). Many entities, such as the City of Peoria, have sought to replenish the groundwater system through storing or recharge, but groundwater can be depleted much faster than it can be replenished and over-pumping can cause an aquifer to dry up entirely (Tenney, 2020). Reclaimed water will likely be looked to more as an asset to the water supply portfolio in years to come, but several risks to consider include public health, environmental protection, and the suitability of the use to meet specific needs (EPA, 2020).

Sensitivity assessment

It is predicted that over the coming decades, Arizona's climate will become warmer and drier (EPA, 2016). As the climate warms, less precipitation falls, subsequently decreasing flow in rivers such as the Colorado River (EPA, 2016). Less precipitation also means less snow, and snowpack is vitally important to the water system as it supplies the rivers (EPA, 2016). The past 50 years have seen snowpack decreases in Arizona and most of the mountainous areas in the Colorado River Basin. This trend is projected to continue and result in reduced water supplies (EPA, 2016). Rising temperatures also accelerate the rate at which water evaporates and transpires from soils, plants, and surface water causing drier conditions and reducing the water supply (EPA, 2016).

This is a concern because, as mentioned, Peoria heavily depends on surface water and surface water resources are particularly vulnerable to drought, increased temperatures, and reduced precipitation. As mentioned, Peoria's buffer is groundwater. However, groundwater is a finite resource that is impacted by drought and can not be sustainably relied upon. Reduced precipitation results in less water recharging the aquifers, and higher temperatures increase the amount of water that evaporates on land which reduces the amount available to replenish groundwater (Wu, Lo, Wada, Famiglietti, Reager, Yeh, Ducharne, & Yang, 2020). The water systems for Peoria are sensitive to the changes in climate. Another buffer that could be implemented is the increased use of reclaimed water wherever possible, as state laws may prohibit certain uses of reclaimed water.

Adaptive capacity assessment

Not just the City of Peoria, but the Phoenix-metro area, as a whole, is limited in adaptive capacity due to its reliance on the Colorado River and in-state surface water resources. One change that will need to take place in the coming years is increased use of recycled water. The City of Scottsdale has already begun performing indirect potable reuse – further treating water from the reclamation plant to safe drinking water standards and recharging it into the aquifer for later use in the City's water system (City of Scottsdale, 2021). While this is currently a good measure, the program has the potential to advance toward a "toilet to tap" system where wastewater is treated to safe drinking water standards and then pumped back through the city pipes to water users. However, there currently is a statutory preclusion in Arizona that prevents recycled water from being used for direct potable reuse (City of Scottsdale, 2021). Recycled water is a valuable underused water resource that should be made available through changes in state law. Another factor for municipalities to consider is their ability to expand water reclamation plants to include the technology and infrastructure needed to further treat wastewater. At the City of Scottsdale's advanced water treatment plant, tertiary effluent from the City's conventional water reclamation plant is further treated through ozonation, membrane ultrafiltration, reverse osmosis, and ultraviolet photolysis (City of Scottsdale, 2021). The City of Peoria may want to consider upgrading their water reclamation plants if and as needed to further treat wastewater to safe drinking water standards. If done now, Peoria could follow Scottsdale's model by treating the wastewater and reinjecting it into the aquifer while having the capability in place for using the recycled water for direct potable reuse should Arizona law change to allow it.

Drought management analysis

This section examines potential drought scenarios. Using the tiered drought model, estimates are presented of the water reductions at each stage, the potential impacts, and the suggested mitigation measures. The purpose of this section is to present a rough picture of what each drought stage could look like.

Figure 9 *Water is pumped into Lake Pleasant through CAP canals in the winter months, then drawn down throughout the year as needed*

Drought Contingency Plan

The Drought Contingency Plan (DCP) was signed into law on May 20th, 2019 by all seven Colorado River Basin States, the U.S. Department of the Interior, and the Bureau of Reclamation (Colorado River Drought Contingency Planning, 2019). The DCP will hopefully stabilize the Colorado river system and reduce the risk of the reservoirs falling below critical levels (Colorado River Drought Contingency Planning, 2019).

Editor's Note

The DCP is a collection of voluntary water conservation agreements adopted by the Colorado River Basin states as well as Native American tribes in Arizona and various water agencies. For further information, a variety of DCP documents are accessible at **https://new.azwater.gov/lbdcp**

Present trigger points

Peoria is not only concerned about the limited water resources, but also about what actions to take if CAP water should be restricted or turned off. According to Arizona Law, rights to surface water are based on prior appropriation, with senior right holders having priority to surface water before junior stakeholders (Governor's Drought Task Force, p.14, 2004). In accordance with the agreement made by the 2007 Interim Guidelines and the Lower Basin Drought Contingency Plan Agreement, Arizona must comply with certain water level benchmarks for Lake Mead levels. As of 2019, Arizona had an allocation of 2.8 million acre-feet of Colorado River water, and CAP's allocation was 1.6 million acre-feet, of which the City of Peoria receives **25,236 acre-feet** (0.0252360 million acre-feet) per year (Powers, 2019 & City of Peoria, 2017). Breaking it down, CAP receives 57% of Arizona's Colorado River water allotment, and Peoria receives 2% of CAP's allotment.

Editor's Note

An additional 7,000 acre-feet of Gila River Indian Community (GRIC) water could also be added to this total, as Peoria receives this amount from the Colorado River through the CAP canal.

Water supply reduction based on Lake Mead elevation

Lake Mead elevation	*Arizona supply reduction*	*Approximate CAP supply reduction*	*Approximate Peoria supply reduction*
1,075 ft	512,000 AF	512,400 AF	0 AF
1,050 ft	592,000-640,000 AF	592,000-640,000 AF	0 AF
1,025 ft	720,000 AF	720,000 AF	4,835 AF
AF = acre-feet			

Figure 10 *Arizona, CAP, and Peoria water supply reduction estimates using the elevation of Lake Mead as a guiding trigger point, by Cape Powers*

Editor's Note

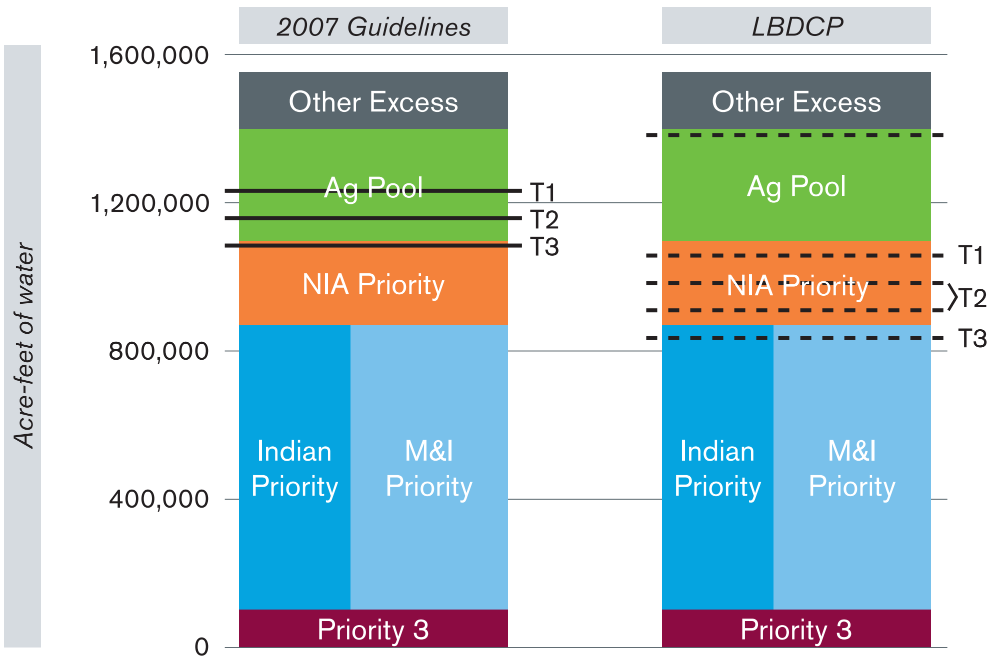
In the original student content, supply reduction numbers from 2007 were used in Figure 10 as well as in the subsequent calculations. In this report, the numbers and calculations have been replaced with updated reduction totals.

Calculations for Figure 10

- Arizona's allotment of Colorado River Water = 2.8 million acre-feet per year (2,800,000 acre-feet)
- CAP's allotment of Arizona's Colorado River Water = 1.6 million acre-feet per year (1,600,000 acre-feet) (57% of Arizona's allotment)
- City of Peoria's allotment of CAP water = 0.032236 million acre-feet per year (32,236 acre-feet) (2% of CAP's allotment)
- Peoria's allotment of GRIC water, which flows through the CAP canal = 7,000 acre-feet-per year

Approximate Peoria supply reduction (in acre-feet)

1. When CAP's Supply Reduction = 512,000 (Tier 1)
    - CAP's Supply After Reduction = 1,600,000 - 512,000 = 1,088,000
    - Peoria's Supply After CAP's Reduction = 32,236 (no loss due to water allocation priority system)
    - Peoria's Supply Reduction = **0**
2. When CAP's Supply Reduction = 592,000 (Tier 2)
    - CAP's Supply After Reduction = 1,600,000 - 592,000 = 1,008,000
    - Peoria's Supply After CAP's Reduction = 32,236 (no loss due to water allocation priority system)
    - Peoria's Supply Reduction = **0**
3. When CAP's Supply Reduction = 720,000 (Tier 3)
    - CAP's Supply After Reduction = 1,600,000 - 720,000 = 880,000
    - Peoria's Supply After CAP's Reduction = 32,236 x 85% = 27,400
    - Peoria's Supply Reduction = 32,236 x 15% = **4,835**



NIA = Non-Indian Agriculture, M&I=Municipal & Industrial

Figure 11 *CAP priority pools and shortage from 2007 guidelines, and the Lower Basin Drought Contingency Plan (LBDCP), by Meyers, 2019*

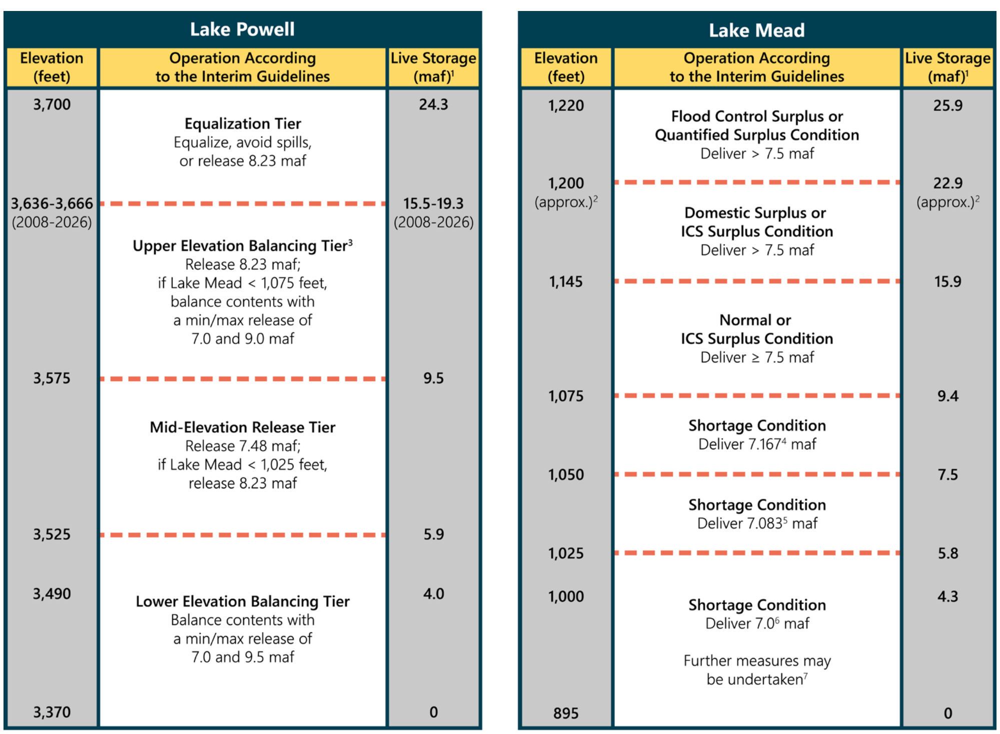


Diagram not to scale, maf=million acre-feet

Figure 12 *Lake Powell and Lake Mead "operation tiers," corresponding to elevation and live storage levels, by U.S. Bureau of Reclamation*

In Accordance with the Drought Management Plan, the continuum of water reductions and messaging is mandatory. This presents unique challenges for the City. Questions to consider include:

1. How are the mandates going to be enforced?
2. If the mandates are going to be enforced with fines, how will that be done operationally?
3. How will the mandates and enforcements work from a policy standpoint?
4. How will people respond to the mandates and enforcements?

For example, it can be seen from the COVID-19 pandemic that implementing mandates and enforcement actions, even at the city level, can be very difficult. While many municipalities in the Phoenix area have developed some form of drought management or drought contingency plans, the research done for this report has not discovered any information to indicate that these municipalities have determined enforcement actions to support the mandates in their plans. Peoria may have an opportunity here to pave the way and set a framework for enforcement actions that other cities may be able to replicate.

Figure 13 on the following pages illustrates the Lake Mead trigger points as outlined in the DCP, the drought stage corresponding to these trigger points in the DCP, and plan ideas in response to these levels based on the research done for this project. Suggested mitigations are in place to respond to a water shortage.

Editor's Note

As the largest water reservoir in Arizona, Lake Mead levels are a commonly-used proxy that indicates the general health of Arizona's water supply, and are also used as metrics in the DCP. In practice, the City of Peoria is not strictly tied to these tiers, and has the flexibility to consider additional sources in their decisions making around conservation trigger points; for example, Peoria may consider SRP system shortages as well. The recommendations outlined in this table use the Lake Mead water level measures as approximate trigger points, in a similar fashion to the DCP. Further specifics on Peoria's existing trigger points, tiers, and how they relate to the DCP, can be found in Peoria's Drought Management Plan.

Suggested response plans for drought stages 1-4
Stage One Drought: Water Alert
Trigger points Lake Mead elevation is at or below 1,075 ft - Tier 1 (City of Scottsdale, 2019) ***Plan*** At this stage, insufficient water supplies seem likely, the Water Services Department Director may want to impose and enforce water use reduction regulations (City of Phoenix Water Services Department, p.4, 2015). Initial waves of conservation involve public education for water saving measures, what the Stage One Drought Plan entails, and minor restrictive measures on water usage. This includes timed use for commercial and residential sprinklers, drip systems, and hoses (Sydney Water, n.d.). Businesses who are heavy water users should be encouraged to conserve water (Sydney Water, n.d.). Limited restrictions should also be placed on filling pools and washing items with significant runoff (Sydney Water, n.d.). The City of Peoria Administrator, upon the recommendation of the Director of Utilities, will need to declare a stage one drought when the level of available water is nearing an insufficient amount to sustain the population. At this point, the amount of available water has decreased enough to predict an impact on the City of Peoria. This triggers an overall public service campaign for water education among the public to encourage voluntary water conservation and compliance (City of Peoria, 2017). The City may also want to set certain water use restrictions such as time limits for certain water uses such as car and sidewalk washing.
Stage Two Drought: Water Warning
Trigger points Lake Mead elevation is at 1,050 ft - Tier 2a the elevation is 1,050 ft, and Tier 2b the elevation is 1,045 (City of Scottsdale, 2019) ***Plan*** At this stage, an insufficient water supply event is occurring (City of Phoenix Water Services Department, p.4, 2015). At this point, the water availability has reached a level where it is completely insufficient. Water audits should be conducted to advise businesses and homeowners on how to curb their water usage and identify possible waste from leaks (City of Phoenix Water Services Department, p.4, 2015). The Water Services Department Director will also need to enforce fines and surcharges (City of Phoenix Water Services Department, p.16, 2015). Sprinklers, hoses, and drip systems should be restricted daily and have limited times when they can run (City of Phoenix Water Services Department, p.4, 2015). The goal is to significantly decrease non-essential water use. Fines can be implemented for violations, for example, $200 for residential, $500 for commercial (Sydney Water, n.d.). At this stage, there is a high probability that the City will not be able to meet all customer water demands (City of Peoria, 2017). Therefore, as outlined in Peoria's Drought Management Plan, the City will want to monitor the situation daily, seek further ways to conserve water, and make plans to augment the City's water supply (City of Peoria, 2017).

Figure 13A *Suggested response plans for Water Alert and Water Warning drought stages*

Suggested response plans for drought stages 1-4 (cont'd)
Stage Three Drought: Water Emergency
Trigger points Lake Mead elevation is at 1,025 ft - Tier 3 (City of Scottsdale, 2019) ***Plan*** The water level in Lake Mead has fallen 25 ft, and stricter water regulations need to be implemented by the Water Services Department Director. This indicates that the water supply can no longer meet demands, and further action must be taken (City of Peoria, 2017). Peoria has junior rights, and therefore at this point, it is assumed that CAP will no longer deliver water, and if it does, it will be a minimum amount. The use of sprinklers, drip irrigation, or hard surface cleaning with hoses should not be allowed at this time. According to Peoria's Drought Management Plan, supply augmentation and demand reduction strategies determined in Stage 2 will be implemented as education to the public continues, and further enforcement monitoring and actions may be necessary (City of Peoria, 2017).
Stage Four Drought: Water Crisis
Trigger points Lake Mead elevation drops below 1,025 ft - Tier 4 (City of Scottsdale, 2019) ***Plan*** At this stage, the Water Service Department Director deems the situation to be a severe crisis and additional measures must be in place to ensure the health and safety of the public (City of Phoenix Water Services Department, p.25, 2015). Drought surcharges will be applied to bills to prevent excess usage and encourage greywater reuse. This stage involves major failure of the water systems of SRP, CAP, and the City of Peoria (City of Peoria, 2017). At this stage, the City of Peoria will act according to the Water System Emergency Response Plan, August 2013 (City of Peoria, 2013). This confidential document is protected by Homeland Security and is only to be used by the City in such emergencies (City of Peoria, 2013). The City Manager declares the Stage 4, and the Peoria Municipal Code provides guidance on notifying the City Council and the public (City of Peoria, 2017).

Figure 13B *Suggested response plans for Water Emergency and Water Crisis drought stages*

Drought management action ideas for each stage

This section details recommended drought management actions the City of Peoria could implement at each drought stage, should they occur. Please note that this is not an exhaustive list, and, as illustrated in the previous section, there are many factors to be considered in taking water shortage actions. Ultimately these recommendations are based on the class research process, and would represent best practices when implemented in the appropriate context. That said, the City may face political obstacles to some of the recommended actions that render them infeasible, and may also wish to consider additional factors or nuances that were beyond the scope of the class project to consider. Ultimately, the city staff and policymakers at Peoria will need to establish the policies needed for the restrictions and enforcements, determine how the restrictions will be enforced and carried out operationally, and consider how people will respond to these actions. Some of the suggestions listed here were ideas based upon information from Sydney Water in Australia (Sydney Water, n.d.).

Drought management actions: Stage One Drought	
Water use category	***Stage One Drought restrictions***
Human and animal water use (i.e., drinking, cooking, showering, laundry, toilet flushing, etc.)	None
Business/commercial water use	Encourage businesses who are heavy water users to conserve water
Hospital water use	None
Watering lawns, gardens, and outdoor landscaping	***Residential and Commercial*** Standard sprinklers can be used only during certain hours of the day and for a certain length of time, for example, before 9am and after 7pm for 1 hour. Drip sprinklers can be used any time. Hoses can be used only during certain hours of the day and for a certain length of time, for example, before 9am and after 7pm for 1 hour.

Figure 14A *Suggested water use restrictions for Stage One Drought: Water Alert*

Drought management actions: Stage One Drought (cont'd)	
Water use category	***Stage One Drought restrictions***
Filling pools and spas	***Residential and Commercial*** Existing pools and spas can be topped off to replace water lost through evaporation, but no new pools or spas can be filled. Do not allow the pool or spa to overflow when filling. Recommend the use of pool covers to reduce evaporation.
Washing vehicles (i.e., cars, boats, etc.)	***Residential*** Implement time limits for vehicle washing and mode. For example, the hose cannot be run for more than 10 minutes, and washing should be done with a filled bucket and sponge. ***Commercial*** Implement time limits for vehicle washing and mode. For example, the water cannot be run for more than 10 minutes, and high pressure water equipment should be used.
Washing buildings, sidewalks, and other hard surfaces	***Residential and Commercial*** Implement time limits for hard surface washing and mode. For example, the water cannot be run for more than 10 minutes, and alternate modes of cleaning other than a hose should be used (i.e. mop and bucket, broom, trigger nozzle hose, etc.).
Filling manmade lakes and ponds	Restricted, unless reclaimed water is used to maintain levels for existing aquatic life.
Watering golf courses and public parks	Standard sprinklers can be used only during certain hours of the day and for a certain length of time, for example, from before 9am and after 7pm for 1 hour. Reclaimed water must be used.
Building construction	Water should only be used for necessary activities such as cleaning walkways for safety and to prevent contamination or to safely operate equipment. Only reclaimed water should be used for dust suppression if absolutely necessary for health and safety.
Firefighting	Water is only to be used for actual firefighting.
Public education and compliance	Notify the public of the Stage One Drought and launch campaign to educate the public and encourage water conservation. Communication methods may include mailers, notices with water bills, information on the city website, city workshops, billboards, and social media posts.
Fines and penalties	None. Encourage voluntary compliance and water conservation.

