Water Resources Research Center Seminar Series

May 17, 2023

Title: “Green infrastructure in Tucson, AZ”

Presented by:

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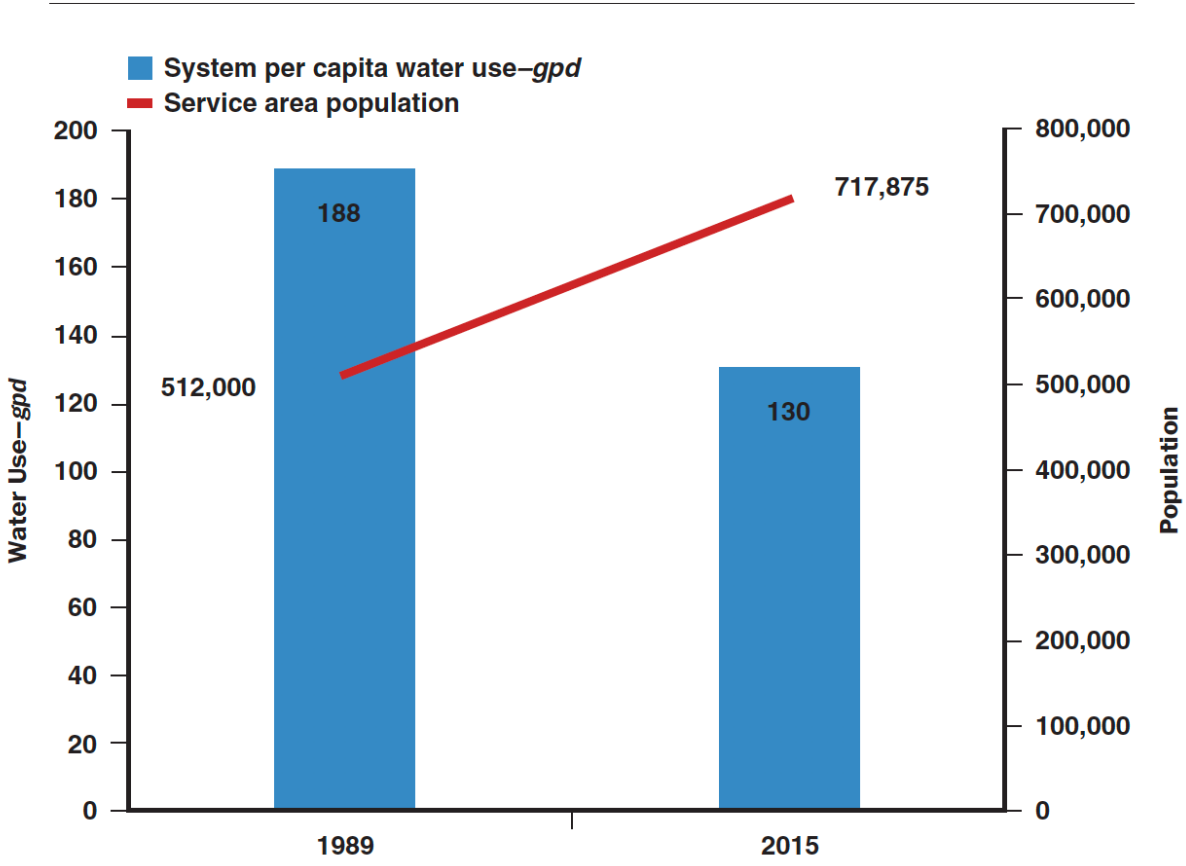
Overview of the seminar

- Why Tucson?
- Tucson and groundwater pumping
- Institutional context
- Action at the local level
- Green infrastructure
- Conclusions

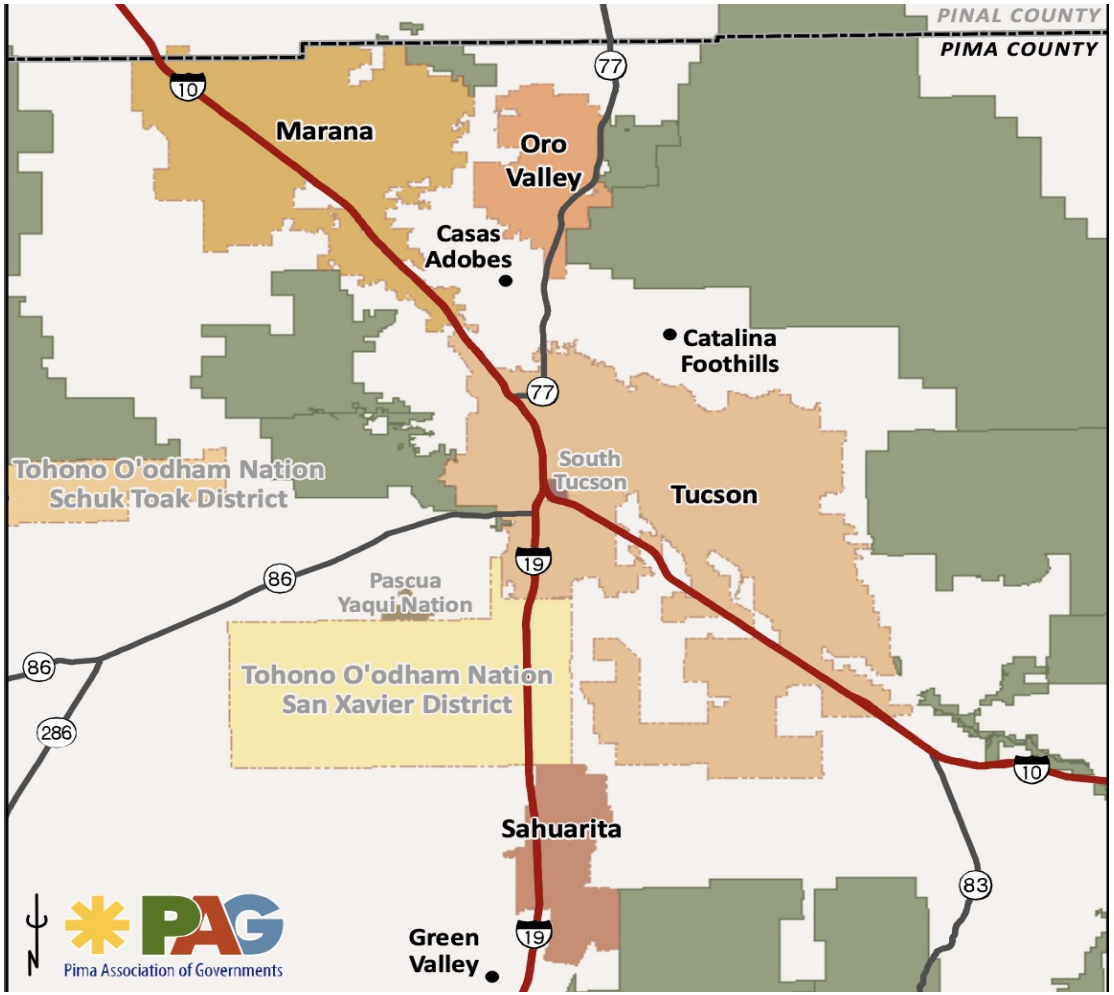
Why Tucson?

- Tucson is located in a desert environment with a growing population, yet the city has managed to reduce not just per-capita, but *overall* water consumption over time.
- They have lowered their system per capita water use by 58 gpcd, with respect to 1989.



Comparison of system per capita water use and service area between 1989 and 2015 in Tucson (Rupprecht et al. 2020)

Tucson Metropolitan Area



Jurisdictions of the Tucson Metropolitan Area

Tucson is located in a hot and semiarid region (300mm ave. annual precip.) and is home to about 1 million people.

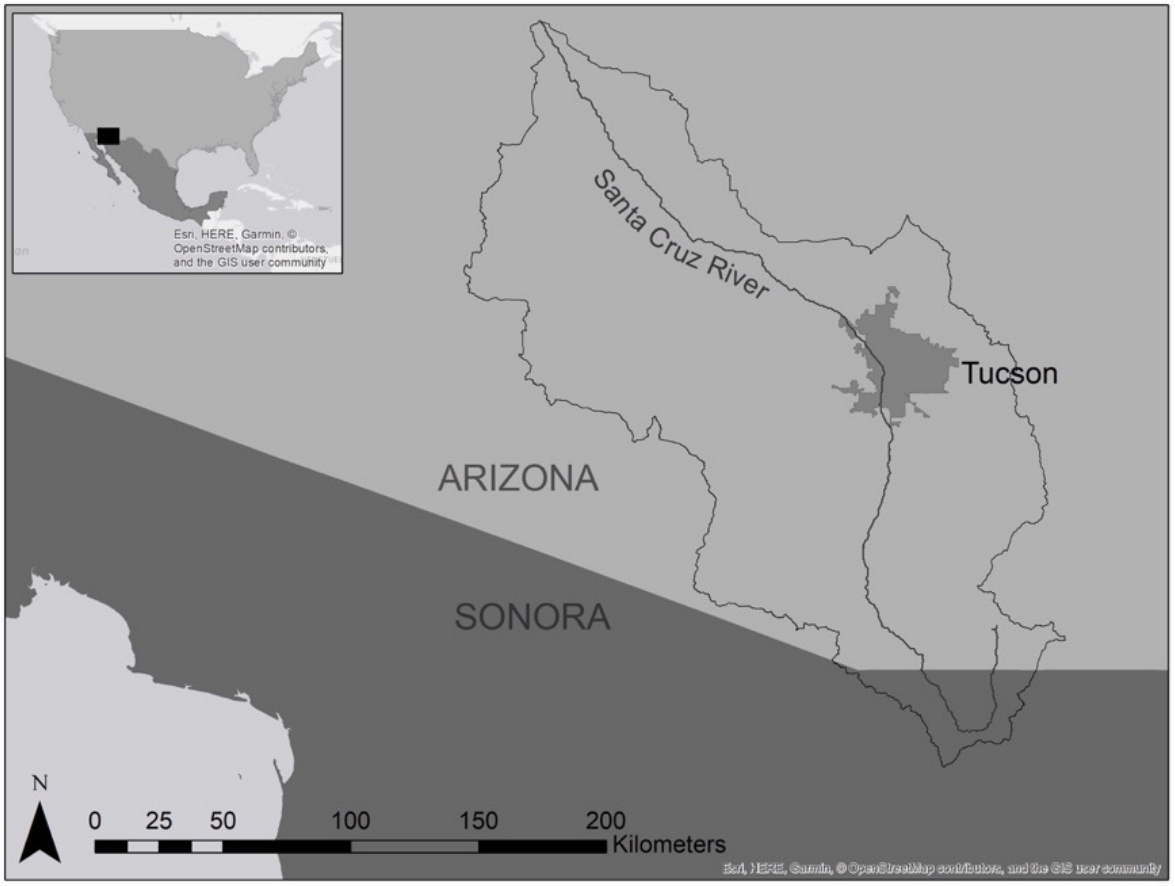
Tucson encompasses several jurisdictions:

- the City of Tucson,
- the City of South Tucson,
- Oro Valley,
- Sahuarita,
- Marana,
- Tohono O'odham district,
- Pascua Yaqui district,
- the rest is unincorporated area in Pima County.

Tucson before water pumping

The original water source for Tucson was the **Santa Cruz River** that has provided water to established communities throughout history:

- Hohokams,
- Pimas,
- Tohono O'odhams,
- Pascua Yaquis,
- Spaniards,
- Mexicans,
- Americans



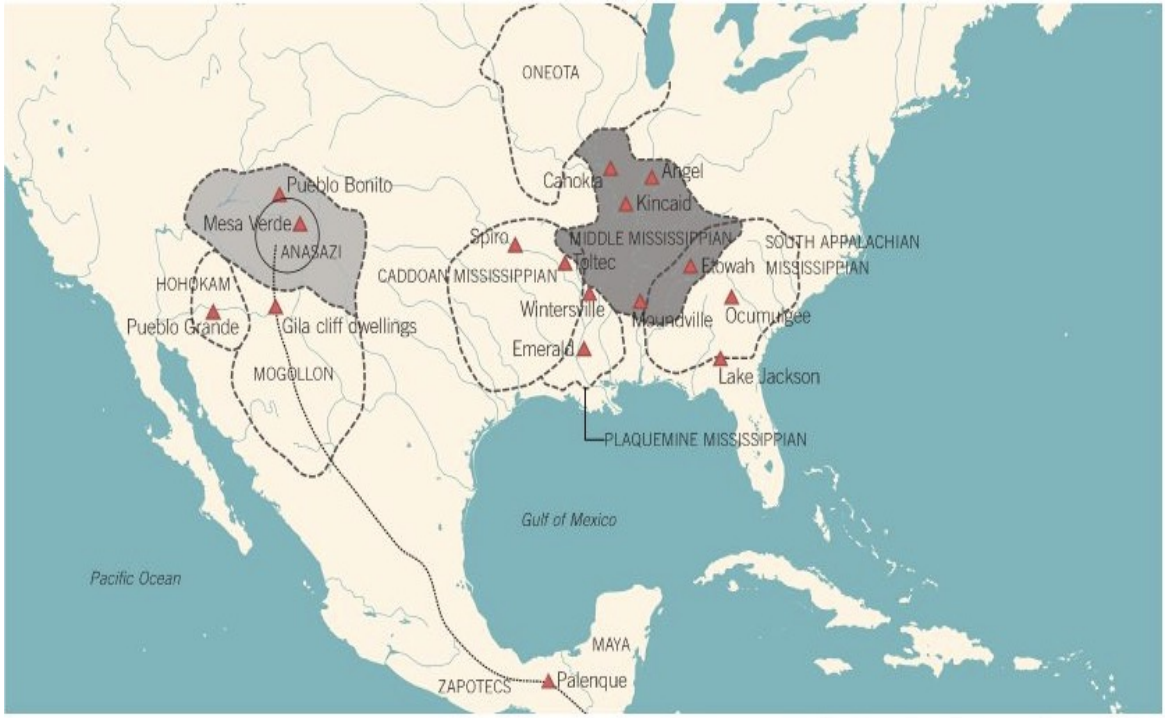
The Santa Cruz River Basin – a binational river that provided water to Tucsonans and other communities in Southern Arizona and Northern Mexico

Hohokams

The Hohokams lived in this region from the first years of CE to 1450 CE, just 95 before the Spaniards arrived.[1]

They are admired for their irrigation canals – the most complex in the New World north of Peru.

Their villages were located along the canals and hosted several hundred people.



11.7 North America and Mesoamerica, ca. 1000 CE

Hohokams and Puebloans inhabited this region in 1000 CE

Hohokam archaeological site in Casa Grande, AZ

1: National Park Service. Hohokam Culture.

Hohokams

Hohokam farmers figured out a way to successfully grow crops in the same location for hundreds of years, and create a large, prospering society.

Their descendants are the Pima and Tohono O'odham people of Southern Arizona.[1]

Canals in Mesa, AZ 1200-1450. Mural in the AZ Museum of Natural History by Ann and Jerry Schutte

Map of Hohokam irrigation canals in the Salt River (Phoenix). Map by Turney in 1929

1: National Park Service. Hohokam Culture.

The Santa Cruz River

In 1870, as a U.S. Territory, communities in Tucson still received water from the Santa Cruz River.

Historic photos of the Santa Cruz River. AZ Daily Star. Arizona Historic Society

Electric wells

In 1808, mechanical drilling of wells was invented in the US.

In 1830, wells were drilled in AZ, and since then, the technology has advanced rapidly.

Groundwater = a hidden resource. It provides good water quality and does not require massive infrastructure.

In 1889, Tucson Water Company started drilling wells and pumping groundwater to meet municipal water demand, and for other uses (farming and mining).