Figure 14B *Suggested water use restrictions for Stage One Drought: Water Alert (cont'd)*

Drought management actions: Stage Two Drought	
Water use category	***Stage Two Drought restrictions***
Human and animal water use (i.e., drinking, cooking, showering, laundry, toilet flushing, etc.)	Provide information to homeowners on how to curb their water usage (i.e. reduce shower time, not leave sinks running, etc.), and how to identify and fix possible leaks.
Business/commercial water use	Advise businesses to reduce water usage as much as possible, and implement restrictions on heavy water users.
Hospital water use	Reduce water usage where possible.
Watering lawns, gardens, and outdoor landscaping	***Residential and Commercial*** Standard sprinklers can be used only during certain hours of the day and for a certain length of time, for example, before 9am and after 7pm for half an hour. The use of drip sprinklers and hoses may have a similar, though more lenient, standard.
Filling pools and spas	***Residential and Commercial*** Not allowed. Recommend the use of pool covers to prevent evaporation.
Washing vehicles (i.e., cars, boats, etc.)	***Residential*** Implement time limits for vehicle washing and mode. For example, the hose cannot be run for more than 5 minutes, and washing should be done with a filled bucket and sponge. ***Commercial*** Not allowed.
Washing buildings, sidewalks, and other hard surfaces	***Residential and Commercial*** Not allowed.
Filling manmade lakes and ponds	Not allowed, unless is required to maintain aquatic life, in which case reclaimed water should be used to maintain the minimum levels.
Watering golf courses and public parks	Standard sprinklers can be used only during certain hours of the day and for a certain length of time, for example, from before 9am and after 7pm for half an hour. Reclaimed water must be used.
Building construction	Not allowed except to operate essential equipment.
Firefighting	Water is only to be used for actual firefighting.
Public education and compliance	Notify the public of the Stage Two Drought, the restrictions, and the fines. Continue to educate the public and encourage water conservation. Communication methods can include mailers, notices attached to water bills, information on the City website, City workshops, billboards, and social media posts.
Fines and penalties ***First offence*** Warning ***Second offence*** Warning ***Third offence*** Fine	***Residential*** $200.00 ***Commercial*** $500.00

Figure 15 *Suggested water use restrictions for Stage Two Drought: Water Warning*

Drought management actions: Stage Three Drought	
Water use category	***Stage Three Drought restrictions***
Human and animal water use (i.e. drinking, showing, laundry, toilet flushing, etc.)	Strongly advise homeowners to curb their water usage (i.e. reduce shower time, not leave sinks running, etc.), and how to identify and fix possible leaks. Encourage the saving of greywater, such as from showers, to use for activities such as toilet flushing.
Business/commercial water use	Restrict water usage to the minimum required for essential functions such as plumbing.
Hospital water use	Continue reducing water usage where possible to only essential needs.
Watering lawns, gardens, and outdoor landscaping	***Residential and Commercial*** Not allowed.
Filling pools and spas	***Residential and Commercial*** Not allowed. Recommend the use of pool covers to prevent evaporation.
Washing vehicles (i.e. cars, boats, etc.)	***Residential and Commercial*** Not allowed.
Washing buildings, sidewalks, and other hard surfaces	***Residential and Commercial*** Not allowed.
Filling manmade lakes and ponds	Not allowed.
Watering golf courses and public parks	Not allowed.
Building and construction	Not allowed, unless to operate essential machinery for essential tasks.
Firefighting	Water is only to be used for actual firefighting.
Public education and compliance	Notify the public of the Stage Three Drought, the restrictions, and the fines. Continue to educate the public and encourage water conservation. Communication methods can include mailers, notices attached to water bills, information on the City website, City workshops, billboards, and social media posts. Set City staff to monitor water use by the public, answer questions, and provide enforcement when needed.
Fines and penalties ***First offence*** Warning ***Second offence*** Fine	***Residential*** $200.00 ***Commercial*** $500.00

Figure 16 *Suggested water use restrictions for Stage Three Drought: Water Emergency*

Drought management actions: Stage Four Drought	
Water use category	***Stage Four Drought restrictions***
Human and animal water use (i.e. drinking, showing, laundry, toilet flushing, etc.)	Strongly advise homeowners to curb their water usage (i.e., reduce shower time, not leave sinks running, etc.). Leaks must be fixed. Strongly advise the saving of greywater, such as from showers, to use for activities such as toilet flushing. Stronger measures could include implementing a base amount of water allotted to households and extra charges for water used above that amount or applying surcharges to bills to prevent excess water usage and encourage greywater reuse.
Business/commercial water use	Provide a limited amount of water to businesses.
Hospital water use	Continue reducing water usage where possible to only essential needs.
Watering lawns, gardens, and outdoor landscaping	***Residential and Commercial*** Not allowed.
Filling pools and spas	***Residential and Commercial*** Not allowed. Recommend the use of pool covers to prevent evaporation.
Washing vehicles (i.e. cars, boats, etc.)	***Residential and Commercial*** Not allowed.
Washing buildings, sidewalks, and other hard surfaces	***Residential and Commercial*** Not allowed.
Filling manmade lakes and ponds	Not allowed.
Watering golf courses and public parks	Not allowed.
Building and construction	Not allowed, unless to operate essential machinery for essential tasks.
Firefighting	Water is only to be used for actual firefighting.
Public education and compliance	Notify the public of the Stage Four Drought, the restrictions, and the fines. Act according to the Water System Emergency Response Plan, August 2013, and follow the guidance in the Peoria Municipal Code to notify the public. Continue to educate the public and encourage water conservation. Communication methods can include mailers, notices attached to water bills, information on the City website, City workshops, billboards, and social media posts. Set City staff to monitor water use by the public, answer questions, and provide enforcement when needed.
Fines and penalties ***First offence*** Fine	***Residential*** $200.00 ***Commercial*** $500.00

Figure 17 *Suggested water use restrictions for Stage Four Drought: Water Crisis*

Impact of drought management actions on future growth

The estimations presented here are based on Peoria's current status. The rapid growth of the City could exacerbate and quickly advance the effects of each of these stages of drought because of the increased dependence on the City's water supply. Adding more users will likely mean a corresponding increase in the rate of water consumption. The City may want to consider limiting or restricting expansion and development in some fashion if the stages of drought should be declared, the purpose being to not over-extend the water supply. The potential of drought and water shortages present many challenges for a growing city, but with careful, strategic, and sustainable planning, the City of Peoria can be a successful example for other cities.

Growth analysis

Forecasted population growth

The City of Peoria was established in the 1880s and is located in Maricopa and Yavapai County at the following coordinates: 33°34'34.19" N and -112°14'11.40"W (City of Peoria, n.d. & Latitude, n.d.). The City of Peoria's planning area covers over 233 square miles as depicted by Figure 18 (City of Peoria, 2015). There are several private water companies that service locations within Peoria's planning area, and residents in these locations do not receive water service from Peoria (City of Peoria, 2015). There are also areas within Peoria that have homes on septic tanks that do not contribute to the City's wastewater system (City of Peoria, 2017). This research is meant to give a broad overview, therefore, for the purposes of this report, the potable water demands by the private water company service areas and septic tank areas will not be included in the projections.

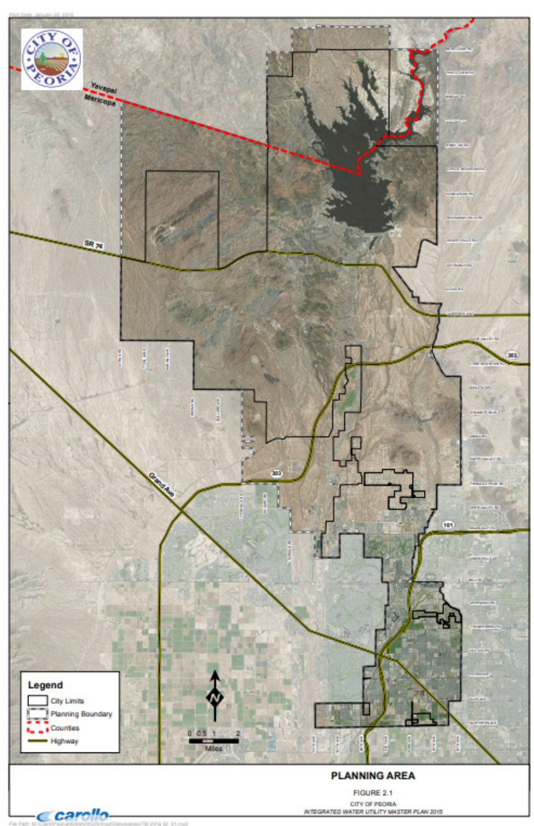


Figure 18 *Peoria Planning Area, from the Integrated Water Utility Master Plan, 2015*

The City of Peoria is planning for new commercial development, redevelopment, and extensive residential development primarily in the northern planning area (Peoria, 2015). Figure 19 below shows a map of Peoria's land use plan, and Figure 20 highlights Peoria's major development areas.

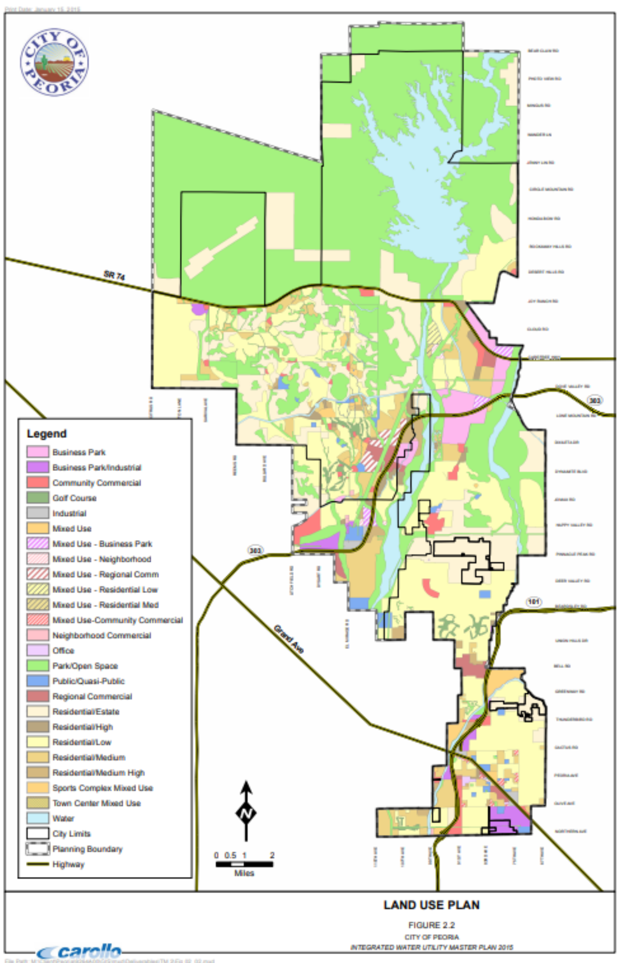


Figure 19 Peoria Land Use Plan, from the Integrated Water Utility Master Plan, 2015

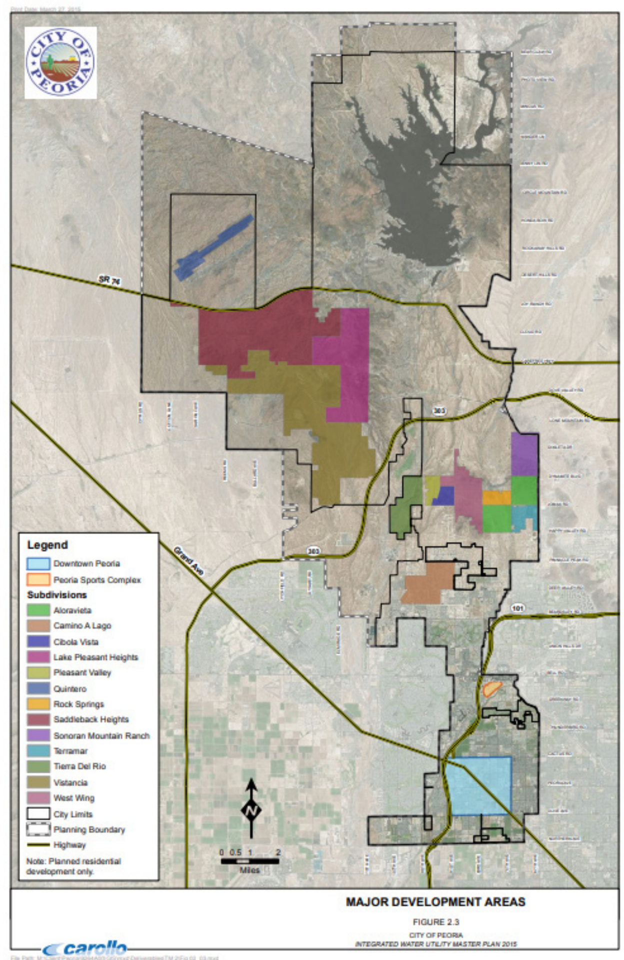


Figure 20 Major Development Areas, from the Integrated Water Utility Master Plan, 2015

Peoria's population is expected to boom in the coming years, rising from approximately 160,000 residents in 2015 to approximately 500,000 residents by buildout (City of Peoria, 2015). For the aim of this case study, the focus of the population analysis will be directed to residential types, due to the fact that this kind of population tends to more accurately represent the population dynamic and tendencies. The forecasted population growth for the coming decades is expected to remain consistent at approximately 1%. Figure 21 further represents Peoria's projected population growth.

MAG population and employment projections				
Allocation	***MAG Horizon Year***			
	2010	***2020***	***2030***	***2040***
Population	162,482	214,412	276,207	342,565
Total dwelling units	67,965	84,425	110,657	135,524
Total employment	40,852	62,563	75,652	94,742
New dwelling units*	-	16,460	42,692	67,559
New employment*	-	21,711	34,800	53,890
**Values used in the Land Use Allocation Model (LUAM) to project dwelling and employment units. This shows that the "buildout" year is beyond year 2040. For example, out of 135,524 total dwelling units, 67,559 were assumed to be developed by year 2040.*				

Figure 21 *Peoria's projected population growth and corresponding needs for new dwelling units and employment, from the Integrated Water Utility Master Plan, 2015*

Editor's Note
As the data presented in Figure 21 is several years old, it is recommended to verify and potentially update the data points before using them to inform major planning decisions.

Forecasted water needs

Two of the major components of estimating future water needs are the forecasted water supply and the forecasted water demand. This section focuses on demand. According to Peoria's map of major development areas, the largest development area is located in the northwest part of the city approximately between State Route 74, the 303, 115th Avenue, and Sarival Avenue (City of Peoria, 2015). This area is currently planned for residential development (City of Peoria, 2015). The other major development area, also residential, is located in the east central portion of the city approximately bounded by Lone Mountain Road, Beardsley Road, 67th Avenue, and 107th Avenue (City of Peoria, 2015). The third major development area is Downtown Peoria in the southern part of the city, approximately located between Cactus Road, Olive Avenue, 75th Avenue, and the 101 (City of Peoria, 2015).

Editor's Note
The student suggestion to limit high density residential development is considered contrary to established sustainable development goals and best practices. It is important to consider the complex trade-offs of varying densities when making high-level development decisions.

Figure 22 shows unit water demands by land use type, using gallons per acre per day (gpad), determined by averaging the annual water used on a per acre basis (City of Peoria, 2015). It shows Mixed Use-High Intensity and Residential/High land uses consume the most water. As noted above, the majority of the major development areas in Peoria are residential. To reduce future water demand, consider limiting high density residential developments in these areas, and require the majority of developments be low-medium density. Similarly, where possible, develop the mixed use areas as low intensity.

Water demand by land use type

Land use type	***Unit water demand (gpad)***
Community commercial	1,177
Golf course	487
Industrial	700
Park/open space	1,251
Schools	1,251
Public/quasi-public	1,128
Regional commercial	1,314
Residential/estate (0-2 DU/ac)	704
Residential/low (2-5 DU/ac)	1,849
Residential/medium (5-8 DU/ac)	1,921
Residential/medium high (8-15 DU/ac)	2,457
Residential/high (15+ DU/ac)	2,457
Mixed use - low intensity	1,484
Mixed use - high intensity*	3,000
**Value adjusted from calculated value to reflect unit demands in similar communities*	

Figure 22 *Peoria's diversity of land use types pose unique water demands, from the Integrated Water Utility Master Plan, 2015*

Figure 23 below illustrates the average daily water demands predicted for each planning year. This chart was developed using Peoria's land use plan and the unit water demand factors (City of Peoria, 2015). There is not a specified year for "buildout," as it refers to the time that Peoria is fully developed (City of Peoria, 2015).

Daily water demand projections					
Demand component	***Production (millions of gallons/day)***				
	2014	***2020***	***2025***	***2040***	***Buildout***
On-project	11.0	12.4	12.4	12.4	12.4
Off-project	13.3	20.6	25.4	45.8	50.2
Irrigation demand*	0	0.8	1.0	1.8	2.0
Additional commercial and industrial demand**	0	1.0	1.3	2.3	2.5
Total*	***24.3***	***34.9***	***40.1***	***62.4***	***67.2***

*4% of off-project water demand
**5% of off-project water demand
***Non-revenue water factor of 4% applied to year 2014 demands (current condition), non-revenue factor of 8% applied to future planning year demands

Editor's Note
In this instance, "on-project" refers to Peoria land tied to SRP water supplies. "Off-project" refers to lands that are not part of this service area, which must be supplied with other water sources such as CAP water.

Figure 23 *Peoria's average daily water demand projections, up to the non-specified "buildout" year, from the Integrated Water Utility Master Plan, 2015*

Figure 24 lists the projected water demands for each year in millions of gallons per day (mgd) from the previous chart, in addition to the amount in acre-feet per year.

Daily water demand projections measurement comparison		
2025	***2040***	***Buildout***
40.1 mgd	62.4 mgd	67.2 mgd
44,947.6 AF per year	69,943.3 AF per year	75,323.6 AF per year

Figure 24 *Peoria's daily water demand converted from millions of gallons per day to acre-feet per year*

Editor's Note
This report began in Spring 2020, with additional work integrated in 2021 by a former ERM student who helped highlight the ever evolving nature of water management.

Planning and sustainability

At present, in the year 2021, sustainable water planning is key. The State of Arizona has established requirements for new developments to demonstrate availability of water. Peoria is located in an Active Management Area (AMA) which means developers rely on Peoria's assured water supply to serve their developments, and are generally expected to follow the Assured Water Supply Program (Arizona Department of Water Resources, n.d.). The program requires developers to demonstrate certain criteria before recording plots, selling parcels, or selling lots (Arizona Department of Water Resources, n.d.). Figure 25 below lists the criteria expected to be demonstrated by developers.

Required developer criteria

Criteria	*Description*
Physical water availability	Sources of water have specific requirements for demonstration of physical availability. A list of those specific requirements can be found in the Arizona Administrative Code (A.A.C. R12-15-716)
Continuous water availability	Water providers or developers must demonstrate that the water supply is uninterruptible for the 100-year period, or that sufficient backup supplies exist for any anticipated shortages (A.A.C. R12-15-717)
Legal water availability	An applicant must demonstrate legal rights to all water supplies included in the application (A.A.C. R12-15-718)
Water quality	Proposed sources of water must satisfy existing state water quality standards and any other quality standards applicable to the proposed use after treatment (A.A.C. R12-15-719)
Financial capability	Water providers or developers must demonstrate financial capability to construct the water delivery system and any storage or treatment facilities. Financial capability for developers is typically considered through the local government's subdivision review process. A demonstration is also required that adequate delivery, storage and treatment works will be available to the applicant or the applicant's customers for 100 years (A.A.C. R12-15-720)
Consistency with the Management Plan (Assured Water Supply Only)	Each AMA's Management Plan prescribes water conservation requirements for municipal water providers. Water demand associated with proposed subdivisions is evaluated in accordance with these conservation requirements (A.A.C. R12-15-721)
Consistency with the Management Goal (Assured Water Supply Only)	Applicants must demonstrate consistency with the management goals of each AMA (A.A.C. R12-15-722)

Figure 25 *Developer criteria for the Assured Water Supply Program, by Arizona Department of Water Resources*

The first point to be examined with supply is sustainability. The Assured Water Supply Program requires a guaranteed uninterrupted water supply for only up to 100 years (Arizona Department of Water Resources, n.d.). The City of Peoria possesses a "Designation of Assured Water Supply" (DAWS), and this means that the City must periodically demonstrate that they have a 100 year supply of water and renew their DAWS with ADWR every 10 to 20 years (Toy, personal communication, February 27, 2021). DAWS is effectively a sustainable supply of water (Toy, personal communication, February 27, 2021). To clarify, sustainability is the idea of planning for the water supply to last into perpetuity, forever.