Pima cotton grown in Marana

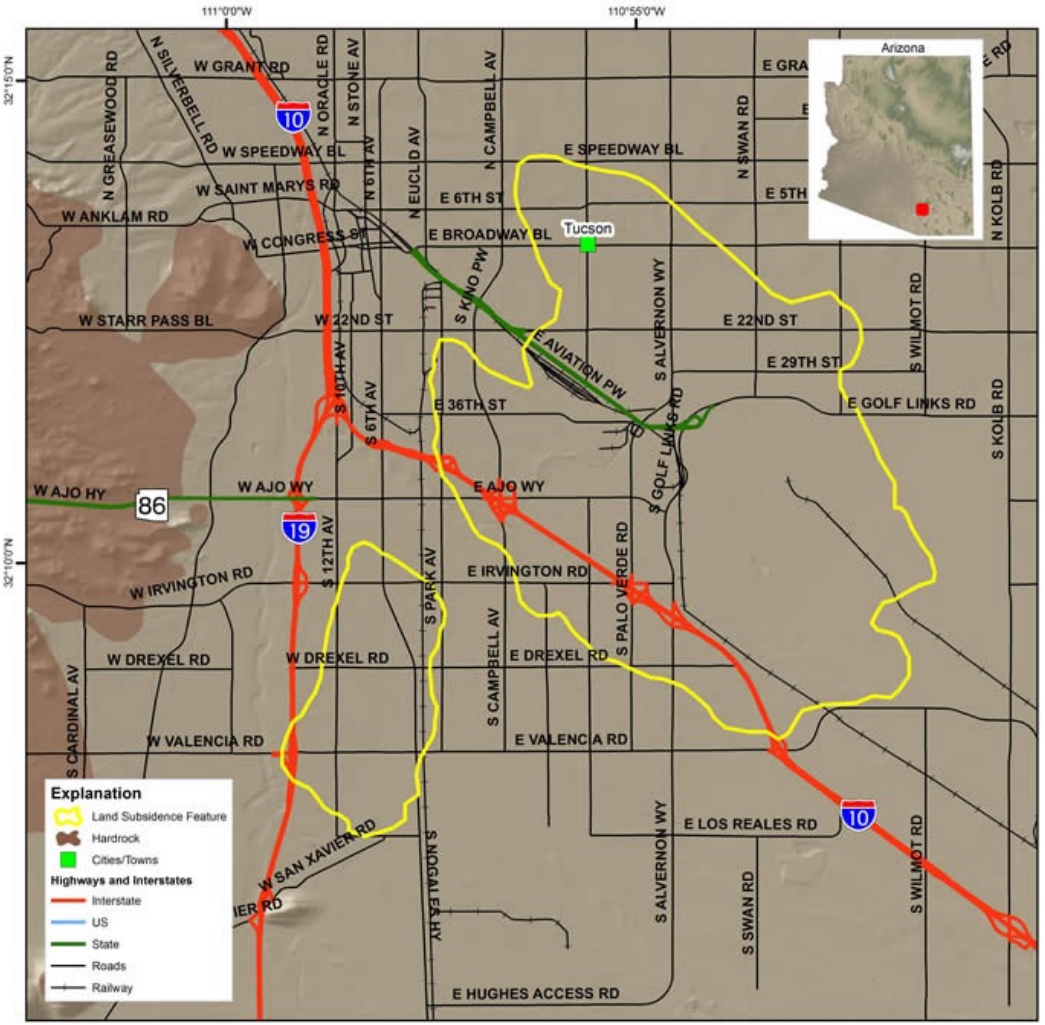
Electric water well

Groundwater depletion

As population continued to grow, groundwater pumping increased and became unsustainable – Tucson faced aquifer depletion and experienced land subsidence.

Something needed to change…

Land subsidence



The Groundwater Management Act

The state of Arizona developed three policy instruments to prevent groundwater depletion:

1. A state-wide groundwater conservation policy
2. Enforcement of such policy
3. The retirement of groundwater rights

The first policy (conservation) is supported by the other two (enforcement and rights retirement) and was exercised by the state legislature through the enactment of **the Groundwater Management Act (GMA)** in 1980.

Signing of the GMA by Gov. Bruce Babbitt in 1980

The Groundwater Management Act

The GMA's goal is to prevent groundwater depletion through long-term reduction plans:

- **Current withdrawals** - the GMA outlines five-year conservation plans with stringent conservation measures with a pumping tax.

- **Future withdrawals** - the GMA requires new subdivision development to demonstrate 100 years of assured water supply.

New development within an Active Management Area must demonstrate 100 years of assured water supply.

Active Management Areas

The GMA designated five Active Management Areas (AMAs) include:

- Prescott
- Phoenix
- Pinal
- Tucson
- Santa Cruz.

And three Irrigation Non-expansion Areas (INAs) include:

- Joseph City,
- Harquahala, and
- Douglas

Areas are delineated based on the geology of the aquifers and not according to political boundaries

Institutional context - institutions

Also established in 1980, the Arizona Department of Water Resources (ADWR) became the **institution** in charge of executing the GMA and administering 2.8 acre feet of Colorado River Water (40% of the state water use).

In 1987, the Arizona Department of Environmental Quality (ADEQ) was created to regulate water quality issues across the state.

Water management is distributed into several institutions that many times **work in siloes.**

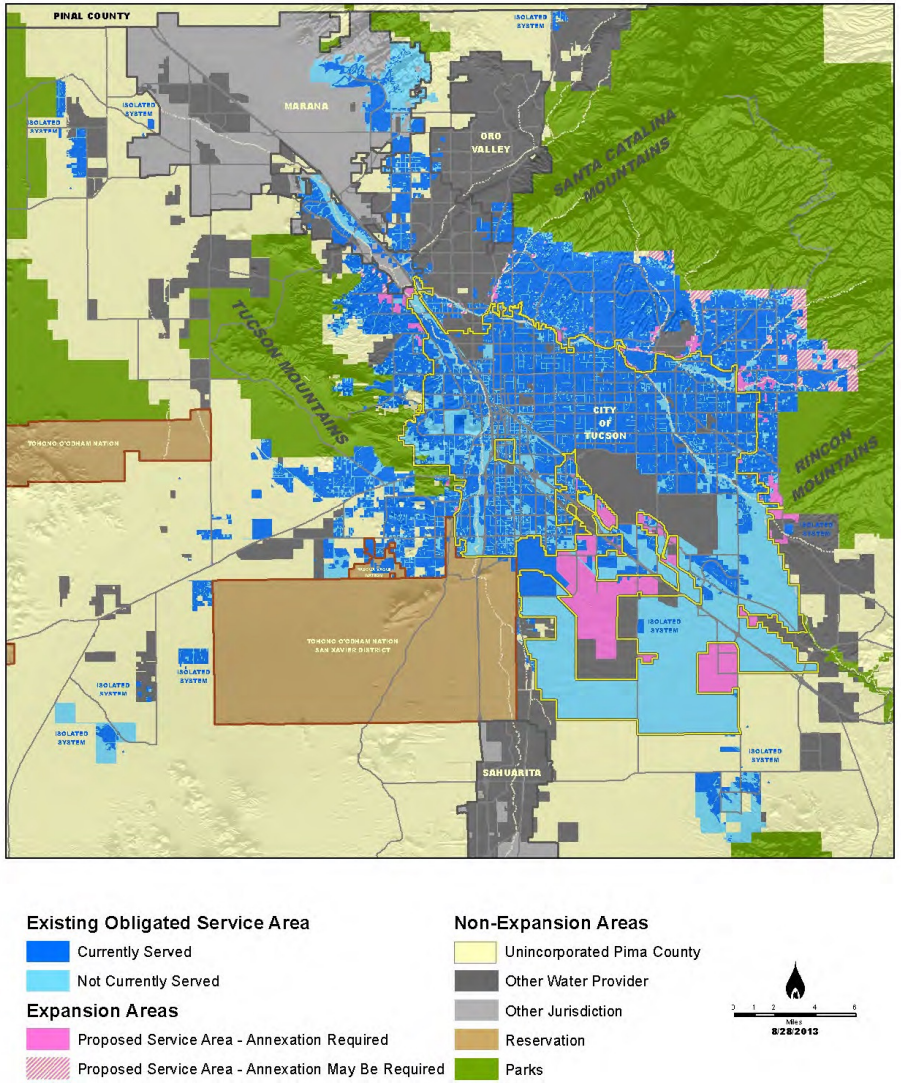
Municipal water utilities

Tucson Water provides potable and reclaimed water to 75% of Tucson's population.

The other water utilities that serve the rest of the population:

- Tucson Metro Water District,
- Oro Valley Water and Sewer,
- Marana Water Utility, and
- Vail Water Company.