The second point regards the difference between physical water availability and legal water availability, commonly referred to as wet water vs. paper water. Physical water, or wet water, is the water that is actually available (Toy, ABWC Water Management Certificate O&M Class, February 29, 2020). Sources of wet water include local rivers, the Colorado River, wells, and wastewater treatment plants. Paper water is legal fiction, meaning that it is water that exists on paper but may or may not exist in actuality (Toy, ABWC Water Management Certificate O&M Class, February 29, 2020). Sources of paper water include CAP, SRP, groundwater, reclaimed water, and groundwater credits (Toy, ABWC Water Management Certificate O&M Class, February 29, 2020). A city for example, may have a CAP contract and SRP water right, but this water may or may not be available 100% of the time.

Figure 26 on the following page illustrates the estimated water supply now and at each drought stage in comparison with the estimated demand now and at milepost years of future development and at each drought stage. This chart is an estimation of how water supply and demand compare now while forecasting future supply and demand from the present perspective. This estimation does not take into account water that may be saved through conservation efforts. It should also be noted that the percentages are strictly estimates. The percentage demand reduction goals are taken from City of Peoria documents, and the percentage supply reductions are estimated loosely on the reduction in CAP water supply at each drought stage. Though the amounts and percentages are estimates, it can be seen that there is a gap between the water supply and water demand. To combat this, the City should look for sustainable ways to augment the water supply and look for conservation measures to reduce the water demand. The next section will present ideas on each of these aspects.

Editor's Note
The water supply figures in the following table only represent Peoria's supply provided by CAP, and excludes other water sources such as SRP and groundwater. This exclusion in supply numbers somewhat exaggerates the projected deficit calculations.

Forecasted water supply and demand				
	Water supply	***Water demand 2025***	***Water demand 2040***	***Water demand buildout***
Current (2018)	34,046	44,948 *-10,902*	69,943 *-35,897*	75,324 *-41,278*
Stage One Drought 10% supply reduction 5% demand reduction goal	30,641	42,701 *-12,060*	66,446 *-35,805*	71,558 *-40,917*
Stage Two Drought 15% supply reduction 10% demand reduction goal	28,939	40,453 *-11,514*	62,949 *-34,010*	67,792 *-38,853*
Stage Three Drought 20% supply reduction 15% demand reduction goal	27,237	38,206 *-10,969*	59,452 *-32,215*	64,0125 *-36,788*
Stage Four Drought 25% supply reduction 20+% demand reduction goal	25,535	35,958 *-10,423*	55,954 *-30,419*	60,259 *-34,724*
All figures in acre-feet *All amounts and percentages are strictly estimates* *Italic figures represent the deficit between existing supply and projected demand*				

Figure 26 *Student calculated water supply juxtaposed with forecasted demand*

Water supply and conservation measures

This section examines water supply augmentation and water conservation measures. The use of rainwater, stormwater, and greywater are presented along with water conservation ideas such as xeriscaping and water wise home development and construction. The purpose of this section is to present ideas to supplement the water supply and reduce water demand and consumption.

Xeriscaping

Xeriscaping is a landscape style used in arid regions that requires little to no watering or other maintenance (Lexico Online Dictionary, 2020). Xeriscaping employs drought resistant plants that are native to arid climates and arranges them in such a way as to use as little water as possible.

While it is a common misconception that xeriscape landscaping results in a barren and rocky landscape with a few sparse cacti, nothing could be further from the truth (Fuller, 2008). The wide range of native desert flora leaves the only limitation to be one's imagination.

It is astounding to consider that landscape watering is the largest user of potable water in Arizona, with as much as 70% of residential water used outdoors (Arizona Department of Water Resources, 2021). Xeriscaping is a great alternative to more water intensive forms of landscaping, as it saves both water and money. For example, the Canyon Trails Community located in Goodyear, Arizona, has converted two areas of turf totaling more than three acres to xeriscape, with additional areas in the process of being converted (Bell, 2017). This has saved the community more than $12,000 annually and has allowed the community to save 60% of its water through the summer months (Bell, 2017). For these outstanding efforts, Canyon Trails Community was recognized by the City of Goodyear, and Arizona State University has considered using the community to train water management students (Bell, 2017). The use of native plants in xeriscaping is also good for the environment as the plants serve the needs of native wildlife, providing food and habitat, and helping prevent invasive plants from replacing native vegetation and wildlife (Schuch, 2019).

Figure 27 *Example of lush residential xeriscape design, which is not only aesthetically pleasing but also uses much less water than traditional landscaping*

There is a myriad of benefits to xeriscaping, only a few of which have been listed in this report. Just as the benefits are vast, so are the opportunities for Peoria to implement xeriscaping principles throughout the city.

- First, where possible, the City could replace water intensive landscaping with xeriscaping on City property and offer rebates or incentives to encourage private property owners to replace their landscaping with xeriscaping.
- Second, new commercial developments in the city could be required to use xeriscaping, and new residential developments could be encouraged to primarily use xeriscaping. Rather than prohibit the use of turf in new neighborhoods, the City could require new home developments use xeriscaping for their model homes so that potential buyers are accustomed to it and see the beauty and benefits of xeriscaping up front.
- The City could also require all the front yards in new neighborhoods to be xeriscaped, and permit only a percentage of backyards to be non-xeriscaped. A point to make here is to state that the goal of xeriscaping is to reduce water intensive turf areas without taking away from the functionality or aesthetic of neighborhood landscaping. Therefore, to actualize the benefits of xeriscaping and encourage its use, the City of Peoria could include the strategic placement of green spaces (such as parks) in the public domain, to ensure that there continue to be green areas for people to enjoy, but that net water savings are realized in aggregate.

Rainwater and stormwater capture

Planning for future growth

One of the challenges that the City of Peoria will face with expanding development is the need for new water resources. The projected future growth of Peoria is in the northern desert part of the City. Since it is a desert, as new development comes, new water resources will be needed. This need will require Peoria to look for alternate and renewable water resources to allow for and sustain the future growth. Despite this challenge, the City of Peoria has the opportunity to demonstrate sustainable leadership and water management. As the development is new, Peoria has the ability to incorporate sustainable measures and water saving technology and infrastructure into the development plans. In addition to conserving and responsibly using water, taking such measures and including sustainable water management in the future development plans will set Peoria as a leader in sustainability that can be an example to the rest of the state and even the country and the world.

Rainwater is a valuable resource that should not be allowed to go to waste in the urban environment. Rainwater can be very beneficial whether collected as stormwater, allowed to infiltrate into the aquifer through water basins and dry washes, or captured as a potential water resource (Toy, ABWC Water Management Certificate O&M Class, February 29, 2020). This section will present the potential of rainwater harvesting and stormwater capture as supplemental water resources, the feasibility and impacts of harvesting and using rainwater and stormwater, examples of how the City of Mesa, the City of Tucson, and the Texas Hill Country incorporate rainwater and stormwater capture in their water management and conservation plans, and ideas on how the City of Peoria could incorporate rainwater and stormwater capture and reuse in their plans for future development.

Rainwater is a valuable water resource for several reasons. First, it is generally a relatively clean water source that with certain precautions can even be used for potable consumption (Rahman et al., 2019). Secondly, rainwater is a free water resource that can be collected from roof catchments and pavement areas in large quantities (Rahman et al., 2019). Harvested rainwater can be used for many things including cooling and heating, laundry, toilet flushing, showering, washing, and outdoor plant watering (Rahman et al., 2019). Using rainwater for these things can easily reduce the reliance on other water sources (Rahman et al., 2019).

The term “water sustainability” is often used to describe the intention of reducing water “waste” while providing for daily needs and customer satisfaction (Rahman et al., 2019). Whereas “water conservation” is the idea of reducing water usage and saving water. “Water sustainability” is the concept of building and planning with sustainability in mind to improve water efficiency through recycling and harvesting to reduce water consumption (Rahman et al., 2019). Rainwater harvesting is one of the primary ways that water sustainability can be implemented in buildings and urban development (Rahman et al., 2019). As the City of Peoria looks to grow, it may be helpful to plan from the perspective of water sustainability and incorporate technology and strategies into development plans that include water efficiency and reuse, and rainwater collection and use infrastructure.

Another important distinction to make at this time is rainwater versus stormwater. The term "rainwater" refers to rain that falls on a roof or surface and is channeled into a storage tank before coming into contact with the ground (National Poly Industries, 2018). The term "stormwater" refers to rainwater that drains from surfaces such as roofs, roads, sidewalks, and land surfaces often through gutters and pipes (National Poly Industries, 2018). Rainwater is generally clean and of high quality because it falls from the sky into the storage tank without coming into contact with contaminants (National Poly Industries, 2018). Stormwater is often polluted with contaminants picked up from the surfaces it runs along, including soil, fertilizers, oil from vehicles, and organic matter (National Poly Industries, 2018). Due to this contamination, many cities have stormwater systems that collect, channel, and treat this water before it can be discharged into waterways or used for activities such as garden, park, and lawn watering; swimming pool filling; and toilet flushing (National Poly Industries, 2018). While different, both sources of water have the potential to augment a city's water supplies. The City of Peoria currently has stormwater infrastructure, but at present after the stormwater has gone through the City's system, it is discharged either to the Agua Fria River, New River, or the ADOT drainage channel (City of Peoria, 2018).

Figure 28 *Rainwater flows into a catchment from a roof*

Figure 29 *Stormwater flows into a street-level sewer*

The City of Peoria receives an annual average of 9.2 inches of precipitation (Weather Atlas, 2020). For comparison, the City of El Paso, Texas receives an annual average rainfall of 8.5 inches, which has equated to approximately 9,000 gallons of rainwater harvested from domestic systems (Texas Electric Cooperatives, 2012). Figure 30 further illustrates the average monthly rainfall in Peoria.

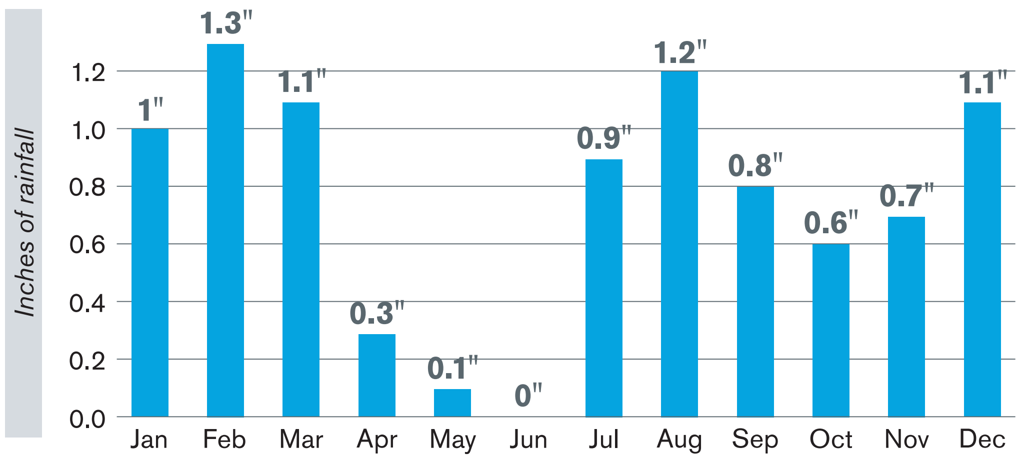


Figure 30 *Average inches of rainfall in Peoria, Arizona, from Weather Atlas, 2020*

In desert climates, rainfall is an invaluable resource. As the City of Peoria grows, future development plans should incorporate water sustainability measures emphasizing ways to implement rainwater harvesting and stormwater capture and reuse.

Feasibility of harvesting rainwater and stormwater

The following section presents the feasibility of using harvested rainwater and stormwater, including a review of capture systems and how they function; the costs of implementing these systems; the amount of rainwater and stormwater that could be harvested compared to household and commercial needs; and the environmental impacts of collecting and using the water resources to illustrate the potential of rainwater and stormwater as viable sources to augment Peoria's water portfolio.

It is recommended that new buildings should be constructed sustainably with infrastructure to reduce water consumption as well as improve water efficiency through recycling and harvesting (Rahman et al., 2019). An example of such infrastructure would be rainwater harvesting systems. These systems generally collect runoff from catchment areas and have a storage tank, distribution networks, and overflow unit (Rahman et al., 2019).

To determine and estimate the costs of installing rainwater harvesting systems, an economic analysis needs to be performed to determine the performance and achieve as short a payback period as possible (Rahman et al., 2019). The most significant portion of the total installation cost of rainwater harvesting systems is generally the storage tank (Rahman et al., 2019). It is best to determine the financial feasibility during the planning phase of construction by performing a life cycle cost assessment (LCCA) which evaluates the cost of the rainwater harvesting systems over their life spans while converting past, present, and future cash flows to present values (Rahman et al., 2019). Several such studies have been done on rainwater harvesting systems in Australia, and these studies have demonstrated that rainwater harvesting systems are financially feasible and therefore a viable option to improve the water sustainability of buildings as well as provide good financial return (Rahman et al., 2019). The payback period in these studies was estimated to be between 10-21 years for residential and commercial buildings depending on the tank size, climate conditions, and future water prices (Rahman et al., 2019).

Rainwater harvesting systems capture rainwater from roofs, gutters, and downpipes on buildings or other large surfaces and then direct the water to underground or above ground storage tanks (Waterways Environmental, 2014). The stored rainwater is filtered and then directly pumped to the appliances or to a header tank (Waterways Environmental, 2014). There are many domestic and commercial uses for harvested rainwater such as flushing toilets, washing machines, car washing, landscape or garden irrigation, showers, sinks, and baths (Waterways Environmental, 2014). Many countries, including Germany and Australia, have made rainwater harvesting the norm, and the green building movement is causing rainwater harvesting systems to gain popularity in America (Innovative Water Solutions LLC, 2020). It is believed that rainwater harvesting systems are viable in an urban environment (Innovative Water Solutions LLC, 2020). With filtration and disinfection treatment to potable water standards, harvested rainwater can even augment municipal potable water supplies (U.S. Department of Energy, n.d.). Figures 31-32 illustrate different rainwater harvesting systems and processes.

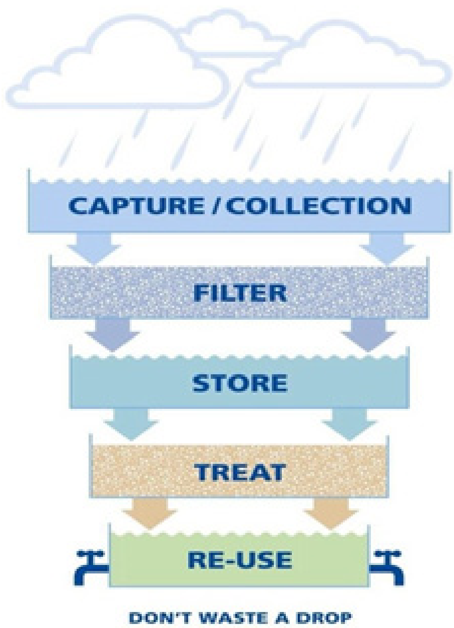


Figure 31 Simplified rainwater harvesting process, as described by Waterways Environmental

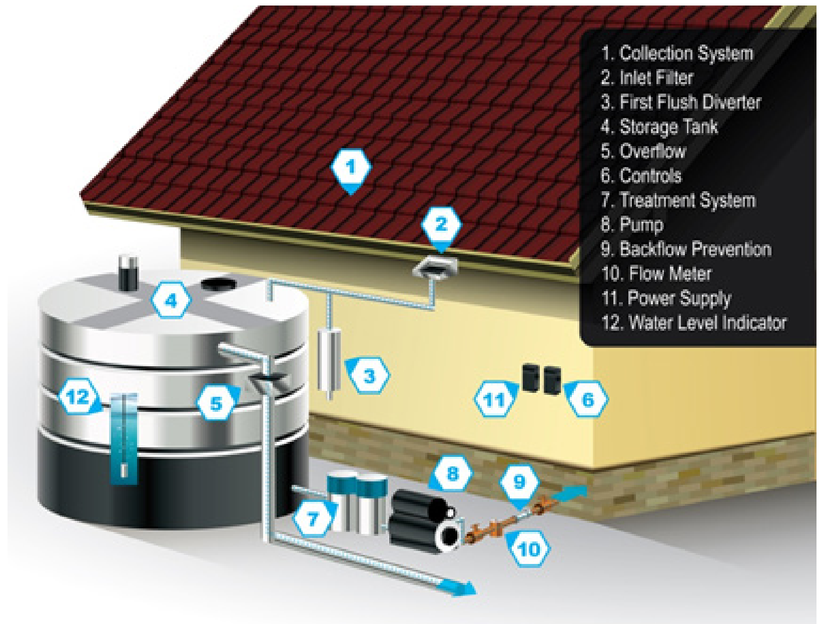


Figure 32 *An example small-scale rainwater harvesting system, by the U.S. Department of Energy*

The size of rainwater harvesting systems can vary. The following formula created by the Federal Energy Management's Rainwater Harvesting Tool can be used to help calculate monthly rainwater available for harvest (U.S. Department of Energy, n.d.).

Monthly rainfall collected (gal) =

catchment area (roof size, square feet) × monthly rainfall (inches) × conversion factor of 0.62 × collection factor (75% - 90% recommended depending on the efficiency of the system)

(U.S. Department of Energy, n.d.).

Editor's Note
0.62 is a standard conversion factor in collection calculations as most systems collect 0.62 gallons per square foot of catchment area.

Rainwater harvesting systems also require regular operation and maintenance (U.S. Department of Energy, n.d.). Appendix A in the original student content specifies the components and maintenance of a standard rainwater harvesting system. Additionally, Appendix B in the original student content lists the components and maintenance of a rainwater harvesting system that treats water to potable standards. As the City of Peoria plans for the future, consideration should be given to installing rainwater harvesting systems in new homes and commercial buildings. The City of Peoria could also seek to implement rainwater harvesting to supplement the City's potable water supply.

Cost estimates

There seems to be a wide spectrum of costs to install a fully functioning domestic rainwater harvesting system. One source claims that the national average cost for a 5,000-gallon polyethylene storage tank "dry" system is $2,500 (FIXR, 2020). Another source states that a complete rainwater harvesting system for a typical single-family home costs $8,000-$10,000, and yet another source states the cost for a typical sized home is between $3,000-$4,000 (Texas Electric Cooperatives, 2012 & Renewable Energy Hub USA, n.d.). The cost variance is caused by factors such as the location, the types of rainwater collection systems (above ground or in-ground), the type of tank (such as fiberglass or welded steel), the type of parts used, extra features (such as drinking water purification), and the installation (FIXR, 2020 & Texas Electric Cooperatives, 2012). For more details, refer to Appendix C in the original student content for summarized cost breakdowns of basic as well as optional system components (FIXR, 2020). The basic necessary system components include a collection method, storage, treatment, and distribution (FIXR, 2020).

Rainwater and stormwater supply calculations

This next section will analyze the amount of rainwater and stormwater that could be harvested as compared to household and commercial needs. As mentioned previously, the City of Peoria receives an annual average of 9.2 inches of precipitation (Weather Atlas, 2020). The following method can be used to estimate the amount of rainwater that can be collected from a building. The square footage of the building can be used to estimate the size of the roof with the following formula (The Ecology Center, 2013):

(width x length [floor in feet] = catchment area [square feet])

Next, the amount of harvested rainwater can be calculated as:

Harvested Water (Gal) = Catchment Area (sqft) x Rainfall Depth (inch) x Conversion Factor (0.623)

According to 2015 U.S. census data and the Cromford Report, the median square footage of homes on all property types in Peoria, Arizona was 1,870 square feet in 2016 (Matheson, 2016). Therefore, following the calculation methods above and assuming an average building size of 1,870 square feet and 1 inch of rain per month on average, the average home or commercial building in Peoria could harvest 1,165.01 gallons of rainwater per month. As a note, the larger the surface of the roof, the more rainwater that can be harvested.

According to the EPA, the average American family uses roughly 300 gallons of water per day (70% indoors and 30% outdoors on average) which would equate to approximately 9,000 gallons of water per month (EPA, 2018). The previous water harvest calculations indicate that implementing rainwater harvesting systems could, on average, supply at least one-tenth of a household's monthly water needs in Peoria, Arizona. Rainwater supply coverage for commercial buildings is more difficult to calculate as commercial water use varies greatly with the size and purpose of the building (U.S. Energy Information Administration, 2012). Figure 33 depicts the average number of gallons of water consumed daily per square foot of different types of commercial buildings. Like private homes, rainwater harvesting systems could also be used to help supply commercial water needs.

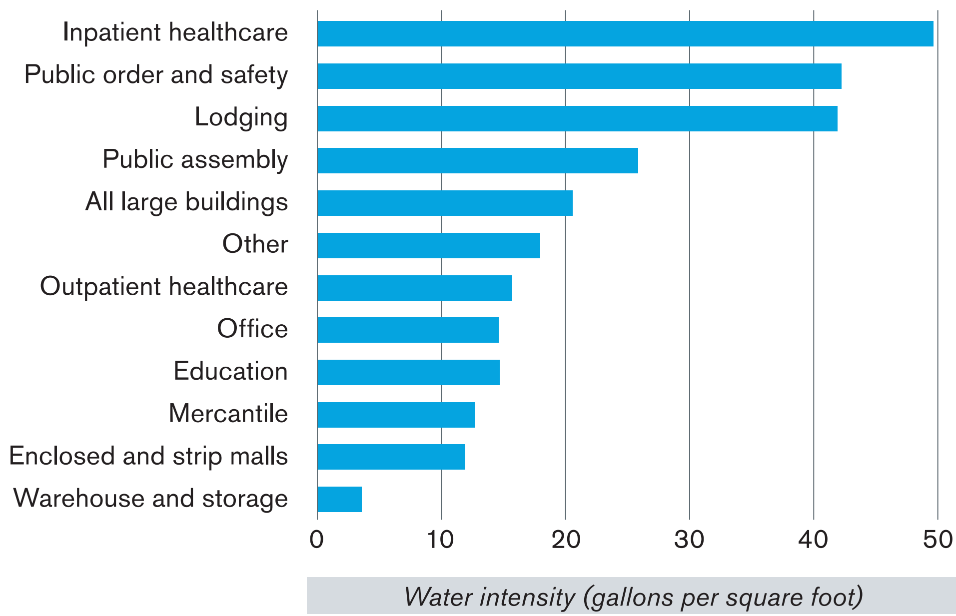


Figure 33 *Average water use intensity for different types of buildings, by U.S. Energy Information Administration, 2012*

Municipal applications

A city can supplement its municipal water supply with harvested stormwater. As mentioned previously, the City of Peoria currently has stormwater infrastructure, but at present after the stormwater has gone through the municipal system it is discharged either to the Agua Fria River, New River, or the ADOT drainage channel (City of Peoria, 2018). Instead of discharging this water, the City of Peoria could keep the harvested stormwater, and use it in the municipal water system following treatment.

The annual volume of stormwater runoff in the City of Peoria is estimated to be 68,000,000 cubic feet which is a vast quantity of water that could be collected, treated, and used to augment the municipal water supply (Fossum, O'Day, Wilson, & Monical, 2001).

Environmental impacts

Rainwater collection can benefit the environment in a variety of ways. In urban areas, as much as 90% of water from rainfall runs off due to the ubiquity of hard surfaces, such as roads, parking lots, and roofs (Ecovie, 2020). Capturing this rainwater can help reduce the amount of stormwater runoff that becomes loaded with contaminants, and then pollutes lakes, streams, and groundwater (Ecovie, 2020). Reducing this runoff also helps prevent flooding and erosion (Ecovie, 2020). However, a predicted trend indicates that urbanization and rainwater harvesting systems could lower groundwater recharge by reducing infiltration and soil moisture storage, and diverting runoff (Gwenzi & Nyamadzawo, 2014). However, empirical data on groundwater recharge from 23 arid and semi-arid urban sites contradict this theory, and instead report a rise in groundwater levels (Gwenzi & Nyamadzawo, 2014). Urban areas may be able to successfully harvest rainwater from roofs while protecting the groundwater levels through innovative pathways of recharge such as utility trenches, tunnels, and other buried structures that replicate a natural shallow karst system and increase the permeability by orders of magnitude (Gwenzi & Nyamadzawo, 2014). Other potential hydrologic impacts of harvesting rainwater from roofs is not well known at this time (Gwenzi & Nyamadzawo, 2014). Further research on hydrologic measurements and process modeling could provide a more complete understanding of the potential impacts (Gwenzi & Nyamadzawo, 2014).

Editor's Note Further information on green infrastructure and low-impact development standards and specifications are available in the SCN LID Handbook at **sustainability-innovation.asu.edu/sustainable-cities/resources/lid-handbook/**

Case studies

Mesa, Arizona

The City of Mesa, Arizona has utilized "green infrastructure" (GI) to sustainably manage stormwater and put it to beneficial use, preventing it from running off and going to waste or contaminating the water system (Hyneman & Whittaker, personal communication, September 26, 2019). The primary way the City of Mesa accomplishes this is through curb cuts and basins along roadways (Hyneman & Whittaker, personal communication, September 26, 2019). These are measures that must be implemented during construction, making them important to incorporate in the planning stages of roadway development (Hyneman & Whittaker, personal communication, September 26, 2019).

Curb cuts are openings in the curbs along roadways to allow stormwater from the road to run off into basins alongside the roads (Hyneman & Whittaker, personal communication, September 26, 2019). These basins may contain vegetation and rocks, and provide a place for the water to settle and the pollutants to be filtered as water either soaks into the ground or evaporates (Hyneman & Whittaker, personal communication, September 26, 2019). The characteristic pollutants of oil and hydrocarbons break down naturally in the basin while any existing nutrients or nitrogen in the water can benefit the plants (Hyneman & Whittaker, personal communication, September 26, 2019). The plants and trees improve the livability of the City by providing shade and lowering temperatures (Hyneman & Whittaker, personal communication, September 26, 2019). According to a presentation by City of Mesa officials on this topic, the Arizona Department of Environmental Quality (ADEQ) would like all cities in Arizona to have this type of system in place to help manage stormwater, but such a system must be incorporated when the roadways are being constructed (Hyneman & Whittaker, personal communication, September 26, 2019).

Figure 34 *Curb cut and landscaped basin on Southern Avenue in Mesa's Fiesta District, by Arizona Water Facts*

Tucson, Arizona

The City of Tucson is leading the way in rainwater harvesting in the state (Nenadovich, 2018). Tucson receives an average of 12 inches of rain per year, making it similar to Peoria (Best Places, n.d.). Rainwater harvesting has been practiced in Tucson for more than a decade, but it has accelerated in the last 5 years primarily due to the City's rebate incentive program (Nenadovich, 2018). The City passed a law in 2012 that requires at least half of the landscaping for any new building to use rainwater, and it is theorized that Tucson may become the first city in the country to require all new commercial buildings be designed to meet 80% of their water needs with harvested rainwater (Nenadovich, 2018). Tucson is very much involved in community outreach through offering programs in schools and the community, as well as, free workshops for those interested in submitting plans for installing rainwater harvesting systems (Nenadovich, 2018). These community outreach programs are having an impact as Tucson residents are embracing conservation measures and growing Tucson's rebate program 35% since 2012 as applications increase yearly (Nenadovich, 2018). The success of Tucson's rebate program is attributed to the community adopting the ideals behind it and seeking to conserve water (Nenadovich, 2018). Due to this momentum, it is likely that rainwater harvesting will be further incorporated into Tucson's development plans in the future (Nenadovich, 2018).

Figure 35 *Residential rainwater harvesting system installed at a home in Tucson, by City of Tucson*

Texas Hill Country

The Terra Scena home development in Dripping Springs, Texas is one of a handful of neighborhoods in the state's Hill Country area that has developed with sustainability and water conservation in mind (Lim, 2018). The homes in the Terra Scena development are designed with rainwater harvesting systems that collect rainwater from the roofs into steel drums which then channel the water through filters and pipes to the showers and sinks of the homes (Lim, 2018). Many homes across Texas have begun installing rainwater harvesting systems as droughts become more routine, but designing and building entire neighborhoods with rainwater harvesting being a primary source of water is a relatively new idea (Lim, 2018).

A Texas Water Development Board completed a study several years ago that proved that it is feasible and efficient for a subdivision to depend upon rainwater (Lim, 2018). The houses in the Terra Scena development cost between $575,000 - $750,000 which includes the approximately $30,000 rainwater harvesting system. According to the neighborhood's models, a home for a family of four requires that the roof be at least 4,500 square feet and the cistern have a capacity of **35,000 gallons** (Lim, 2018). Several other Texas home developments that have incorporated rainwater harvesting systems include The Constellation in Driftwood, Texas and the Preserve at Walnut Springs near Johnson City, Texas in Blanco County (Lim, 2018). Since there is not much regulation of rainwater harvesting, Hays and Travis Counties in Texas have implemented rainwater harvesting requirements for developers (Lim, 2018). These requirements include providing an estimate of the amount of rainwater that will be available, a draft of the standard design of the rainwater harvesting system as well as an operation and maintenance plan, and counties may also begin to require that developers propose backup water supplies (Lim, 2018).

Editor's Note
The Terra Scena homes are much larger than the average single-family home, which typically ranges from 1,600-1,650 square feet.

Editor's Note
According to the EPA, average household water use is 88 gallons per day, per person. Therefore, a typical family of four would generally use around 10,500 gallons in a 30-day period. A cistern of 35,000 gallons would be capable of holding approximately three months supply of water for the average family of four.

***Figure 36** Aerial view of a property with rainwater harvesting and storage system, by Strong Roots Development*

In Texas, cost has been a primary hurdle to overcome in installing more rainwater harvesting systems (Lim, 2018). According to a study done by the Water Development Board, it costs approximately $25,600 to extend a water line to a home and pay the water bills for twenty years, whereas, a rainwater harvesting system can cost $47,000 over the same length of time (Lim, 2018). However, drying aquifers and more frequent droughts have continued to spur Texas developments to implement rainwater harvesting systems (Lim, 2018). The City of Austin has encouraged rainwater harvesting by offering $5,000 rebates or half the cost of the rainwater harvesting system for those who adopt it for non-potable uses such as irrigating yards or plants, and rainwater harvesting has become a primary supplemental source of water in Austin (Lim, 2018). According to Matt Hollon, an environmental planner in Austin's Watershed Protection Department, the City is focused on giving the "carrot" right now, but the "stick" part could come soon (Lim, 2018).

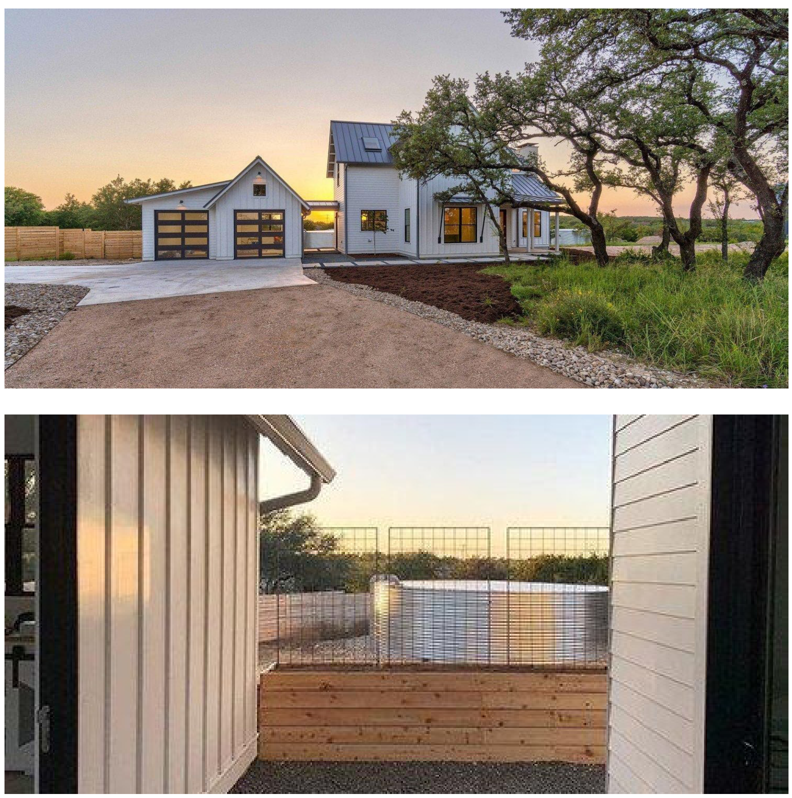


Figure 37 *A Terra Scena home and its integrated rainwater harvesting equipment, by Strong Roots Development*

Greywater use

Another water option the City of Peoria can consider is the use of greywater. Greywater includes any wastewater that comes from washing machines, bathtubs, showers, and bathroom sinks (Yuma County Water Quality Management, n.d.). Greywater does not include water from kitchen sinks, dishwashers, or toilets (Yuma County Water Quality Management, n.d.). Greywater is a great way to reuse water through landscape irrigation, and toilet flushing, and can help reduce the need to use fresh water. In residential homes, greywater can account for up to 75% of the home's wastewater and reusing this water can reduce water bills by an average of 30-70% (Oteng-Peprah et al., 2018 and Holsclaw, 2014). While implementing greywater systems may not seem cost effective up front, the positive environmental impact is invaluable, especially during times of drought. Costs for greywater systems can also vary widely. The simplest of methods is the laundry-to-landscape pumps, which can be built for approximately $100-$250 in materials with the cost increasing depending on the build (Green Building Alliance, 2016). Branched drain systems, which use gravity, can be constructed with materials for approximately $400 and pumped systems are usually approximately $700 for residential buildings (Green Building Alliance, 2016). For the more elaborate commercial builds, greywater systems could cost up to $10,000 or more for installation (Green Building Alliance, 2016).

Using greywater is relatively simple with few key guidelines that need to be followed per state or city ordinances. The following are a few basic points to know regarding greywater:

1. Greywater should not be stored for more than 24 hours, and human contact should be minimized (Greywater Action, n.d.-a).
2. Yards need to be adequately built to prevent greywater from pooling in areas or leaching onto walkways.
3. It is important to know the composition of the greywater and how it will interact with plants in the vicinity.

The composition of greywater can vary greatly depending on the environment producing it. In general, greywater contains a high concentration of organics, such as nitrates and phosphorus (Oteng-Peprah et al., 2018). Physically, greywater often has a Total Suspended Solids (TSS) between 190-537 mg/L, and greywater that comes primarily from showers will have a lower TSS count (Oteng-Peprah et al., 2018).

Tax credit and regulations

To encourage people to implement greywater systems, information should be provided to residents to illustrate the benefits and provide rebate information. The State of Arizona already offers a one-time tax credit for 25% of the total cost of a greywater system with a maximum return of $1,000 (Rock, 2009). This incentive is encouraging more people to use greywater systems in their homes. In Pima County, approximately 20,000-30,000 homes are currently using greywater systems resulting in millions of gallons of drinking water being saved each year (Rock. 2009). Individual cities within Arizona also offer their own rebates to incentivize people to implement greywater systems. The two most notable cities are Tucson and Tempe.

The City of Tempe offers a residential rebate for greywater reuse systems of 50% of the price of the system components up to $200 per home (City of Tempe, n.d.). This rebate however does not extend to businesses. The City of Tucson estimated the amount of potable water used each day per house was 95 gallons and that 27-32% of the total water usage was greywater (Graf, 2012). The generation of greywater per person in the City of Tucson has been recorded at 123 liters per day per person (Oteng-Peprah et al., 2018). This amount increases depending on family size, and greywater being reused could result in a decrease of water usage by 21 gallons per day (Graf, 2012). The City of Tucson offers the Tucson Water's Single Family Residential Gray Water Rebate Program which will reimburse a single resident home up to $1,000 if a permanent greywater system for irrigation is installed (City of Tucson, 2019). The rebate is available to any systems built after January 1st, 2013, and covers the design, material, tanks, pumps, and installation (City of Tucson, 2019). Additionally, Tucson has gone one step further by mandating that all new homes be built with greywater harvesting systems to be implemented from the start of construction through their Greywater-Harvesting Stub-Out Ordinance (Lancaster, n.d.). Appendix D and E in the original student content show the City of Tempe's and City of Tucson's tax rebate forms for greywater systems, respectively.

To use greywater systems for irrigation purposes in private residential homes all guidelines in the Type 1 Recycled Water General Permit for Gray Water in the Arizona Administrative Code must be followed. If all the guidelines are followed, greywater systems used in private homes for irrigation can be constructed without any permits or fees (Rock, 2009).

The Code for Type 1 Gray Water use is simple to follow. The Code allows for systems to be implemented if they are under 400 gallons a day and the water stays contained within the property, meaning that it does not leach onto public walkways or pool on the surface (Type 1 Recycled Water General Permit for Gray Water, p.103, 2017).

Figure 38 *Water pooling and leaching, which is not approved for greywater use*

Humans must avoid contact with greywater, and it should not be used to water plants grown for food unless it is guaranteed that the water will not encounter the edible portions of the plant. Doing this requires restricting water distribution methods to only flood or drip irrigation (no sprinklers) (Type 1 Recycled Water General Permit for Gray Water, p.103, 2017). The greywater must not contain any hazardous contaminants like chemicals from washing, oils from kitchen use, fecal matter, or infectious contagions (Type 1 Recycled Water General Permit for Gray Water, p.103, 2017). Another major condition is that the greywater system be built outside of major floodways making greywater use prohibited in floodway areas (Type 1 Recycled Water General Permit for Gray Water, p.103, 2017).

The process for business is similar to that for residential. The permit needed for a business is the Type 3 Recycled Water General Permit for Gray water, and it does have an application and fee associated with it (S. Shah, personal communication, March 6, 2020). The business that desires to utilize greywater for landscape irrigation, needs to submit a Notice of Intent (NOI) for the Type 3 Permit which comes with an application fee of $1,500 and is good for 5 years before it needs to be renewed (S. Shah, personal communication, March 6, 2020).

The Type 3 permit covers the use of greywater if the flow is less than 3,000 gallons per day, there is a description of the source of the greywater, and there are calculations to prove the flow is provided in the NOI (Type 3 Recycled Water General Permit for Gray Water, p.103, 2017). All guidelines in the Type 1 permit must be adhered to and a design plan of the system must be submitted to ADEQ along with the NOI (Type 3 Recycled Water General Permit for Gray Water, p.103, 2017). See Appendix F in the original student content for a copy of a NOI for a Type 3 Gray water Permit for Arizona Businesses.

If a business or residential home is interested in using greywater for toilet flushing, another additional permit, the Individual Recycled Water Permit, needs to be acquired. There is no limit on the flow of greywater with this permit as long as the total volume of the flow is reused (S. Shah, personal communication, April 2, 2020). This permit can also cover multiple buildings on the same site, so that there is not a need to apply for the permit for each building that is being equipped with a greywater system (S. Shah, personal communication, April 2, 2020). The Individual Permit rules are located in the Arizona Administrative Code under R18-9-A703 and R18-9-B703. A few key differences are that the Individual Permits have a public participation period. In this period, the public will be notified, be able to give their opinions or concerns on the permit being issued, and a public hearing will be held if needed (Recycled Water Individual Permit Application, p.96, 2017). In addition to signage that will need to be posted per the Type 1 and 3 General Permit guidelines, an Individual Permit needs to have the class of reclaimed water described and the specific types of reuse (e.g., toilet flushing) identified (General Provisions for Recycled Water Individual Permit for Reclaimed Water, p.100, 2017). The cost for the Individual Permit is much more expensive compared to the General Permit. Given the more complex nature of these permits, a permit team is assigned, and their rate starts at $122 an hour with a maximum payout of $32,000 (S. Shah, personal communication, April 2, 2020). This permit does have an expiration date of 5 years after the date the permit was issued, and it needs to be renewed 60 days prior to expiration (S. Shah, personal communication, April 2, 2020). See Appendix G in the original student content for a copy of the Application for the Recycled Water Individual Permit in Arizona.

Potential negative impacts

While implementing greywater systems can provide substantial water savings, as with any sustainable project, all the environmental impacts should be considered, including the negative ones. The reuse of greywater and the implementation of low water use toilets reduces the need to use fresh water, but these systems also decrease the water available for the sewer system. A decrease in the flow of water into the wastewater treatment plants could cause more blockages in the pipes due to the increase in sedimentation caused by the lower flow velocities (Penn, Schutze, & Friedler, 2013). With the lower flow and increased blockages more odors could occur (Penn, Schutze, & Friedler, 2013). However, as greywater use increases in neighborhoods, the flow, velocity, and depth of the wastewater will likely primarily decrease during the morning peak of usage and not throughout the whole day (Penn, Schutze, & Friedler, 2013). It has also been shown that the largest reduction in velocity, which is lower than the required velocity for treatment plants, is seen when greywater is used for 100% of the toilet flushing and irrigation needs (Penn, Schutze, & Friedler, 2013).