Wastewater treatment - most of the service (75%) is provided by the Pima County Regional Wastewater Reclamation Department through two main treatment facilities.

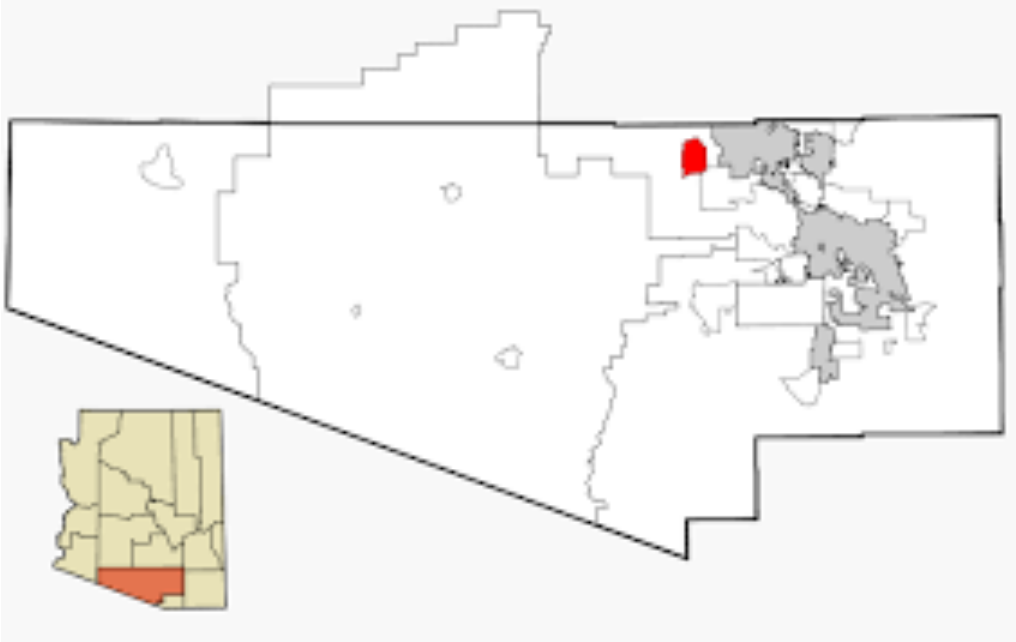


Action at the local level

Tucson Water – 1970s – changing water uses

In the 1970s, 1980s, and 1990s, Tucson dramatically shifted their water management approach.

In the 1970s, Tucson Water started purchasing agricultural land (Avra Valley) and along with the land, their water rights to be used for municipal uses.



Location of Avra Valley.

Hard path approaches – inter basin transfers

Tucson Water – 1980s – Large-scale infrastructure

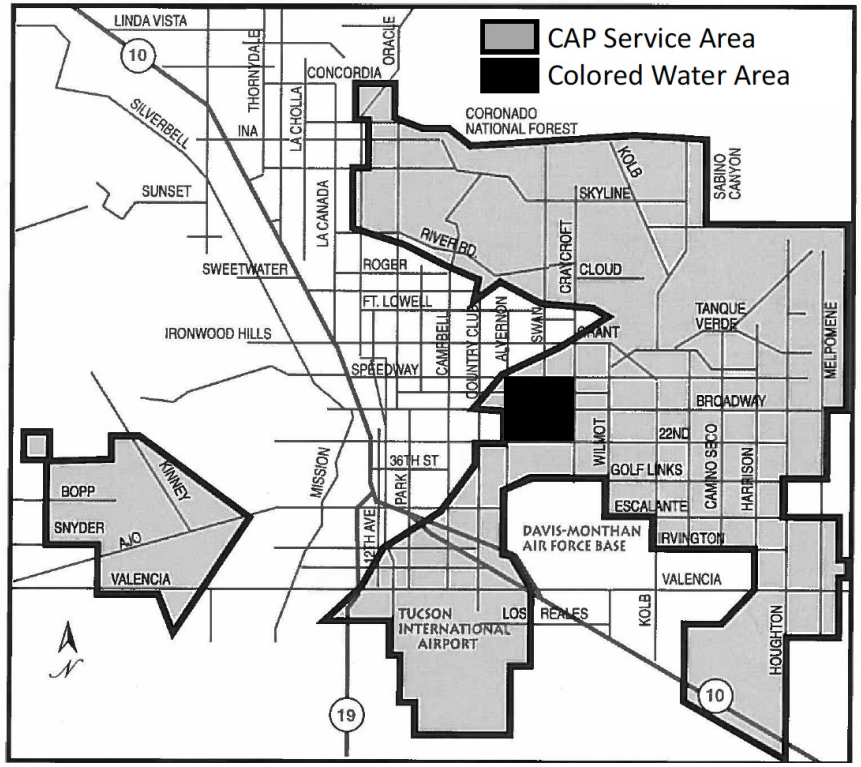
Central Arizona Project.

In the 1980s, Tucson turned to a large-scale federally funded infrastructure to achieve water security - the Central Arizona Project (CAP).

CAP is a conveyance system and replenishment facilities that conveys Colorado River water to the main cities in the state of Arizona – Phoenix and Tucson – some 540 km away and 730 m above its point of origin - Lake Havasu.

But deliveries of CAP water to Tucson customers did not go as planned…

Tucson Water – 1990s – water quality issues



Water quality issues angered Tucson residents.

In the early 1990s, after numerous complaints from customers, Tucson's Mayor and Council prohibited the direct use of CAP water.

Colored water came out of taps because of chemical reactions linked to pH levels and the old pipes.

CAP water treated in a newly-built treatment plant could no longer be piped directly to the customers.

Hard path approaches – aquifer recharge

Tucson Water – 1990s – aquifer recharge

Colorado River water is conveyed via CAP to the Avra Valley recharge facilities for infiltration.

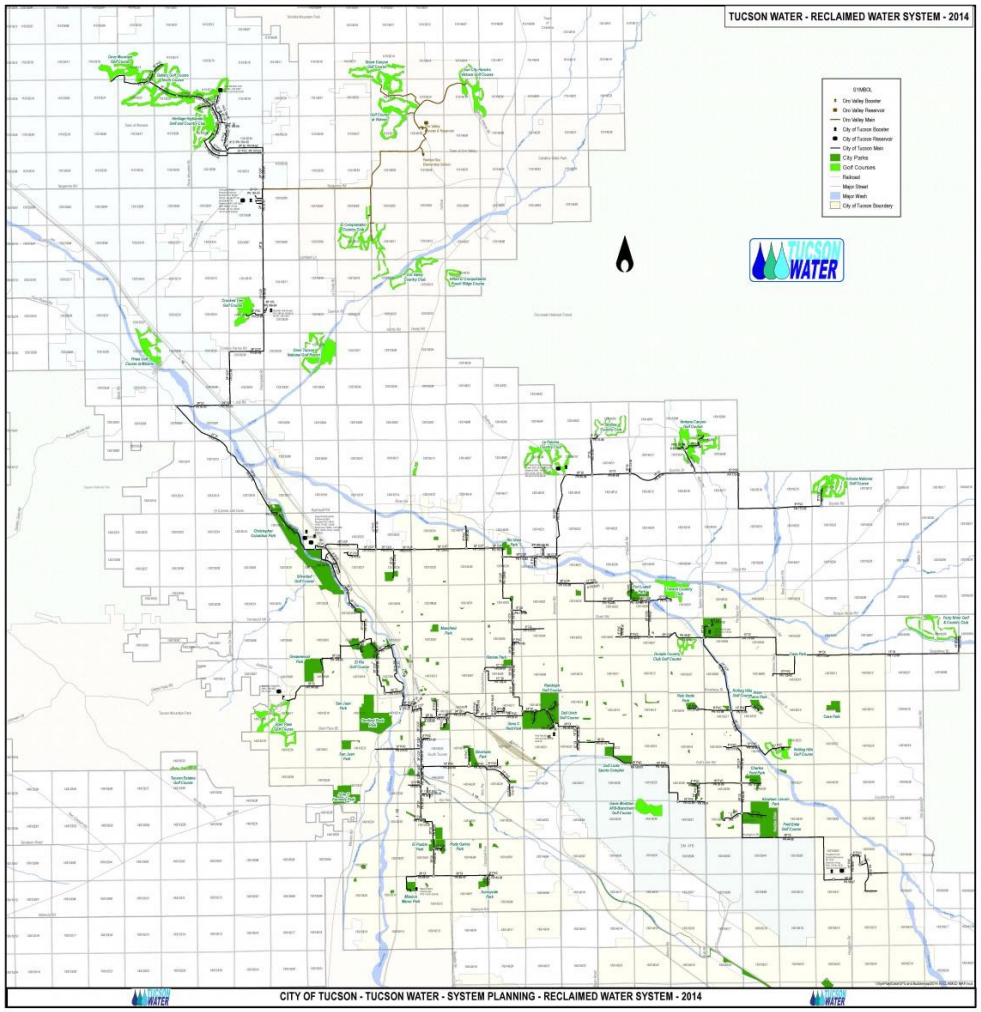
In the 1990s, the land purchased in the 70s (the Avra Valley farms) was used as recharge facilities.

The farm was used to infiltrate CAP water to be mixed with groundwater.

Mixed water was then pumped and delivered to customers or store it in the aquifer for future use (**water banking**).

In this decade, Tucson Water started reclaiming wastewater for landscape irrigation, diversifying their water source portfolio.

Reclaimed water

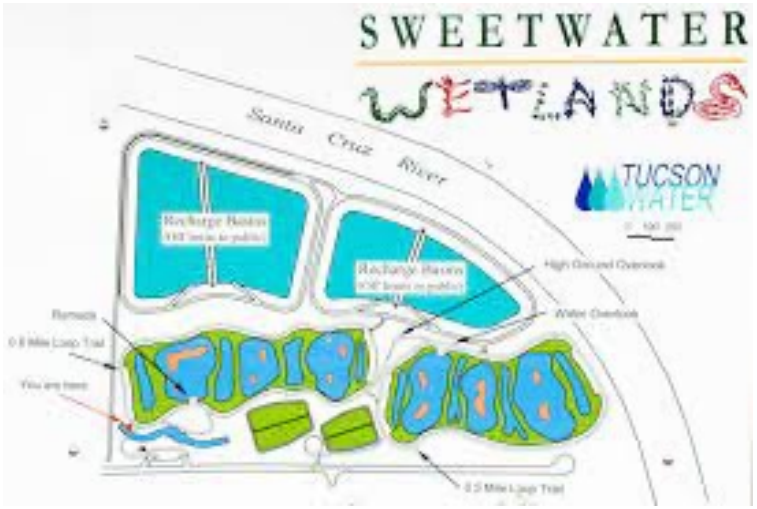


Although the use of reclaimed water can save potable water and costs, there are still some health risks associated with this water that can influence public opinion.

Tucson's main use for reclaimed water is the irrigation of golf courses and other landscapes through a network of purple-colored pipes.

Tucson Water's Clearwater Program

Clearwater Program Facilities	Recharge capacity (ac ft/yr)
Central Avra Valley Storage and Recovery Project	100K
Southern Avra Valley Storage and Recovery Project	60K
Pima Mine Road Recharge Project	30K
Sweetwater Wetlands Recharge Facility	6.5K
South Houghton Area Recharge Project	4K



Soft path approaches - Diversification

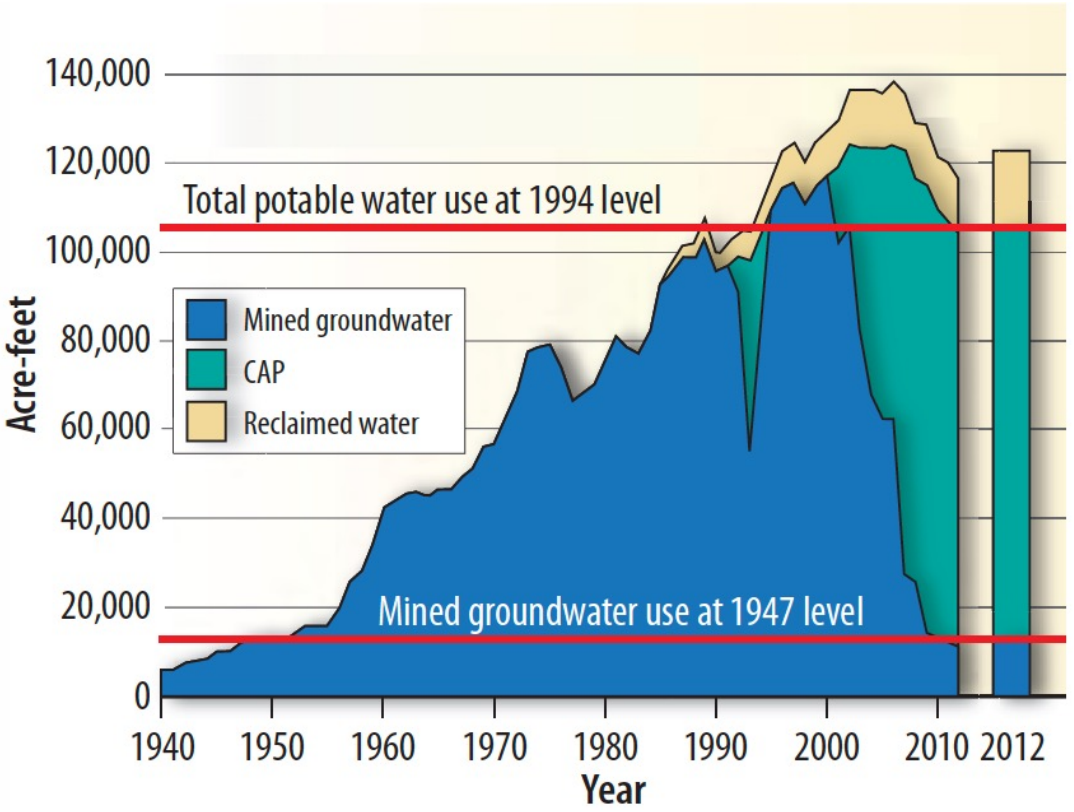
Diversifying the water portfolio

Five water sources in Tucson:

1. Groundwater (mined)
2. Central Arizona Project (CAP) water
3. Reclaimed water
4. Graywater (at the household level)
5. Rainwater/stormwater

Tucson's current groundwater use resembles the use during 1947.

Tucson's current potable water use resembles the use during 1994.



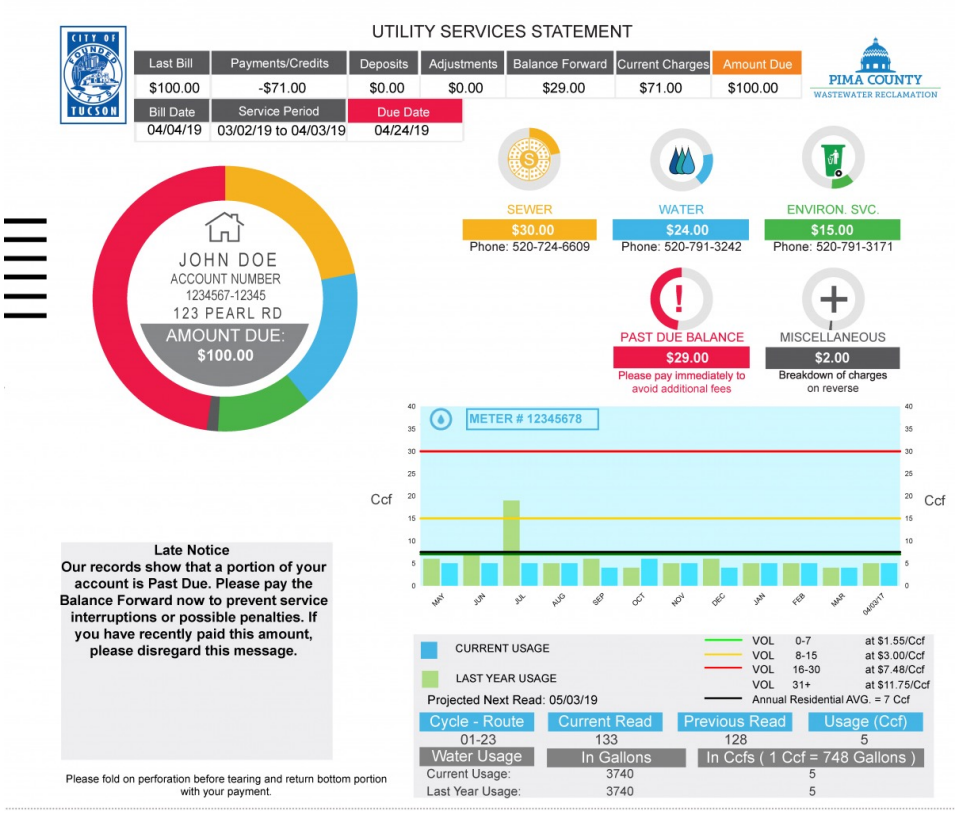
Water use in Tucson over time (City of Tucson 2003)

Soft path approaches - Conservation

Conservation programs

Since the 1970s, Tucson water have launched conservation programs, supported by education and communication.