In addition to the impact on sewer systems, greywater also may be contaminated with personal care products, such as soaps, and microbial contaminants from the human body (Penn, Schutze, & Friedler, 2013). Greywater also has the potential to increase the soil alkalinity which could harm certain plants that are pH sensitive and may reduce the transpiration rate of plants with a pH above 9 (Matos, Bentes, & Sampaio, 2012). Greywater may also increase the salt and metal content in the soil which can hinder the growth of certain plants (Matos, Bentes, & Sampaio, 2012). Due to these impacts, minor treatment of the greywater should be conducted to decrease these risks (Matos, Bentes, & Sampaio, 2012). Treatment options for greywater include basic filters and chlorine treatment (Matos, Bentes, & Sampaio, 2012). With protection in place, such as filtration, greywater systems can be a viable option for homes and businesses to consider to conserve and recycle water.

Editor's Note

Another potential impact of implementing greywater systems is they reduce the amount of water cities receive at treatment plants, which reduces the amount of reclaimed water available. This reduced water, however, may be offset by customers using less potable water for non-drinking purposes.

Sustainable home developments

A growing trend in the homebuilding industry is building sustainable, energy efficient, and water wise homes. The City of Peoria may want to consider finding ways to attract such developers to the community, and encourage developers to reduce their water usage during construction by offering incentives for using less water intensive construction materials and methods. This section will highlight several examples of efficiencies in the construction process of new homes, as well as profile several efficient home builders in Arizona and the work that they have done.

The water and energy nexus

To begin, it is important to realize that water use and energy use are closely linked (Energy Star, n.d.). The drops and watts are very connected as it takes energy to pump, heat, treat, and deliver water to homes every day (EPA, 2017). Water companies use energy to purify and pump water and treat sewage, thereby making part of the water bill actually an energy bill (Energy Star, n.d.). According to the EPA, a low estimate would be that the amount of energy it takes to treat and deliver water to 10 houses for a year could power a refrigerator for over two years (EPA, 2017). It also takes a tremendous amount of energy to heat water (EPA, 217). For example, homes with electric water heaters, on average, spend one-fourth of their total electric bills just on heating water (EPA, 2017). Therefore, reducing water usage not only helps conserve water, but also reduces water and energy bills (Energy Star, n.d.). More and more homebuilders are becoming focused on being energy efficient in their construction and design which leads to energy, water, and dollar savings.

The appliances, construction materials, and the very floor plan of a house all play a role in building an efficient home (Century 21 Northwest, 2018). Insulation, flooring, and window choices all contribute to the structure's overall sustainability. In Arizona, keeping the home cool is a must, and items such as wood tile, dual-pane windows, and ceiling fans can help keep the climate and energy bills under control (Century 21 Northwest, 2018). Design is also key as window placement and room orientation can factor into how energy efficient the home is (Century 21 Northwest, 2018). Newer, more efficient water and electrical fixtures and features can also contribute to a more energy- and water-efficient home (Century 21 Northwest, 2018).

Water and energy reduction programs

The average American uses about 88 gallons of water per day, and roughly 92% of that water goes down the drain in some capacity (Mullen, n.d.). In the face of water shortages, this high usage rate is even more concerning. Local governments can help combat this by adopting water-efficiency standards (Mullen, n.d.). There are federal, state, and third party water-efficiency standards such as the EPA WaterSense Program and the Leadership in Energy and Environmental Design (LEED) that offer minimum standards that can be adopted for water-efficient fixtures in new construction projects which make use of new technology to reduce water consumption (Mullen, n.d.). Most inefficient water use in buildings is due to inefficient water fixtures (Mullen, n.d.). To help combat this, the EPA's WaterSense program identifies and places its seal of approval on water fixtures that are, at a minimum, 20% more efficient than other products, and the LEED certification has similar mandates for water fixtures (Mullen, n.d.). Local governments can either adopt existing standards or create their own to require water-efficient fixtures in new construction or renovations to help reduce water usage and help consumers save money on water bills (Mullen, n.d.). It is recommended that the City of Peoria **adopt water efficiency standards** such as requiring EPA WaterSense or LEED certified water-efficient fixtures in all new construction and remodeling projects within the City to decrease water consumption and increase water savings. The City could also offer incentives or rebates to people who install new Energy Star or WaterSense Certified fixtures and appliances in their homes. A potential downside is that the improved water efficiency fixtures in homes could reduce the amount of water going down the drain into the City's sewer system, and thereby reduce the amount of reclaimed water that the City gains through its wastewater treatment plants.

Editor's Note
Peoria is engaged in statewide efforts to encourage state legislators to pass a bill that adopts water efficiency standards such as those listed in this section.

The EPA WaterSense program offers specifications for new water-efficient single family homes (EPA, 2008). The purpose of these specifications are to reduce the amount of water used indoors and outdoors in new residential homes, as well as, encourage community infrastructure savings (EPA, 2008). Even though the idea of green home construction is becoming more mainstream, the use of water-efficient products is still often overlooked, and there is room for improvement (EPA, 2008). Studies have shown that it is possible to build new homes that use 20% less water than other homes, and through the initiative of the WaterSense Labeled New Homes program, the hope is to transform the home building industry to exhibit increased water efficiency (EPA, 2008).

Homebuilders can obtain the WaterSense label on their homes by integrating the program into their existing green home building programs (EPA, 2008). The WaterSense New Homes Program sets both indoor and outdoor water use criteria and requires education for homeowners to help them improve their water-efficient behaviors (EPA, 2008). For homes to gain the WaterSense label, they must meet all the water efficiency criteria and be certified by a third party (EPA, 2008). Appendix H in the original student content displays the EPA WaterSense Label Water Efficiency Criteria. There are tremendous potential water, energy, and financial savings with EPA's WaterSense Program. For reference, Appendix I in the original student content lists potential savings and relevant calculations.

Figure 39 *WaterSense, Energy Star, and LEED Certification programs are desirable achievements for both homeowners and developers, as they can increase the value of a property while making it more sustainable*

Arizona home developers

There are a number of home developers in Arizona that have made green building a priority. This section will highlight several of them and describe the work that they have done.

Elliot Homes

Elliott Homes builds with the future in mind by building energy efficient homes following green building practices while exercising environmental stewardship (Elliott Homes, 2021). Elliott Homes strives to build in a way that conserves resources, reduces waste, and enhances that natural environment (Elliott Homes, 2021). Water conservation efforts include using water-conserving faucets, shower heads, and toilets, and designing the landscaping with water conservation in mind by using low-water use plants and drip irrigation systems (Elliott Homes, 2021). Elliott Homes currently has neighborhoods in Queen Creek, Phoenix, Waddell, and Yuma (Elliott Homes, 2021).

Woodside Homes

Woodside Homes stands by its motto "Better by Design" to build homes that are sustainable, reduce utility bills, and preserve natural resources (Woodside Homes, 2021). Among the many features offered by Woodside Homes are Energy-Star Certified Appliances, water saving fixtures, and energy saving plumbing (Woodside Homes, 2021). Woodside Homes currently has neighborhoods in Mesa, Buckeye, Phoenix, and Surprise (Woodside Homes, 2021).

KB Homes

KB Homes is committed to building homes that are better for the environment, and therefore, every home built is Energy Star certified and verified by a third party inspector to ensure they meet EPA's stringent certification standards (KB Homes, 2021). KB Homes are built using sustainable construction techniques and offer many energy efficient features (KB Homes, 2021). KB Homes include water conservation features such as WaterSense fixtures and EnergyStar certified appliances (KB Homes, 2021). KB Homes also offers the option to install smart systems to maximize energy and water performance (KB Homes, 2021). KB Homes currently has neighborhoods in Avondale, Buckeye, Casa Grande, Coolidge, Gilbert, Glendale, Goodyear, Marana, Maricopa, Mesa, Phoenix, Sahuarita, Surprise, Tucson, and Vail (KB Homes, 2021).

Tri Pointe Homes

Tri Pointe Homes is committed to building homes that incorporate technologies and features that are Health Smart, Energy Smart, Earth Smart, Water Smart, and Home Smart (Tri Pointe Homes, 2021). Tri Pointe Homes consider themselves Green Pioneers and won "Builder of the Year" in the 2019 Green Building Magazine (Tri Pointe Homes, 2021). Tri Pointe Homes have also been progressive in building LEED certified homes (Tri Pointe Homes, 2021). For example, their homes in Goodyear are Energy Star certified and registered with the U.S. Green Building Council and the goal is to achieve LEED Certified designation (Tri Pointe Homes, 2021). Tri Pointe Homes currently has neighborhoods in Phoenix, Chandler, Goodyear, Gilbert, Queen Creek, Peoria, and Mesa (Tri Pointe Homes, 2021).

These are just a few profiles of the sustainable home builders in Arizona that prioritize sustainability and water conservation in their design and construction. Other green home builders in Arizona include Fulton Homes, winner of EPA's 2020 WaterSense Partner of the Year Award for its water-saving construction and its WaterSense labeled homes, Meritage Homes, and Lennar Homes (Century 21 Northwest, 2018 & Fulton Homes, 2021).

RECOMMENDATIONS

- Perform a vulnerability assessment for the water supply to assist with conserving water now and provide information needed to create a framework for water resource planning as the City grows and develops.
    - Within the vulnerability assessment, identify situations where there is exposure, high sensitivity, and low adaptive capacity.
    - Monitor and re-assess the vulnerability periodically as it can change due to water conservation measures, changing regulations, climate change, and the implementation of preparedness actions.
- Consider upgrading the water reclamation facilities to further treat wastewater to safe drinking water standards.
    - If done now, Peoria could do as Scottsdale, treat the wastewater, and reinject it into the aquifer while having the capability in place for using the recycled water for direct potable reuse should Arizona law change to allow it.
- Consider the following questions regarding the enactment and enforcement of the Drought Management Plan should it be necessary.
    - How are the mandates going to be enforced?
    - If the mandates are going to be enforced with fines, how will that be done operationally?
    - How will the mandates and enforcements work from a policy standpoint?
    - How will people respond to the mandates and enforcements?
- Refer to Figure 13 in the Present Trigger Points section for suggested mitigation plan ideas in response to a water shortage.
- Refer to Figures 14-17 in the Drought Management Action Ideas for Each Stage section for drought management action ideas for the City of Peoria to implement at each drought stage should they occur.
- Consider policies that limit new expansion and development plans should a Stage One Drought be declared.
- Develop slowly in stages, and monitor the water situation while developing so that the water supply does not become over-extended especially should a water shortage occur.
- Limit high density residential developments, and require the majority of new developments be low-medium density and, where possible, mixed use areas to be low density, to reduce future water demands.

- Reduce the gap between the water supply and water demand by investigating sustainable ways to augment the water supply and look for conservation measures to reduce water demand.
- Whenever possible, replace City water intensive landscaping with xeriscaping, and when possible use xeriscaping for new landscaping.
- Require new commercial developments to use xeriscaping.
- Require new home developments to use xeriscaping for their model homes and primarily use xeriscaping for the homes. For example, all homes have xeriscape front yards.
- Offer educational workshops on rainwater harvesting systems.
- Offer incentives and rebates for installing rainwater harvesting systems on new homes and businesses and for retrofitting existing buildings.
- Like the City of Tucson, pass a law that requires at least half of the landscaping for any new building to use rainwater, and perhaps require that all new commercial buildings be designed to meet 80% of their water needs with harvested rainwater.
- Capture and treat stormwater to use in the municipal water system.
- Utilize curb cuts and basins along roadways to capture stormwater to be filtered by watering the landscaping and prevent runoff.
- Provide information to residents regarding the benefits of greywater systems and relevant rebates and tax credits.
- Provide incentives to encourage installation of greywater harvesting systems in new homes and commercial buildings.
- Implement a greywater harvesting stub-out ordinance similar to Tucson.
- Offer rebates and educational workshops for existing homeowners interested in installing greywater harvesting systems.
- Attract sustainable home developers to the community, and encourage developers to reduce their water usage during construction by offering incentives for using less water-intensive materials and methods.
- Adopt water efficiency standards for new homes and buildings such as requiring EPA WaterSense or LEED certified water-efficient fixtures in new construction and remodeling projects to decrease water consumption and increase water savings.
- Offer incentives or rebates to people who install new Energy Star or WaterSense Certified fixtures and appliances in their homes.

CONCLUSION

Peoria is a growing and vibrant city with much to offer residents and visitors alike. Though there are challenges, it is evident that Peoria is committed to sustainable growth and creating a prosperous future. With creative water management and strategic planning Peoria will continue to grow into a prosperous city.

The City of Peoria has the opportunity to continue to grow into a leader in sustainable development and water conservation. This report has offered recommendations to the City that encompass water management and drought mitigation and management strategies, water conservation and augmentation measures, and sustainable home development ideas. By its current actions and partnership on this project, the City of Peoria has demonstrated a commitment to water conservation, sustainable growth, and environmental leadership.

It will be exciting to see how the City of Peoria develops in the future and implements innovative solutions to conserve and sustainably manage their water resources while growing into a vibrant and expanding community. Including sustainable water management in future development plans will set Peoria apart as a leader in sustainability and water conservation that can be an example to the rest of the state and even the country and the world. Again, we would like to thank the City of Peoria for the opportunity to partner with them on this project, and we look forward to what the future has to hold.

Figure 40 *The expansive West Valley, looking toward Glendale, Peoria and Phoenix, as seen from North Mountain Park, Arizona*

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To access the original student reports, additional materials, and resources, visit:

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FACULTY
MAJIA NADESAN

STC 593: SOCIAL TECHNOLOGIES APPLIED PROJECT
SCHOOL OF SOCIAL AND BEHAVIORAL SCIENCES

Water Shortage Messaging

Strategic public messaging to encourage residential water conservation efforts across the City of Peoria

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INTRODUCTION

Project goals

The general purpose of the applied project is to develop guidelines for the development of water conservation digital content that will engage Peoria residents, generate awareness, and spread knowledge on the importance of saving water as a critical part of living in a desert climate. Specifically, the digital media campaign content is intended to encourage a new valuation of water conservation, and promote the City of Peoria's Sustainable University free classes, workshops, and rebate programs aimed at protecting and preserving Peoria's diverse water supply. Additionally, the proposed campaign will enable Peoria residents to be more informed and conscious of their water use, more educated about water conservation strategies, and more aware of Peoria's existing sustainability resources. The ultimate goal is to provide Peoria residents with the tools to help preserve the city's water resources.

Background

Water is a critical part of life, and a precious resource in Arizona's desert climate. Currently, Arizona is facing an enormous hurdle in controlling its water supply, especially with the compounding effects of climate change (Faller & Reid, 2019). Communities across Arizona face an elevated risk of critical water shortages in the future. The state's water needs will continue to grow as Arizona's population is expected to increase an additional 5 million people by 2050. Simultaneously, available water quantities are expected to continue declining due to drought and the effects of climate change. Arizona cities such as Peoria seek to protect themselves by working with their neighbors and communities on water supply obstacles to prevent vulnerability to the risk of drought.

The main goal of this applied capstone project is to produce a digital and social media campaign for the City of Peoria that creates a new valuation of water conservation, promotes water conservation, and builds educational awareness for city residents. In correlation with these goals, capstone student Denise Delgado aims to develop branding guidelines for water conservation digital messaging in the City of Peoria with the following objectives:

1. Test the usability of the current City of Peoria water conservation web pages.
2. Provide strong web content and design recommendations to improve the water conservation web page and engagement rates.
3. Create a digital media campaign to bring traction to the website and water conservation information.
    a. Generate blogs and articles around water conservation.
    b. Create inspiring social media content.
    c. Create an Augmented Reality (AR) phone application that inspires people to take action by generating personalized feedback based on user input.
4. Test the digital media campaign.
    a. Conduct surveys through Google Forms.
    b. Conduct A/B testing in Amazon Mechanical Turk.

Challenges

A significant number of challenges associated with the successful implementation of a water conservation digital campaign were discovered throughout the project. First, the City of Peoria Water Conservation related web pages have low engagement rates based on the site's Google Analytics results. The low engagement indicates the City of Peoria water conservation related web pages would benefit from a redesign, to make the site more user-friendly, visually appealing, and mobile-friendly. These adjustments can better encourage residents to explore current water conservation information and resources to adopt in their daily routines. Second, there is a minimal amount of social media water conservation messages developed by the City of Peoria. Additionally, existing digital media regarding water conservation tends to have overly dense visuals and lacks engaging messaging. The final challenge identified is the hurdle to create inspiring and memorable content in an era of information overload. New marketing strategies were identified, such as the use of Augmented Reality (AR), to determine what type of digital media can inspire water customers to engage in water-saving behaviors.

RESEARCH METHODS

A literature review was initially conducted to develop a baseline of knowledge to guide the subsequent research. This preliminary step identified key considerations that were carried through the rest of the report and are reflected in the project's messaging efforts. The literature review and its specific takeaways are further detailed in the following section.

Digital analysis tools were used heavily throughout the project, including Google Analytics to evaluate the City of Peoria web pages, and Facebook Audience Insights to determine demographic trends of the city's social media users. User Experience (UX) experts from Arizona State University were also consulted regarding their professional opinions of specific Peoria web pages.

Following this baseline research, a strategic water conservation digital media campaign was developed, including sample articles and posts targeted at Facebook and Instagram. Some sample media used was developed during the Fall 2019 Water Messaging project between Project Cities and Peoria, furthering the value of that initial research. The digital media campaign content was tested using three main strategies: a heuristic evaluation, A/B testing using the online crowdsourcing system Amazon Mechanical Turk, and field testing that involved open-ended and closed-ended survey questions administered through Google Forms. A meta-analysis of the specific qualitative and quantitative data revealed three encompassing themes incorporated into the specific recommendations for the water conservation digital media campaign dissemination. Those themes included: (1) the importance of user-friendly water conservation web pages; (2) the value of adopting new marketing tactics such as augmented reality; (3) the importance of creating inspiring social media content.

It is important to note the digital marketing campaign was partly inspired by research results published by Kristen Cockerill et al., an associate professor at Appalachian State University with over 15 years of experience in environmental policy. The research concludes that most people would prefer solving water conservation issues themselves rather than having the government intervene and mandate conservation practices (Cockerill et al., 2016).

FINDINGS AND ANALYSIS

Literature review

To generate a successful digital water conservation campaign that stimulates sustainable water behaviors, it is critical to explore and understand the specific contributors that can help change said behaviors. Koop et al. (2019) distinguished 8 different Behavioral Influencing Tactics (BITs) that target long-term water conservation behavior within households. The analysis in this research is arranged around 3 information processing paths, reflective, semi-reflective, and automatic. Their study indicated that promoting conservation behavior with information transfer, such as simple statistics, is not inspiring enough.

In order to initiate specific water-saving habits in residents, the literature suggests the need for combined use of a variety of BITs into the overall messaging strategy (Koop et al., 2019, p.874). "Especially the role of repetitive messages, primes, and nudges that reinforce previously introduced normative messages, tailored feedback, or knowledge, seem to be promising approaches to sustaining water conservation behavior in the long run" (Koop et al., 2019, p.874). For example, tailoring feedback messages based on individual household water usage has been proven to increase responsiveness. Personalized feedback on current home water use can potentially invoke discomfort by acknowledging the dissonance between a person's water use and their attitude towards water, ultimately triggering water conservation behaviors (Koop et al., 2019, p.869). In addition to tailored feedback, well-designed priming tactics can reinforce long-term water conservation behavior (Papies, 2016). Water utility companies can apply priming tactics through communication in their water bills, websites, or social media sites.

Studies have also demonstrated that normative messages are very useful in changing water conservation behaviors long-term by repeating normative messages such as communicating a household's water use as part of a rank of all households in the neighborhood (Koop et al., 2019, p.871). Lastly, message framing is of critical importance. "Experimental research has observed that messages framed as suggestive, emphasizing direct impacts, or appealing to intrinsic motivation are more persuasive" (Koop et al., 2019, p.669). An example of suggestive framing is a message that asks people to “please consider conserving water” instead of stating "you must conserve water." Additionally, it was found that animated videos or images can have the potential to evoke positive or negative emotions that help people learn and make more eco-friendly decisions.