- Increasing block rate structure
- Water waste and theft ordinance
- Audit programs
- Zanjero
- Water conservation kits



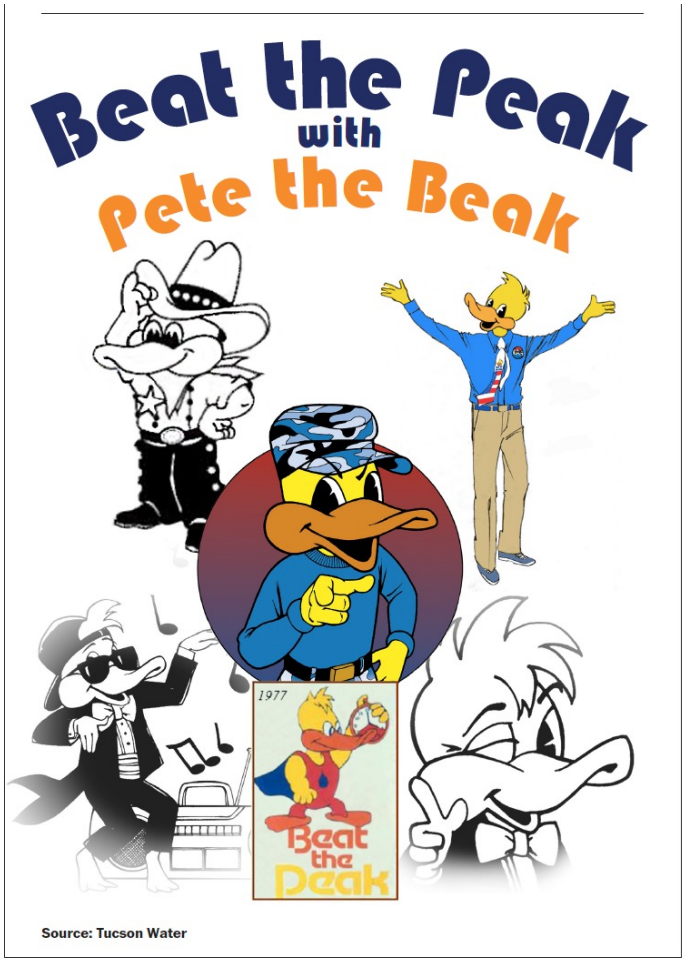
Increasing block rate structure

Education and outreach

Since the 1970s, Tucson water have launched communication and education programs that have established a strong water conservation ethic.

SmartScape Program

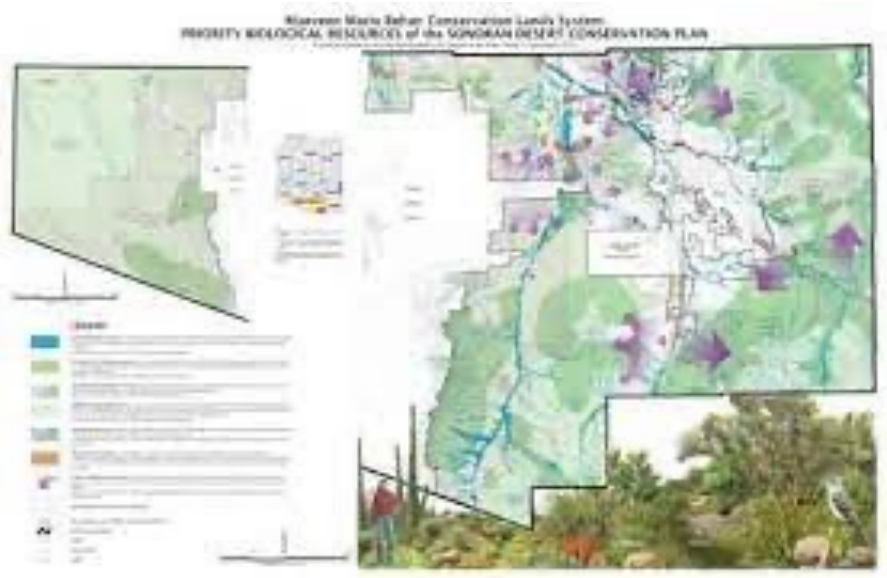
Rainwater harvesting workshop



Evolution of Pete the Beak

Healthy ecosystems

Tucson has recognized the importance of healthy riparian areas for conservation of biodiversity (ecological uses).

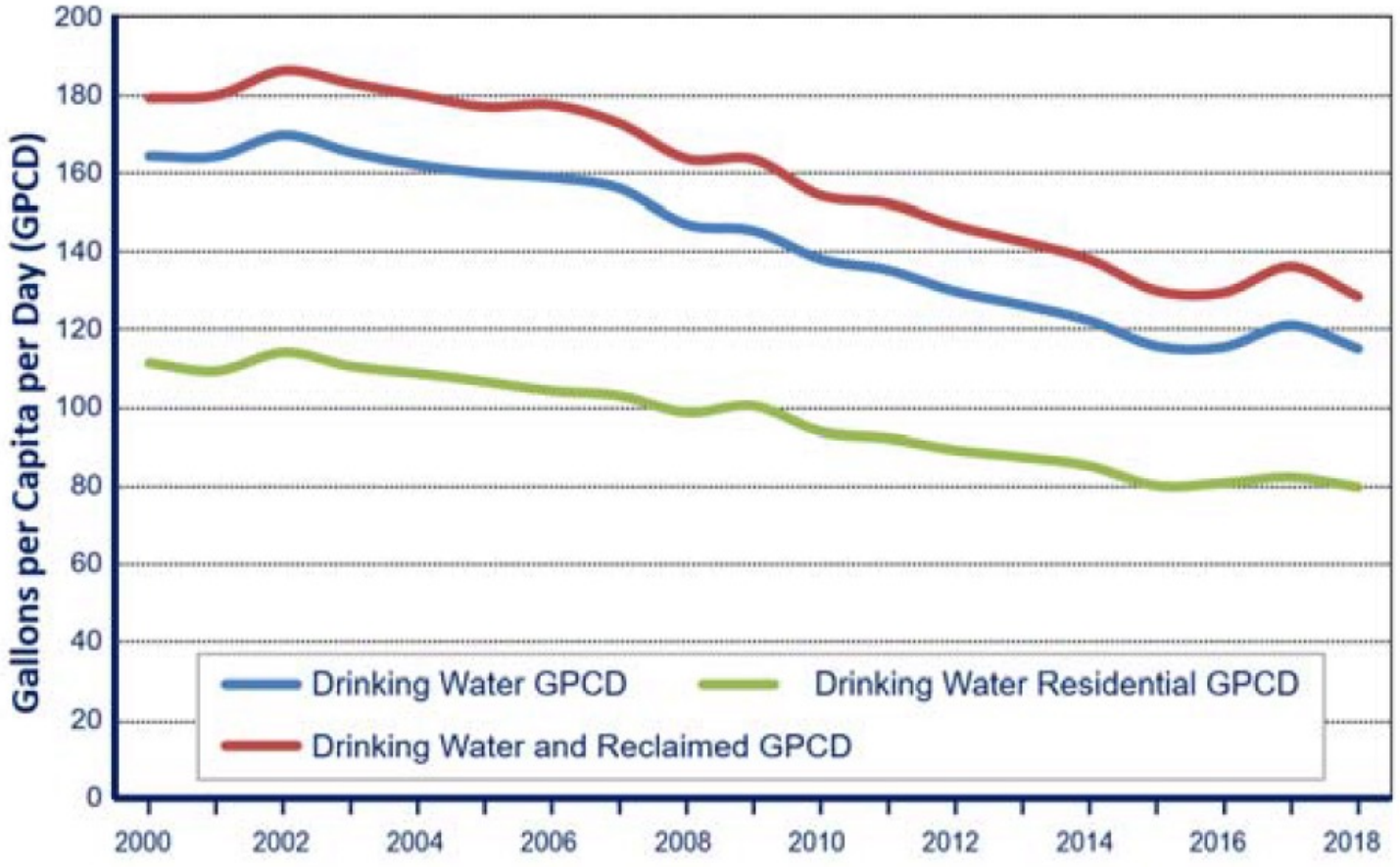


Sonoran Desert Conservation Plan (1998)

Santa Cruz Heritage Project (2016)

Soft path approaches - Reductions in water use

Reducing demand



Reductions in per capita water use over time (Rupprecht, 2020).