Concerning combining BITs, Perren et al. (2019) did an excellent job integrating multiple BITs to promote water conservation behaviors for residential consumers. Perren et al. implemented persuasion into technology by presenting the water user classification (WUC) as the function of a decision support system (DSS) to link personal value systems and social norms, subsequently encouraging water conservation behavior (Perren et al., 2016, p.429). The DSS is a wireless system that not only monitors home water use but also displays water consumption levels through a mobile application to promote environmental behavior. The phone application utilizes two influential behavior change strategies; inconsistency and normative influence (Perren et al., 2016, p.430). The WUC function collects self-reported information regarding water-related behaviors and values. Data combined from the WUC function and DSS create personalized feedback for the homeowner. For example, feedback is demonstrated based on the connection between consumer behavior (e.g., taking a shower) and water usage. A personalized message follows, providing conservation tips that consider the household's recent water use patterns. Water consumers see messages such as, "You are a high tech/high use consumer. High tech households like yours save water and energy by adopting efficient technology." The WUC function and its contribution to the DSS are a perfect example of the behavior change theory's significant function in articulating successful technology-based interventions (Perren et al., 2016, p.429).

Aside from applying BITs to change water conservation behaviors, Parker et al. (2018) examine the effectiveness of two types of marketing interventions, green advertising, and indirect persuasion, on water conservation behavior to link behaviors to self-reported conservation claims. It was found that educational advertising produced by government agencies has been effective in changing consumers' short-term behavior (Phipps and Brace-Govan, 2011). However, it was indicated that government agencies' biggest challenge is keeping people interested in water savings. It was found that people can be convinced to change their behavior to conserve water by using an indirect persuasive advertisement with a green appeal or marketing for water-saving technologies and products. The authors highlighted that marketing is the tool most likely to achieve permanent behavior change because it balances the rights of the individual with the rights of society, allowing people to maintain the right of choice and to use free will to choose to engage in positive change (Rothschild, 1999).

Furthermore, Gregory and Leo (2013) measured attitudes in Australia to understand barriers to water conservation. The two authors examined influential factors, including reasoned influence (cognitive processes); unreasonable influence (habits); and situational influence (size of family, income). Their results demonstrated that people who are conscious of their water use conservation still had medium to high water bills. This research shared insight on the most viable way to change habits through reasoned influences and involvement. To succeed in changing behaviors, the general public must feel they are part of decisions and conversations. To achieve conservation behaviors, new habits need to be formed through water conservation campaigning.

New marketing strategies need to be adopted to create a water conservation campaign that is engaging and appealing. Rajappa and Raj (2016) explore the concept and applications of Augmented Reality (AR). AR allows brands to build a real-world simulation of objects enabling users to manipulate and interact with a digital environment (Rajappa & Raj, 2016, p.435). AR also creates an interactive, user-friendly environment. For example, the Zombies, Run!, phone application did an excellent job utilizing AR to encourage users to adopt an active lifestyle. The application combines the user's daily workout with missions and sound techniques, including zombies that encourage users to run faster. It also features an entertaining storyline that inspires users to look forward to their workout instead of dreading it (Rajappa & Raj, 2016, p.439).

Likewise, AR can be adopted to encourage water conservation behaviors amongst the City of Peoria residents. According to a study by Rauschnabel et al. (2019), the authors hypothesize how consumers perceive the benefits of AR applications. The study reveals consumer inspiration as a mediating construct between the benefits consumers acquire from AR apps and changes in brand attitude (Rauschnabel et al., 2019, pg. 43). Ultimately, it is found that AR provides unique approaches to interact with products, services, offers, raise awareness on issues, promote features, and inspire a desire to engage. AR apps can also influence word-of-mouth behaviors through increasing knowledge and encourage high levels of inspiration that can drive a strong influence on behavior change (Rauschnabel et al., 2019, pg.49).

Overall, the literature review revealed a combination of three key factors that can help build a successful digital water conservation campaign. First is combining different BITs that target long-term water conservation behavior within households. Second is utilizing an indirect persuasive advertisement with a green appeal or a product strategy (e.g., eco-feedback or water saving technology marketing strategy). Third, bringing awareness to residents' water use through influences and involvement. Combining these factors to create a digital marketing campaign that promotes conservation behaviors using an AR application and digital content that includes BITs, eco-feedback, and suggestive messages can encourage eco-conscious decisions from Peoria residents.

Methods and analysis

This research project consists of qualitative and quantitative analysis to identify success factors that will increase water conservation behaviors amongst the City of Peoria residents. Qualitative analysis will provide descriptive feedback and interpretation of the City of Peoria website and the Augmented Reality application. The quantitative data will include descriptive and conceptual information regarding the content and characteristics of the social media campaign. Exploring the results around the water conservation digital media campaign will provide new insight into what will trigger audiences to alter their behaviors and attitudes surrounding water.

Methods

The methods adopted for this digital campaign include a heuristic evaluation to test the City of Peoria's website, an A/B Testing of social media content conducted through Amazon Mechanical Turk (MTurk), and surveying via Google Forms to collect feedback on the Water Conservation AR App. The definition of heuristic evaluation provided by the Interaction Design Foundation reads: "a website usability test is the evaluation of a website to determine the goal to identify any usability problems, collect qualitative and quantitative data, and determine the participant's satisfaction with the website." Usability testing is a critical part of this digital campaign to ensure the City of Peoria's water conservation pages provide an effective, efficient, and enjoyable experience for residents.

The second method utilized is A/B testing through Amazon Mechanical Turk to analyze the social media campaign visualizations and messaging strategies. The test will demonstrate which marketing asset (the social posts about water conservation or the Water Conservation AR App) is the most engaging and accessible to the audience. Lastly, Google Forms will be utilized to collect qualitative information on adopting an Augmented Reality application to push water conservation messages. The quantitative and qualitative methods will evaluate the appeal of the generated water conservation campaigns to single out (un)successful factors to generate a more effective campaign that will successfully encourage water conscious behaviors.

Website review

Websites are a critical piece of a digital marketing strategy, which is why investigating the Google Analytics on the City of Peoria water conservation pages is essential. The Google Analytics filtered for the expression "water-conservation" on www.peoriaaz.org indicated a total of 21 pages containing water conservation information. From January 1, 2019, through December 31, 2019, there were 6,686 visitors on the web pages that concerned water conservation out of the 3,265,603 (0.20%) that visited www.peoriaaz.org. It should be noted that page engagement on web pages concerning water conservation had a 57.75% bounce rate (visitors who navigate away from the site after viewing only one page) and a 39.77% exit rate (visitors who left the site from that page). Redesigning and updating the water conservation webpages can increase engagement and provide effective communication on water usage from the city, in turn educating residents on their water conservation behaviors. Figure 1 shows the full Google Analytics web report filtered for water conservation information.

Analytics 1 - https://www.peoriaaz.gov
All Web Site Data

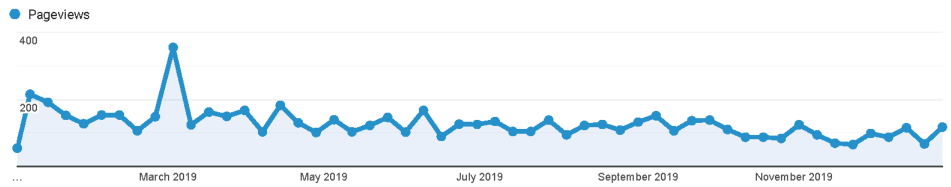
Go to report

Pages

All Users
100.00% Pageviews

Jan 1, 2019 - Dec 31, 2019

Explorer



This data was filtered with the following filter expression: **water-conservation**

	Page	Pageviews	Unique Pageviews	Avg. Time on Page	Entrances	Bounce Rate	% Exit	Page Value
		6,686 % of Total: 0.20% (3,265,603)	**5,807** % of Total: 0.22% (2,660,084)	**00:01:42** Avg for View: 00:01:14 (37.75%)	**2,298** % of Total: 0.19% (1,220,812)	**57.75%** Avg for View: 45.41% (27.16%)	**39.77%** Avg for View: 37.38% (6.38%)	**$0.00** % of Total: 0.00% ($0.00)
1.	/government/departments/water-services/water-conservation/rebate-programs	**2,333** (34.89%)	1,955 (33.67%)	00:01:15	638 (27.76%)	42.16%	25.98%	$0.00 (0.00%)
2.	/government/departments/water-services/water-conservation/rebate-programs/irrigation-controller	**1,455** (21.76%)	1,273 (21.92%)	00:02:13	601 (26.15%)	75.21%	51.68%	$0.00 (0.00%)
3.	/government/departments/water-services/water-conservation	**1,197** (17.90%)	1,033 (17.79%)	00:02:04	535 (23.28%)	59.63%	43.44%	$0.00 (0.00%)
4.	/government/departments/water-services/water-conservation/rebate-programs/xeriscape-conversion	**730** (10.92%)	654 (11.26%)	00:02:45	231 (10.05%)	71.43%	53.97%	$0.00 (0.00%)
5.	/government/departments/water-services/water-conservation/rebate-programs/high-efficiency-toilets	**548** (8.20%)	497 (8.56%)	00:02:19	113 (4.92%)	80.53%	55.66%	$0.00 (0.00%)
6.	/government/departments/water-services/water-conservation/rebate-programs/xeriscape-new-home	**200** (2.99%)	181 (3.12%)	00:01:57	36 (1.57%)	55.56%	35.50%	$0.00 (0.00%)
7.	/government/departments/public-works-and-utilities/water/water-conservation/rebate-programs	**74** (1.11%)	71 (1.22%)	00:00:01	70 (3.05%)	0.00%	0.00%	$0.00 (0.00%)
8.	/i-want-to-/find-learn-or-view-about/water-conservation	**68** (1.02%)	66 (1.14%)	00:00:01	1 (0.04%)	0.00%	0.00%	$0.00 (0.00%)
9.	/government/departments/public-works-and-utilities/water/water-conservation/rebate-programs/irrigation-controller	**24** (0.36%)	23 (0.40%)	00:00:01	23 (1.00%)	0.00%	0.00%	$0.00 (0.00%)
10.	/government/departments/public-works-and-utilities/water/water-conservation	**20** (0.30%)	19 (0.33%)	00:00:01	19 (0.83%)	0.00%	0.00%	$0.00 (0.00%)
11.	/government/departments/public-works-and-utilities/water/water-conservation/rebate-programs/high-efficiency-toilets	**18** (0.27%)	16 (0.28%)	00:00:01	15 (0.65%)	6.67%	5.56%	$0.00 (0.00%)
12.	/government/departments/public-works-and-utilities/water/water-conservation/rebate-programs/xeriscape-conversion	**7** (0.10%)	7 (0.12%)	00:00:02	5 (0.22%)	0.00%	0.00%	$0.00 (0.00%)
13.	/PeoriaAZ6/government/departments/public-works-and-utilities/water/water-conservation/rebate-programs	**4** (0.06%)	4 (0.07%)	00:00:00	4 (0.17%)	100.00%	100.00%	$0.00 (0.00%)
14.	/government/departments/public-works-and-utilities/water/water-conservation/rebate-programs/xeriscape-new-home	**1** (0.01%)	1 (0.02%)	00:00:00	0 (0.00%)	0.00%	0.00%	$0.00 (0.00%)
15.	/government/departments/water-services/water-conservation?fbclid=IwAR090MBPqvAWmld77f5GWAP-wZjE-DOt7zqHNEvwhRoe2h77pa7IbJedSQM	**1** (0.01%)	1 (0.02%)	00:00:00	1 (0.04%)	100.00%	100.00%	$0.00 (0.00%)
16.	/government/departments/water-services/water-conservation/-fbclid-IwAR0C8LsMkFSsfRDVb0Fd429VHaakJBnf7j-RK-BtRc4UbuhhNUlJdlwV1FA	**1** (0.01%)	1 (0.02%)	00:00:00	1 (0.04%)	100.00%	100.00%	$0.00 (0.00%)
17.	/government/departments/water-services/water-conservation/-fbclid-IwAR2-mPUbilSKsBASXL6lzYCfSrd9YP_x7j697-98Pnrn5_yLq_1QOIXFXfM	**1** (0.01%)	1 (0.02%)	00:00:00	1 (0.04%)	100.00%	100.00%	$0.00 (0.00%)
18.	/government/departments/water-services/water-conservation/-fbclid-IwAR2k6BljCrcF6JcTyCk42vY_XzTZD1U5EBfkEdddTRGTrrwRbppOoENE_3Y	**1** (0.01%)	1 (0.02%)	00:00:00	1 (0.04%)	100.00%	100.00%	$0.00 (0.00%)
19.	/government/departments/water-services/water-conservation/rebate-programs?fbclid=IwAR0hrgvGsfk4Q0l3ra6-WSu4uhbQDZbtVJEZmQVSFIDbXg3zRzgK6Gq1oGE	**1** (0.01%)	1 (0.02%)	00:00:34	1 (0.04%)	0.00%	0.00%	$0.00 (0.00%)
20.	/government/departments/water-services/water-conservation/rebate-programs?fbclid=IwAR1TsqZSN0-0_wfsdAEf6PXmDqWqphmbHgaqih5P39HT1zs7zDb6SdUR2Po	**1** (0.01%)	1 (0.02%)	00:00:00	1 (0.04%)	100.00%	100.00%	$0.00 (0.00%)
21.	/government/departments/water-services/water-conservation/rebate-programs?fbclid=IwAR2bKgaqKlGSwNgp9I0hRVAB6hgUm7HKJBdxblwekCSBFEnPKYpVLmCoH08	**1** (0.01%)	1 (0.02%)	00:00:00	1 (0.04%)	100.00%	100.00%	$0.00 (0.00%)

Figure 1 *City of Peoria website Google Analytics Report filtered for water conservation information*

After analyzing the water conservation pages on the City of Peoria website, the reported low page views, and high exit and bounce rates clearly illustrated the need to further analyze the pages' usability. A heuristic evaluation was used to determine the website's usability. "A heuristic evaluation is a type of user interface (UI) or usability inspection where an individual, or a team of individuals, evaluates a specification, prototype, or product against a brief list of succinct usability or user experience (UX) principles or areas of concern" (Wilson, 2014, pg. 2). Figure 2 includes the Heuristic Evaluation Checkpoints utilized as a mnemonic device for the panel of three usability experts Scott Pennelly, Alec Lund, and Ruth Dempsey. The purpose of the UX Testing is to determine design inconsistencies and usability problems that can help explain why the web pages in question have low engagement as portrayed by the web analytics.

Heuristic evaluations recognize common usability problems and serve as a method to discover what aspects of web design can lead to low engagement or general usability problems. Scott Pennelly, Alec Lund, and Ruth Dempsey were chosen to evaluate the user interface of the City of Peoria water conservation webpages against a set of heuristic principles due to their user, design, technical, and interaction knowledge, in addition to their experience and expertise. Scott Pennelly is a Web Specialist at Arizona State University with over 5 years of user experience. Alec Lund is a Graphic Design and Web Specialist at Arizona State University with over 4 years of web design experience. Ruth Dempsey is a Web Administrator at Arizona State University with over 10 years of experience. The heuristic evaluation will collect reviews from the 3 UX specialists to provide insight, data, and feedback on the following heuristic principles:

1. Homepage
2. Task Orientation
3. Page Layout and Design
4. Navigation and Information Architecture
5. Writing Content and Quality

Usability experts were provided a checklist for each Heuristic principal and a list of tasks in a workbook. For each checklist item, UX experts were asked to enter a rating of -1 (does not comply with the guideline), +1 (complies), or 0 (kind of complies). UX experts were also encouraged to share feedback and comments in the workbook, next to each checklist item. Once UX experts submitted their workbooks, the results were analyzed.

Figure 2 summarizes results from UX experts Scott Pennelly, Alec Lund, and Ruth Dempsey. Full results, including additional comments from the panel of experts, are available in Appendix A of the original student content.

Expert panel heuristic evaluation scores for Peoria website				
Scores from expert Scott Pennelly				
Heuristic Principle	***Raw Score***	***Questions***	***Answers***	***Score***
Homepage	11	18	18	81%
Task orientation	3	30	26	56%
Page layout and design	7	35	34	60%
Navigation and information architecture	8	21	21	69%
Writing content and quality	5	20	20	63%
Overall score	**34**	**124**	**119**	**66%**
Scores from expert Alec Lund				
Heuristic Principle	***Raw Score***	***Questions***	***Answers***	***Score***
Homepage	1	18	18	53%
Task orientation	-23	30	30	12%
Page layout and design	-9	35	35	37%
Navigation and information architecture	-3	21	21	43%
Writing content and quality	-6	20	20	35%
Overall score	**-40**	**124**	**124**	**36%**
Scores from expert Ruth Dempsey				
Heuristic Principle	***Raw Score***	***Questions***	***Answers***	***Score***
Homepage	2	18	18	56%
Task orientation	-6	30	25	38%
Page layout and design	-4	35	24	42%
Navigation and information architecture	-4	21	21	40%
Writing content and quality	0	20	16	50%
Overall score	**12**	**124**	**105**	**45%**

Figure 2 *Summary of Heuristic Principle scores from panel of ASU usability experts*

Heuristic evaluation feedback

Based on the information captured from the panel of UX practitioners, the most critical aspects that could be altered to increase engagement on the water conservation web pages include making fundamental typography hierarchy changes. Namely, distancing the type sizes more dramatically and removing the use of all caps. Additionally, utilizing Call-to-Action (CTA) buttons rather than plain hyperlinks makes them more visible, increasing their chances of being clicked. Less text and more calls to action are necessary changes to encourage user participation on the web pages.

A high amount of repetitive information was also noted on each page. The UX experts suggest to further organize the content to reduce the number of clicks and cut down the bulk of site navigation. The overall goal is to make the content display more exciting and less mundane. For that reason, it is advised to remove unnecessary elements (e.g., font size buttons), use relevant graphics only when needed, and add helpful icons throughout the site. These recommendations would help declutter the water conservation webpages.

Some elements the UX experts suggested to increase engagement on the water conservation pages from users was to introduce complicated topics using icons or infographics. In doing so, the icons or infographics reduce a large amount of text and engage the user. The web specialists mentioned that depending on the level of urgency and priority of the water conservation campaign, there should be a banner on the Peoria website's homepage. Additionally, there was a discussion about features and functionality that the website would benefit from. The first feature mentioned was introducing an online form to participate in helping collect information instead of paper mail for publications like Landscape Plants for the Arizona Desert or Landscape Watering by the Numbers. Secondly, creating specific landing pages to be used when marketing any of the marketing programs to quickly introduce users to their rebate options with clear CTAs. Lastly, the use of a series of 30-second videos introducing the idea to explain the importance of conservation, steps residents can take to conserve, and an explanation of the rebate programs would be beneficial.

Following the collection of UX Heuristics, Adobe XD (a vector-based user experience design tool for web and mobile apps) was utilized to bring the recommendations from the UX experts to life. A total of six City of Peoria wireframes were prototyped in Adobe XD: the Homepage, the Water Conservation webpage, the Water Rebate Program webpage, the High-Efficiency Toilet Rebate webpage, the Smart Irrigation Controller Rebate webpage, and the Xeriscape Rebate Program page. The wireframes are a visualization of what the webpages can look like if the design feedback from the UX experts is applied to make the web pages more engaging.

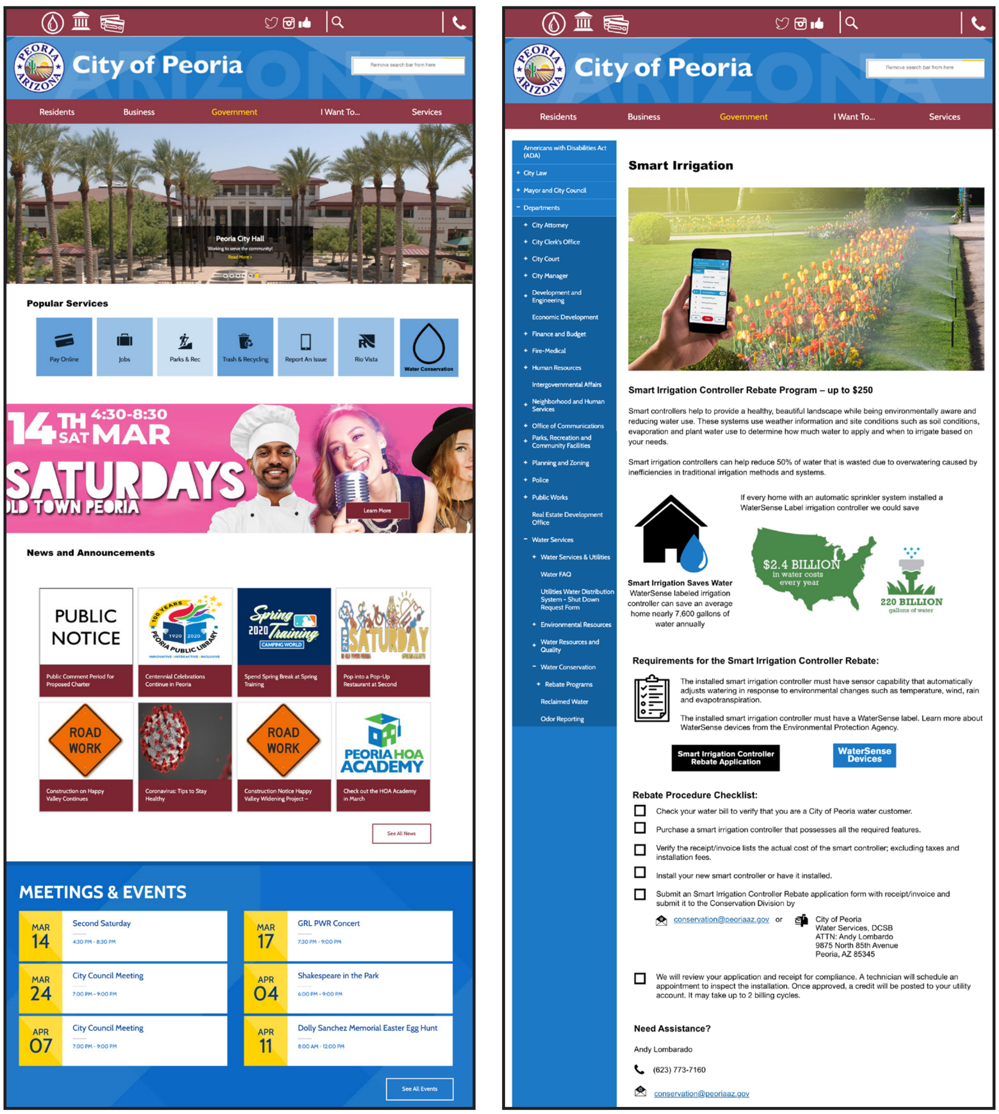


Figure 3 *Wireframes for suggested Peoria website updates based on expert feedback from the heuristic evaluation*

Digital content

The goal of the digital media content is to encourage a new valuation of water conservation, and teach and habituate conservation behavior by generating awareness, knowledge, and engagement on the City of Peoria social media platforms. A critical part of a social media engagement strategy is the conversion. In this case, the conversion is water conservation brand awareness. This means posting content regularly that provides followers engaging and relevant information about water conservation that includes links to blog posts, infographics, statistics, or relevant articles. To generate social media content that will be successful and have high conversion rates, it is critical to understand the audience's demographics and psychographics. Demographics outline who the audience is, and psychographics define the audience's motivation to sign-up for water rebate programs, adopt water conservation behaviors, and reshare the information (Hussain, 2019).

Social media audience analysis

Facebook Audience Insights was used to identify and research the City of Peoria social media audience. The segmented audience chosen was people located in Peoria, Arizona above age 25. Demographics demonstrated that 59% of Peoria users are female, and 41% are male (Figure 4). Additionally, 67% of this population is married, 19% is single, 11% is in a relationship, and 3% is engaged (Figure 5). Data from Facebook Audience Insights demonstrated that 31% of this population has a high school education, 62% is college-educated, and 8% is in graduate school (Figure 5).

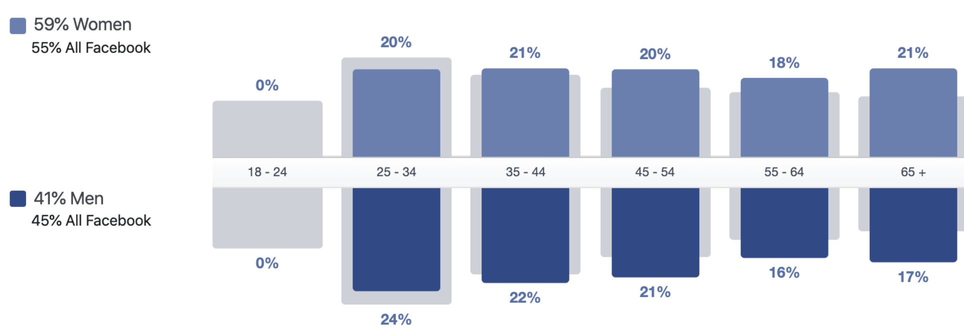


Figure 4 *Peoria Facebook user segmented audience age demographics, by Facebook Audience Insights*

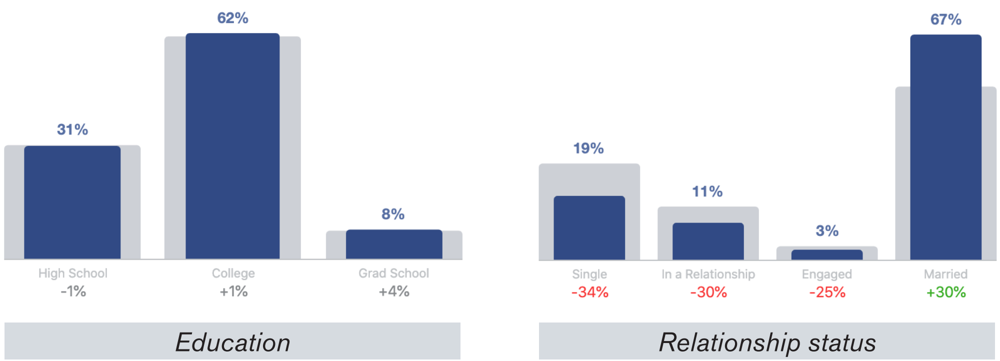


Figure 5 *Peoria Facebook user segmented audience education and relationship status demographics, by Facebook Audience Insights*

The segmented audience selected is about 30% more active on Facebook compared to the rest of the Facebook users in the U.S. For instance, the average number of comments by the selected audience was 12, compared to 8 from the average Facebook user. Additionally, the segmented group is more likely to like a post and engage with a Facebook advertisement than other Facebook users. The segmented audience accesses their social media platform predominantly through mobile phones, 49% are iPhone/iPod users, and 42% are Android users. Figure 6 illustrates the segmented audience's activity in detail.

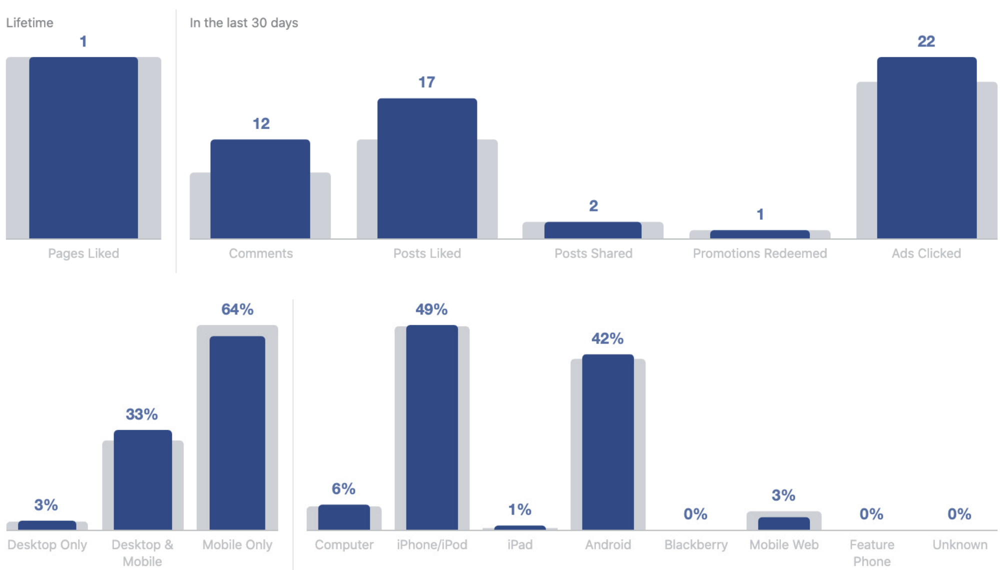


Figure 6 *City of Peoria Facebook user segmented audience activity, by Facebook Audience Insights*

Based on the Facebook pages the segmented audience engages with the most, such as Upper West Side PHX, Peoria Unified School District, and Peoria AZ Parks and Recreation, the content the segmented audience is likely to engage with is informative, visual, and compelling. Almost all posts they engage with include site links to blogs, product ads, image extensions, locations, reviews, or ratings. They engage with local news and radio brands, local restaurants, and the City of Peoria public service pages, such as public schools and police departments. The audience appears to seek beneficial information, illustrated by their engagement with event and community information pages.

Social media content curation

Based on information from Facebook Audience Insights and the goal to promote water conservation, one part of the social media content plan was to generate informative and inspiring blogs or articles pertaining to water conservation. To help produce informative articles, two participants were interviewed. The first interviewee was Thomas Cahill, an associate professor in the School of Mathematical and Natural Sciences at Arizona State University. The focus of the interview was xeriscaping in Arizona to reduce outdoor water waste and promote the City of Peoria's xeriscape rebate programs. The interview was conducted face-to-face at Professor Cahill's home. Professor Cahill was audio recorded during the interview and key points throughout the conversation were written down. The interview was conversational, general concepts and open-ended questions about xeriscaping were discussed. After the conversational aspect of the interview was done, photos of Professor Cahill's xeriscape yard were taken.

The second interview was conducted with Cape Powers, the City of Peoria Water Director, and Victoria Caster, the City of Peoria Sustainability and Water Conservation Coordinator. The focus of the interview was water conservation in Arizona. It was conducted face-to-face and took place at Peoria City Hall. During the interview, Cape and Victoria were asked the following questions:

1. Where does our drinking water come from? Do you think your friends and family know the source of their drinking water? Would it make a difference if they knew?
2. How much water do we use on a yearly basis?
3. What if this 19-year drought continues for the next 5 years?
4. How is Arizona or the City of Peoria different from other cities? How is it similar and what have those cities done to work towards conservation?
5. What are the potential outcomes of residents not being conservative regarding their residential water sources? (ex: water limits, water bill increase?)
6. What are the best strategies to market water conservation behaviors?
7. What are the top 5 water conservation strategies you would recommend City of Peoria residents to adopt?
8. Should our water conservation behaviors change with each season?

The interview was audio-recorded and key points were annotated in a notebook. Following both interviews, the audio was transcribed to text using the Transcribe program. The text was then reviewed and edited to ensure it accurately matched the audio recording. Lastly, the photos taken at professor Cahills' home were uploaded and edited in Adobe Photoshop and added to the xeriscaping article. Upon finishing the photo edits and transcription review, the interviews were utilized to create social media content and articles.

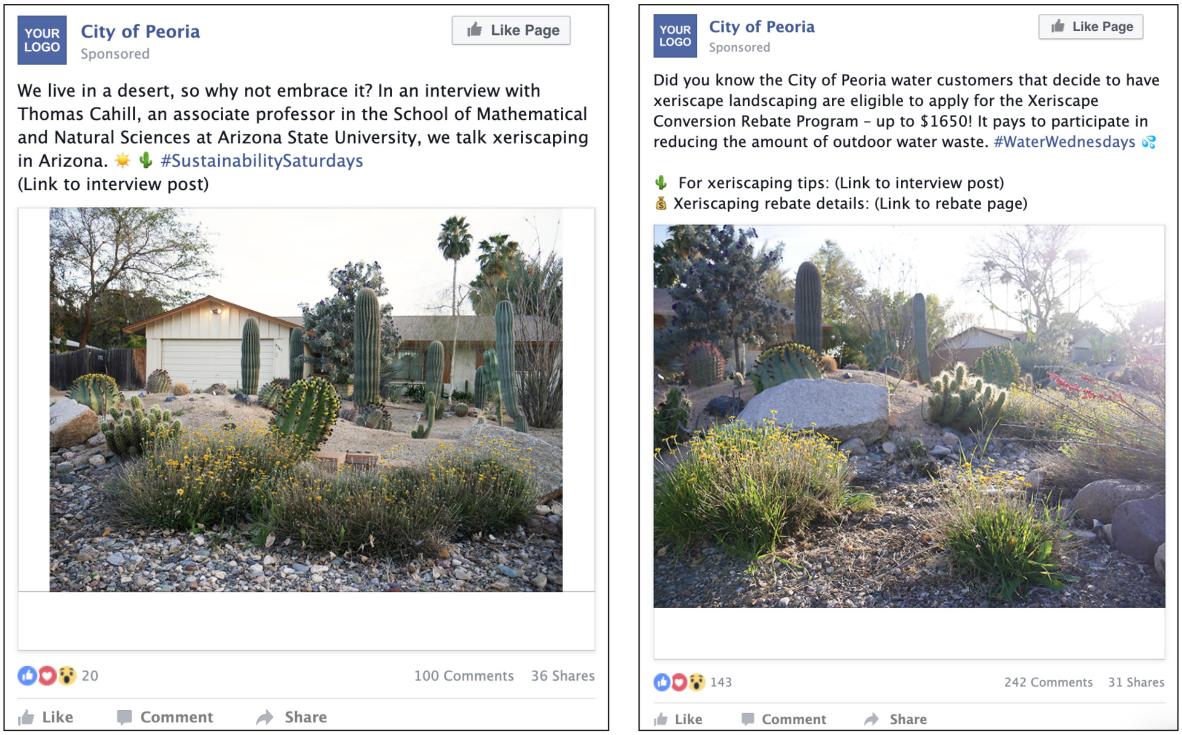


Figure 7 *Sample Facebook posts intended to spread awareness about the benefits of xeriscaping, by Denise Delgado*

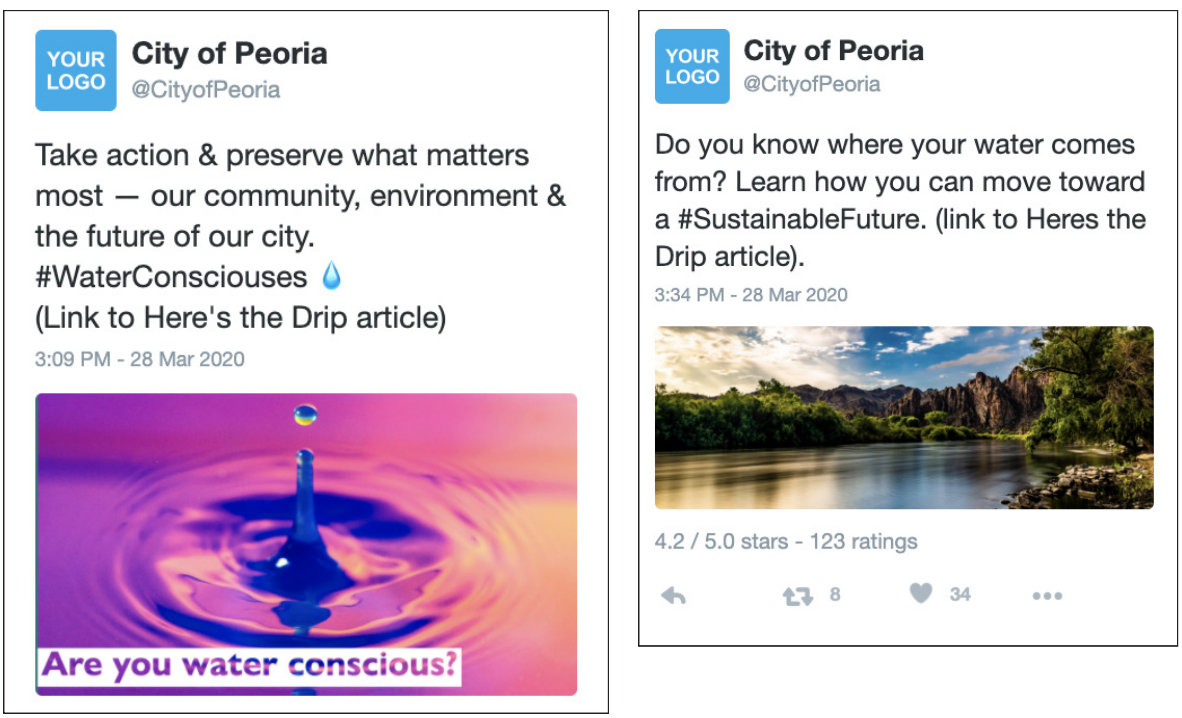


Figure 8 *Sample Twitter posts which would link to informational water conservation articles or other materials, by Denise Delgado*

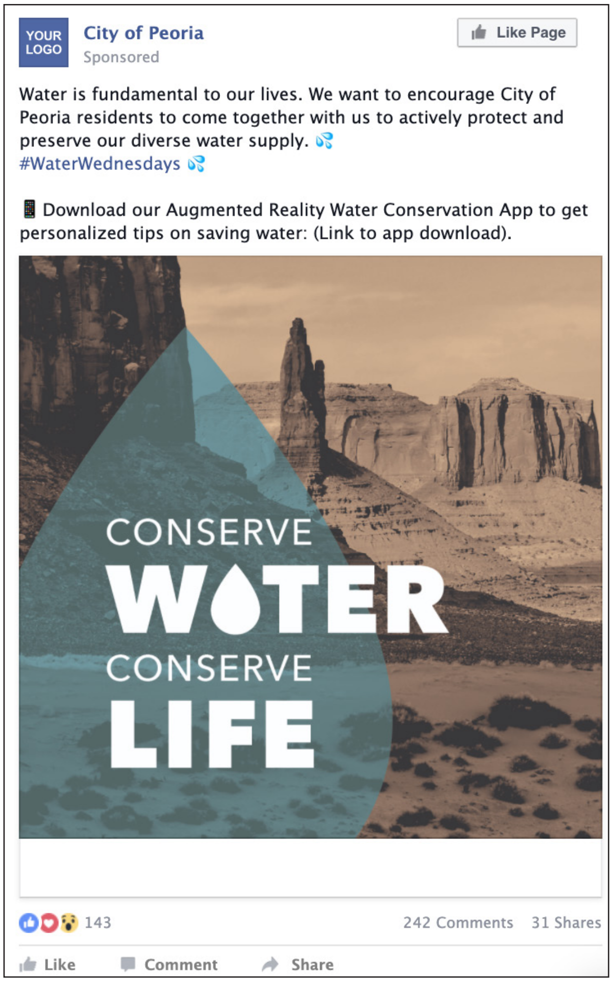


Figure 9 Sample augmented reality app promotion post, by Denise Delgado, main graphic by Knowledge Enterprise staff

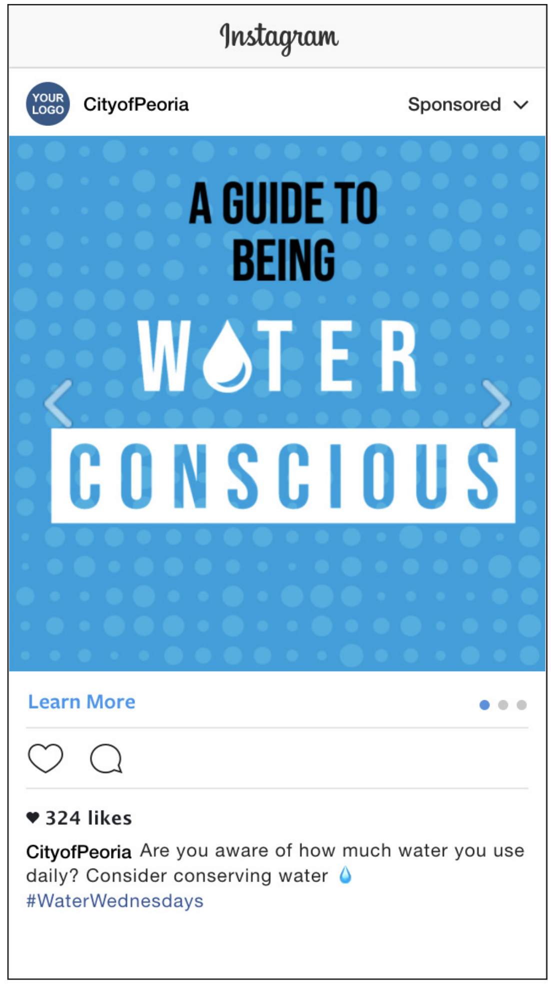


Figure 10 Sample Instagram carousel post, by Denise Delgado

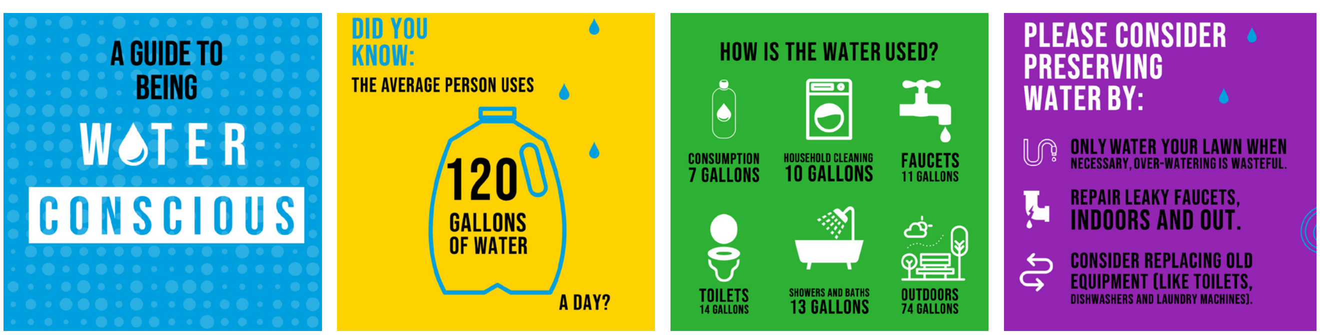


Figure 11 Additional sample graphics for Instagram carousel post, by Denise Delgado

Social media content A/B test

A/B testing of the proposed social media content was conducted with online crowdsourcing via Amazon Mechanical Turk. Online crowdsourcing is one of the most widely used methods to conduct behavioral experiments with large numbers of people. In comparison to the traditional way of performing offline experiments or using surveys, online crowdsourcing enables researchers to collect massive amounts of data. It requires less effort to recruit participants, set up the experimental environments, and run the experiments. Additionally, the quality of experimental results from crowdsourcing is almost the same as that from offline-recruited participants. “MTurk functions as a one-stop-shop for getting work done, bringing together the people and tools that enable task creation, labor recruitment, compensation, and data collection” (Buhrmester, Kwang, Gosling, 2011, pg. 3). As a “requester,” two social posts are generated and then compared against each other in an A/B test where “workers” virtually complete the A/B task. A/B testing provides data on marketing material variations to determine which is most effective with the audience.