Centralized vs. decentralized systems

Tucson's water infrastructure paradigm is based on three strategies:

1. Groundwater is pumped for potable and non-potable uses and distributed through a single infrastructure system.
2. Wastewater is conveyed to central treatment facilities.
3. A percent of reclaimed water is used for landscape irrigation and the rest is discharged into water bodies.

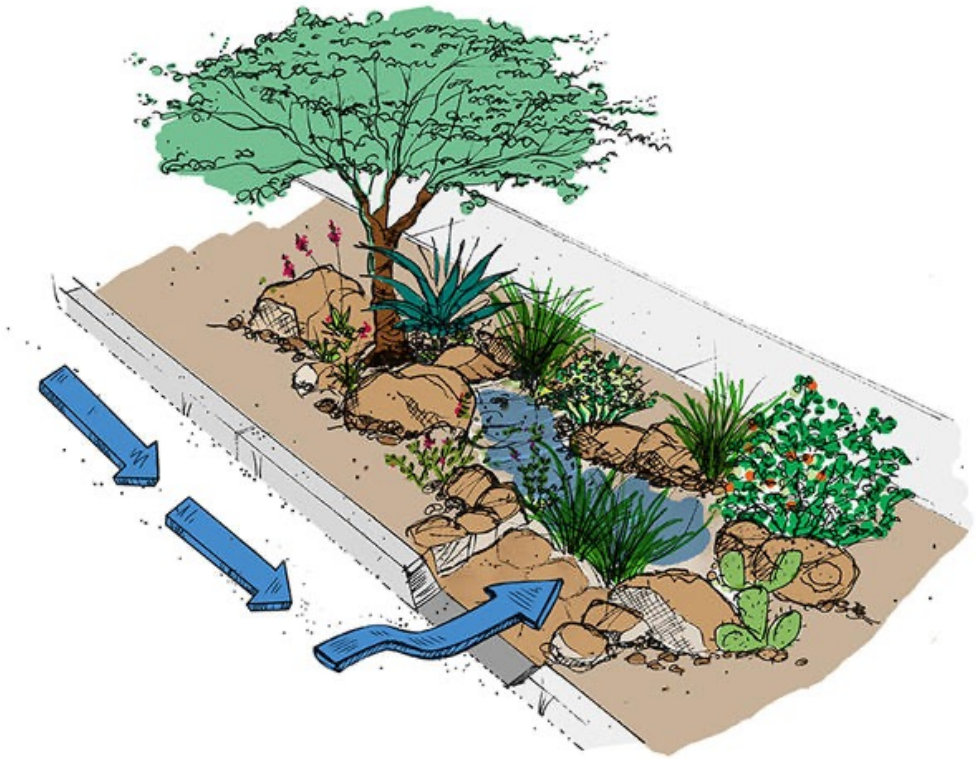
Santa Cruz Heritage Project

Centralized systems are easier to operate up to a certain scale.

But **decentralized systems** have been recognized as effective complements to an ageing infrastructure and a lack of funding to upgrade it.

Green infrastructure – a decentralized approach

Vegetated spaces in cities that can function as retention/detention basins (e.g., swales, rain gardens, green roofs).



Credit: Watershed Management Group

Green infrastructure (GI)

Green infrastructure (GI) plays a critical role in providing the ecosystem services that support livable, resilient and sustainable cities, including:

- **Flood control**
- **Replenishment of aquifers**
- **Improved water quality**
- Reduced heat (shade)
- Local food production
- Improved air quality
- Improved aesthetics
- Increased recreational opportunities
- Enhanced social interaction
- Reduced stress, noise, and overcrowding

Green infrastructure

Definition - The creative combination of natural and artificial structures (blue, green and gray) with the intention of achieving specific goals of resilience (flood management, public health, etc.) with broad public support and attention to the principle of appropriate technology.

Blue

Green

Grey

Staddon, C., Ward, S., De Vito, L., Zuniga-Teran, A., Gerlak, A., Schoeman, Y., Hart, A., Booth, G. (2018). Contributions of green infrastructure to enhancing urban resilience. *Environment, Systems and Decisions*.

Green infrastructure and urban resilience

Environment Systems and Decisions
https://doi.org/10.1007/s10669-018-9702-9

Contributions of green infrastructure to enhancing urban resilience

Chad Staddon[1] · Sarah Ward[1] · Laura De Vito[1] · Adriana Zuniga-Teran[2] · Andrea K. Gerlak[2] · Yolandi Schoeman[3] · Aimee Hart[4] · Giles Booth[4]

Journal of Environmental Planning and Management

ISSN: 0964-0568 (Print) 1360-0559 (Online) Journal homepage: https://www.tandfonline.com/loi/cjep20

Challenges of mainstreaming green infrastructure in built environment professions

Adriana A. Zuniga-Teran, Chad Staddon, Laura de Vito, Andrea K. Gerlak, Sarah Ward, Yolandi Schoeman, Aimee Hart & Giles Booth

Available online at www.sciencedirect.com

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Current Opinion in Environmental Sustainability

Urban resilience and green infrastructure systems: towards a multidimensional evaluation

Adriana A Zuniga-Teran, Andrea K Gerlak, Brian Mayer, Tom P Evans and Kevin E Lansey

Challenges in mainstreaming green infrastructure

Five challenges:

- Design standards
- Financeability
- Regulatory
- **Socio-economic**
- Innovation

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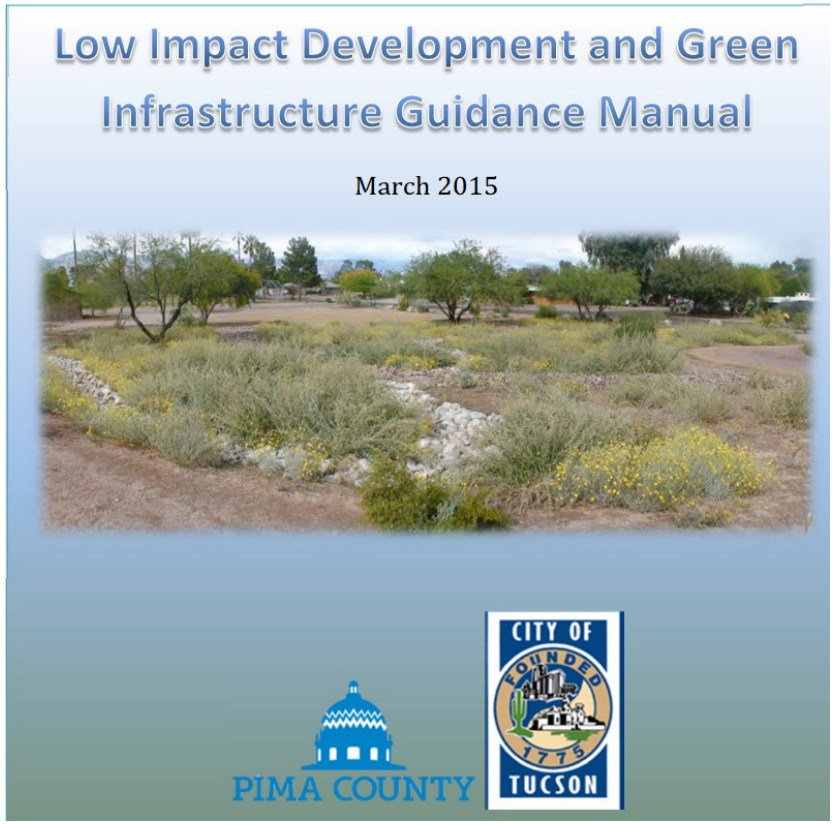
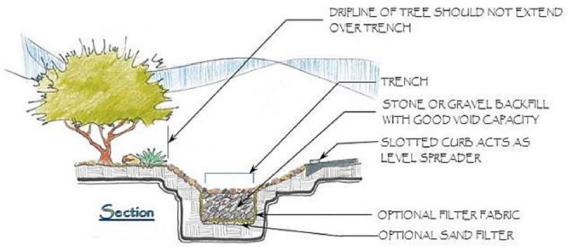
Tucson - Design Standards challenge