In this case, the workers that participated in the A/B test through Mechanical Turk had similar demographics as residents in the City of Peoria. According to the 2018 United States (U.S.) Census Bureau, approximately 92.7 percent of Peoria residents that are over 25 years old have minimally graduated from high school. The median household income in the City of Peoria is approximately $69,589, and on average, 72 percent of residents own their homes (U.S. Census Bureau, 2018). Additionally, according to Facebook Audience Insights, 67% of this population is married, 19% is single, 11% is in a relationship, and 3% is engaged. The specifications and qualifications workers were required to meet to work on the A/B test included:

- Current residence - owned
- A Facebook account holder
- Household income $50,000-$74,999
- U.S. High School Graduate
- Marital status: married

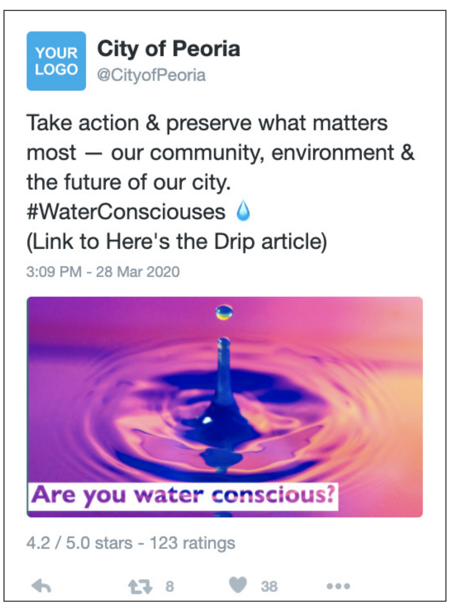
A total of 30 workers participated for a $0.50 reward for the assignment. The use of Amazon MTurk cost a total of $16.50, $15 to pay for task completion and $1.50 for using premium qualifications. Once workers agreed to complete the assignment, they were asked to A/B test the following questions:

1. Which post is most likely to get you to check out xeriscaping rebates?

A

B

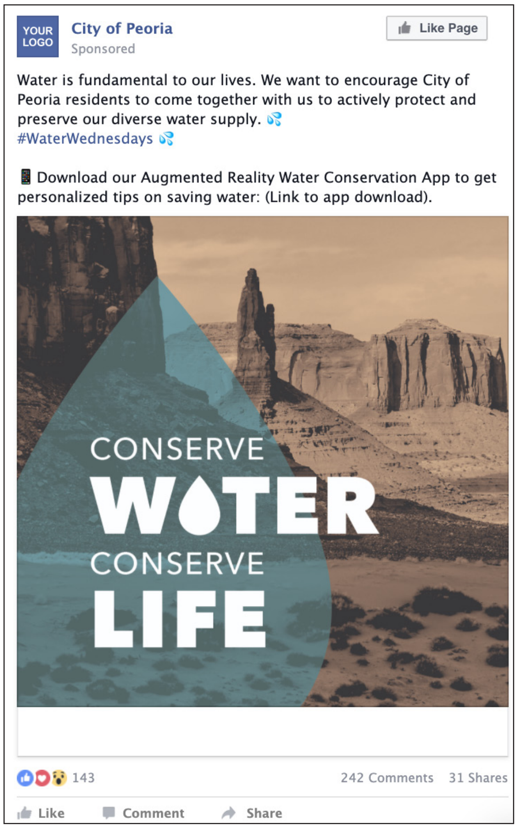
2. Which post is most likely to get you to click on the link to the article about being water conscious?



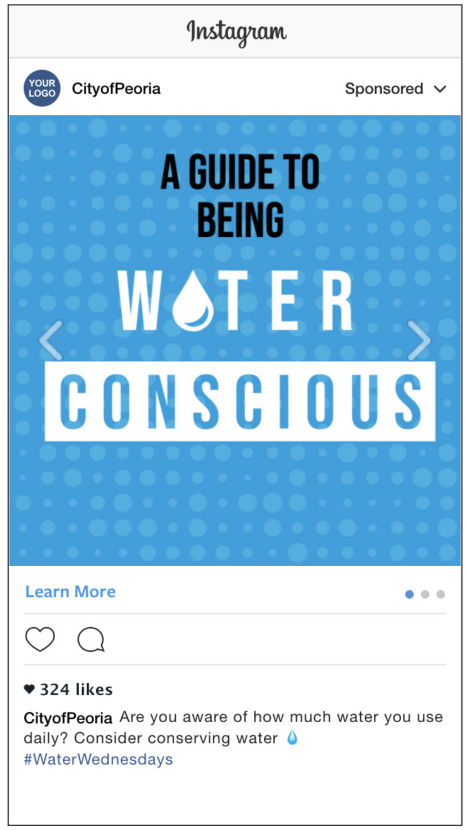
A

B

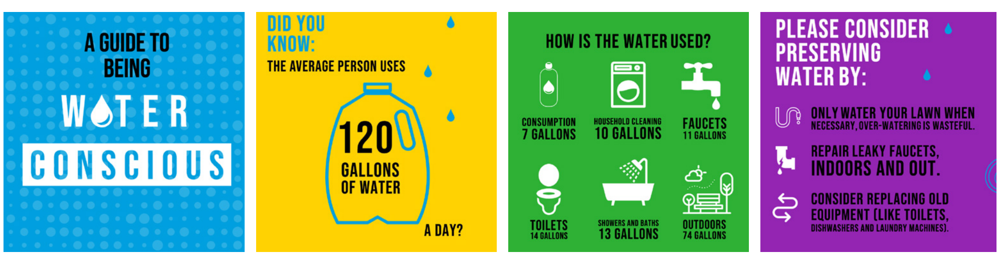
3. Which of the two posts below would inspire you to conserve water the most?



A



B



Remaining graphics in option B

A/B test results		
Question	***A***	***B***
Which post is most likely to get you to check out xeriscaping rebates?	27%	73%
Which post is most likely to get you to click on the link to the article about being water conscious?	57%	43%
Which of the two posts below would inspire you to conserve water the most?	19%	81%

Figure 12 *The A/B testing demonstrated a strong preference toward the Instagram carousel post, and the xeriscaping rebate Facebook post*

Augmented reality

A Water Conservation Augmented Reality (AR) phone application was prototyped to inspire Peoria residents to adopt water conservation behaviors. The AR app provides messages tailored and based on the household's water use displayed on their monthly water bill from the City of Peoria. Upon opening the application, users are prompted with the following question: "Based on this month's water bill, which one of the following best describes your water usage?" Below the question is an interactive user classification panel with three options: High, Intermediate, and Low. Based on the user's selection, a new User Interface (UI) will open with a pop-up message that includes tailored feedback regarding water use, combined with a social normative message relating to water use from other Peoria residents. For example, if High Use is selected, the user will see the following message: "Compared to other City of Peoria residents, you have a low level of environmental awareness regarding water consumption. Your household's day to day routine utilizes a lot of water and energy." The messages are framed so that Peoria residents experience a cognitive dissonance between the feedback information and their actual water use (Koop et al., 2019, p.871).

Following the feedback message, users will be presented with water-saving tips tailored to their individual water use. Once the water-saving tip appears, users are promoted to swipe, and the device camera will open. The Water Conservation AR application is marker-based, which means that to view the augmented reality component, the device camera must be pointed at a specific marker; in this case, the marker is an image. Three different marker images are applied to the app (one for each type of user classification). Once the phone recognizes the image, the application will overlay the image and enable the user to see the augmented reality. The AR illustrations are three different water-saving tips.

For instance, if the user selected High Use, the AR illustration begins, and an image of the backyard of a home with a green garden and lawn with a variety of plants will display with a message that says, "Convert your high water use landscaping to Xeriscape." After swiping or clicking on the pop-up, the green garden will get converted into a xeriscaped landscape. At the end of every AR illustration for each classification, a water conservation message will appear.

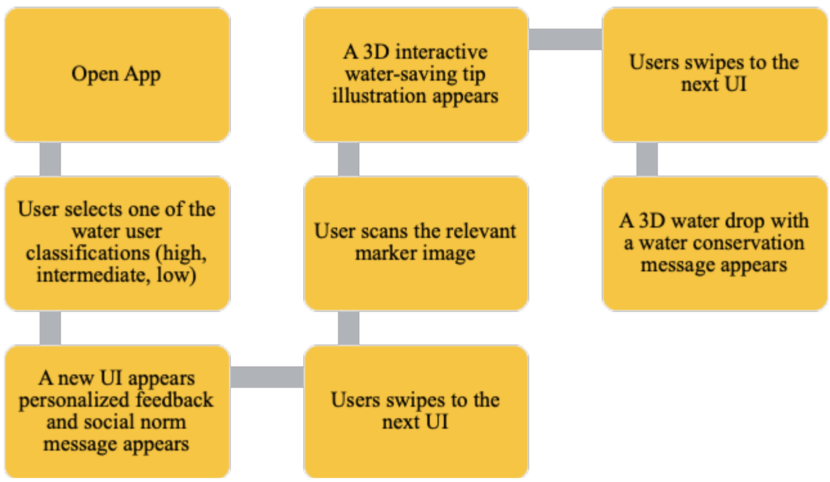


Figure 13 *Water conservation augmented reality application flow chart*

Augmented reality application user classification and feedback		
User classification	***Feedback/social norm message***	***AR illustrated water-saving tip***
Low	You are environmentally aware and your conservative daily routine helps you conserve our precious water and energy.	Even highly conservative water users are offered helpful tips such as: "Reducing your shower by three minutes could save up to 240 gallons per person each month."
Intermediate	Your daily routines in your household utilize too much water and energy to make you a sustainable Peoria resident.	Replace your toilets with High-efficiency toilets (HETs). HETs will reduce up to 7,000 gallons of water per person each year!
High	Compared to other Peoria residents, you have a low level of environmental awareness regarding water consumption. Your household's daily routine utilizes a lot of water and energy.	Convert your high water use landscaping (i.e., grass) to xeriscape (low water use landscaping that includes plant material). You can save water, time, and money!

Figure 14 *An augmented reality app would provide customized messaging dependent on the users classification*

The AR software development kit (SDK) utilized was Unity, a 3D development platform to create immersive and interactive experiences, and the Vuforia portal for augmented reality application development. Once the 3D experience was created, Android Studio (a tool to build apps for Android devices) was utilized to build the AR mobile application. Android Studio was utilized instead of XCode (a tool to build apps for Apple devices) because it is free to use. Upon completion of the AR Water Conservation app, feedback regarding the application was collected.

Water conservation AR app survey

The purpose of the Water Conservation AR App survey is to evaluate how audiences react to social posts about water conservation versus an augmented reality app about water conservation. Due to the Coronavirus outbreak, the Centers for Disease Control and Prevention (CDC) recommends using telework or other alternatives when available. Complying with the CDC restrictions resulted in the participants from this study being dissimilar to the demographics in Peoria. Participants for this study were recruited from Instagram through an Instagram story post, soliciting 30 people to take the survey. Data was collected using a Google Forms survey.

A total of 24 people from multiple age groups (18- 24, 25-34, 35-44, 45-55, 55-64, and 65+) volunteered to take the survey. Once volunteers expressed interest by sending a direct message (DM), a Google Form link was shared with them along with a set of instructions. Participants were asked to complete the first half of the survey that included three questions regarding their demographic information such as:

1. What is your age? (Under 18, 18 - 24, 25 - 34, 35 - 44, 45 - 54, 55 - 54, or 65+)
2. What is your gender? (Male, Female, or Other - Please Specify)
3. Please describe your race/ethnicity. (Asian, American Indian/Alaskan Native, African- American/Black, Hispanic/Latino, Native Hawaiian/ Other Pacific Islander, White, or Other - Please Specify)

Participants were then asked to view a Google Doc with a sample carousel Instagram post about water conservation (demonstrated in Figures 10 and 11). After participants viewed the sample Instagram post, they were asked how likely they are to conserve water at home after viewing a sample water conservation Instagram post with the following questions:

4. After viewing the sample post, how likely are you to conserve water if you see a social media post about water conservation? (Extremely Likely, Very Likely, Somewhat Likely, Not So Likely, or Not Likely At All)
5. After viewing the sample post, how likely are you to spread the message about water conservation if you see a social media post about water conservation? (Extremely Likely, Very Likely, Somewhat Likely, Not So Likely, or Not Likely At All)
6. After viewing the sample post, how likely are you to become more conscious of your water usage? (Extremely Likely, Very Likely, Somewhat Likely, Not So Likely, or Not Likely At All)

Participants were then asked to read the description and goals of the Water Conservation AR App. After reading the app description, participants were prompted to watch one of the three video links of phone screen recordings that demonstrated the Augmented Reality Water Conservation app. The three video options were: Low water use - Augmented Reality Water Conservation App, Medium water use - Augmented Reality Water Conservation App, and High water use - Augmented Reality Water Conservation App. Links to these videos are available in Appendix D of the original student content. After viewing the video demonstration of the AR Water conservation app, participants were asked to complete the rest of the survey. The survey allowed participants to share their reactions and feedback about the Water Conservation AR app using the following questions:

7. After Interacting with the Water Conservation AR App, how likely are you to be more aware of your water use? (Extremely Likely, Very Likely, Somewhat Likely, Not So Likely, or Not Likely At All)
8. After Interacting with the Water Conservation AR App, how likely are you to spread the message about water conservation? (Extremely Likely, Very Likely, Somewhat Likely, Not So Likely, or Not Likely At All)
9. If every month you received new tips in the Water Conservation AR App, based on your monthly water bill, how likely are you to become more conscious of your water usage?
10. What feedback do you have regarding the Water Conservation AR app?
11. After viewing both the sample Instagram post and the Water Conservation AR app, which piece of digital content would inspire you to conserve water the most?
12. Based on your response to the last question, please provide your reasoning for selecting your answer below.

AR app survey analysis

A survey analysis approach was used to examine the AR App Survey data and develop the following content categories: demographics, social media and water conservation, Water Conservation AR App and water conservation, and digital content comparison. The creation of the following content categories utilized relates to the research questions that seek to identify which piece of digital content will move people to adapt water conservation behaviors.

Survey results

From the results, it was found that most survey participants felt the Water Conservation AR App would inspire them to conserve water the most (Figure 15). Less respondents (41.7%) felt constant water conservation social media posts would inspire them to conserve water more. Respondents who suggested the AR App is more inspiring mentioned that the app is more engaging and personal to their household water use. Additionally, a frequent comment was that the app is more memorable since there is an overload of content on social media and it is easy to overlook or forget water conservation information. Respondents who suggested the social media posts were more inspiring mentioned they do not have time to play with or download new apps. Moreover, it was mentioned that constant reminders through social platforms would eventually encourage people to save water. Tables 1-4 in Appendix C of the original student content include further detailed information about the success of social media content regarding water conservation, the success of an interactive application that encourages water conservation behaviors, and feedback on the AR app.

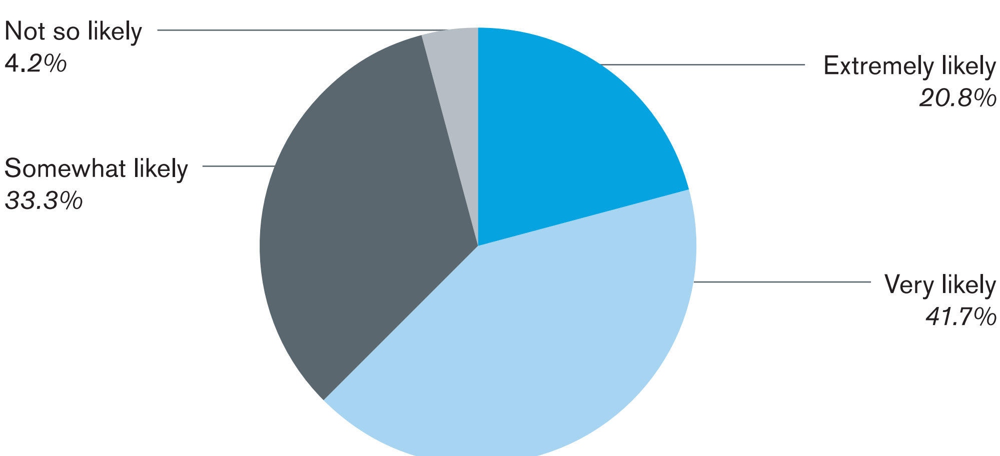


Figure 15 *Augmented reality application effectiveness, n=24*
"Likeliness to be conscious of water use after interacting with the Water Conservation AR App"

RECOMMENDATIONS

After evaluating the digital and social media campaign created for the City of Peoria, three critical recommendations were identified to help pursue the City's water messaging goals.

- **Refine the current City of Peoria website.** The site's user interface design plays a critical part in the success of a water conservation digital media campaign, as a user-friendly website will provide online visitors a positive user experience, thus potentially increasing the number of people signing up for water rebates online. It is specifically recommended to:
    - Distance font sizes more dramatically, and remove the use of all caps.
    - Add Call-to-Action (CTA) buttons in place of hyperlinks to encourage engagement.
    - Further organize and reduce the web pages' text content to cut down the bulk of site navigation.
    - Streamline the pages by removing unnecessary elements such as font size buttons, using relevant graphics only when needed, and utilizing helpful icons throughout the site.
    - Further details of suggested website changes and feedback are available in Appendix A of the original student content.
- **Create an inspiring water conservation social media campaign.** Engaging social media content that is visually striking and consistently themed, such as videos, infographics, photos, or links to other materials, can contribute to widespread public awareness and extend the reach of the water conservation message. Shareworthy content will be promoted by followers who are interested and find it useful, further spreading the message. Sample digital content suggestions can be found in Figures 7-11 as well as Appendix B in the original student content.
- **Adopt innovative new marketing tactics**, such as Augmented Reality (AR), to further enhance social media content. AR applications can greatly impact consumers' perception of social issues, such as water conservation. These strategies are ideal for creating awareness and educating residents about the value of water and how they can conserve it.

CONCLUSION

The City of Peoria has demonstrated its dedication to providing a sustainable future for its residents through efforts such as Sustainable U, the Sustain and Gain publication, and its water rebate program. Capstone student Denise Delgado aimed to assist the City in maximizing these efforts by determining how to best engage the residents of Peoria in water conservation behaviors through strategic messaging. Throughout the semester, Denise conducted a heuristic evaluation of relevant Peoria webpages, developed targeted digital content including social media posts, articles, and an Augmented Reality mobile application mockup, and analyzed the performance of this digital content through survey analysis.

To best utilize the collected data and subsequent analysis, the recommended next steps for the City of Peoria include applying the feedback from the heuristic evaluation, A/B test, and Water Conservation AR App Survey to create a digital campaign that inspires Peoria residents to take action. Refining the city's website, developing engaging social media content, and investigating innovative digital content methods such as Augmented Reality all have the potential to assist Peoria in effectively spreading important information and engaging its residents in stronger water conservation behaviors.

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