INFILTRATION TRENCH

Tucson – financeability challenge

Conservation fee

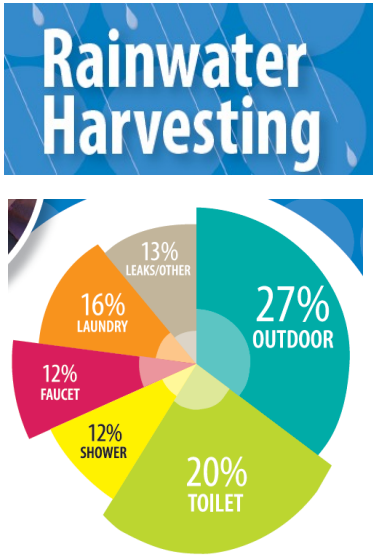
Funding for different programs comes from water bills - a *Conservation Fee* (2008).

The fee is charged to all potable water sales and is 10 cents per ccf (~$1).

The total fund expenditures for FY 2018-2019 was $3,036,034.

Tucson – financeability challenge

- Rainwater Harvesting Rebate Program
- Storm to Shade Program
- Low-Income Rainwater Harvesting Loan/Grant Program
- Flood Control Funds
- Conserve 2 Enhance – funds GI neighborhood projects on floodplains.
- Green Stormwater Infrastructure Program



Storm to Shade

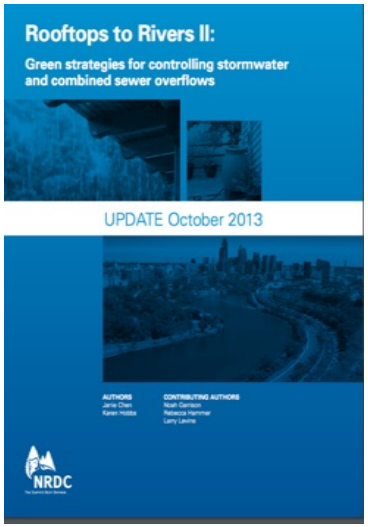
Tucson - Regulatory challenge

Year	Policy	Description
1980s	CoT Riparian Veg. Preser. & Protect.	Codes, policies & stds protecting riparian vegetation
1998	Sonoran Desert Conservation Plan	Protects natural drainage systems at the regional level
2004	Xeriscape Lands. & Screening Ord.	Use of native plants for landscape
2005	Stormwater Quality Ordinance	No non-point source pollutants enter the water system
2008	Comm. Rainwater Harvesting Ord.	Use of rainwater harvesting for landscape irrigation
2010	PC Riparian Management Ord.	Floodplain permits to protect riparian areas
2011	TDOT's Stormwater Mgmt. Program	Codifies GI requirements along roads, boulevards
2018	GI Action Plan	Set of GI policies
2018	Res. Graywater Ord.	Mandatory dual-plumbing system
2020	Land Use Code	Stormwater harvesting to be used for landscape irrigation

Tucson as a leader in green infrastructure

"Emerald Cities," listed darkest to lightest by the number of key green infrastructure actions taken

City	Long-term green infrastructure (GI) plan	Retention standard	Requirement to use GI to reduce some portion of the existing impervious surfaces	Incentives for private-party actions	Guidance or other affirmative assistance to accomplish GI within city	Dedicated funding source for GI
Philadelphia, PA	★	★	★	★	★	★
Milwaukee, WI	★	★	★	★	★	★
New York, NY	★		★	★	★	★
Portland, OR		★	★	★	★	★
Syracuse, NY	★		★	★	★	★
Washington, D.C.		★	★	★	★	★
Aurora, IL	★	★			★	★
Toronto, Ontario, Canada	★	★		★	★	
Chicago, IL		★		★	★	
Kansas City, MO				★	★	★
Nashville, TN	★				★	★
Seattle, WA				★	★	★
Tucson, AZ		★		★		
Pittsburgh, PA		★			★	
Rouge River Watershed, MI					★	

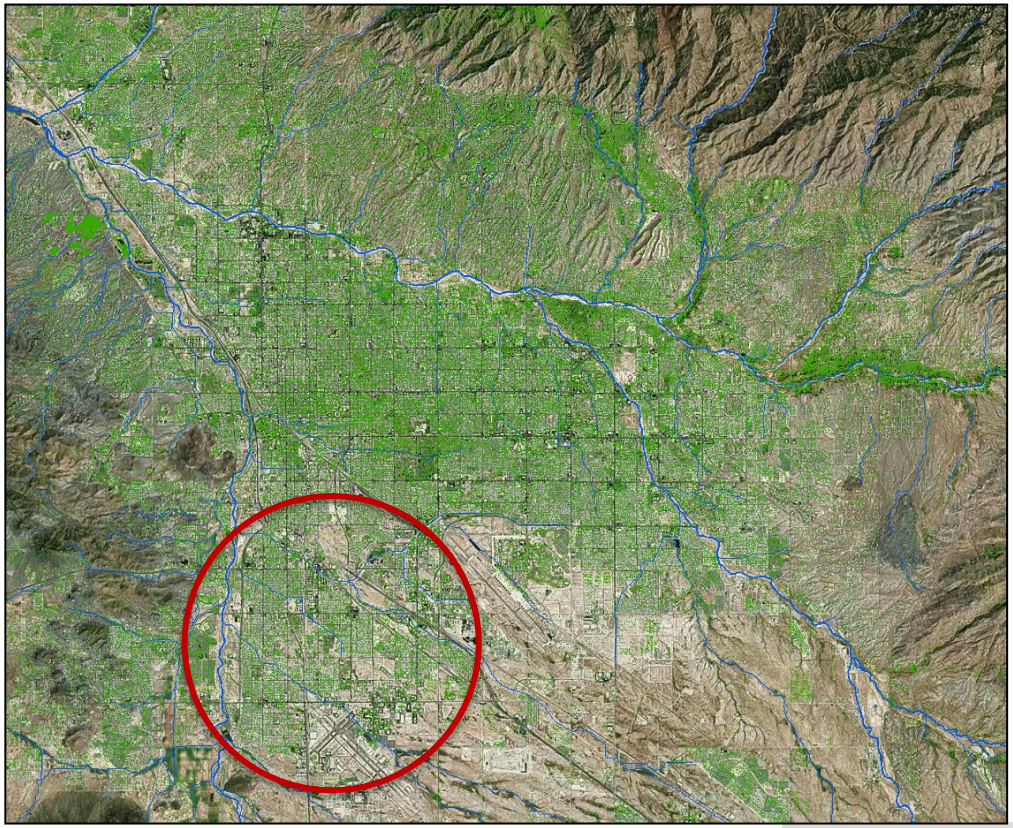


Natural Resources Defense Council

Green infrastructure in Tucson is the result of local action

Socioeconomic challenge - Inequities in green infrastructure

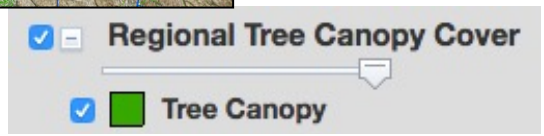
- Although Tucson is considered a leader in green infrastructure, there are considerable equity issues



Tree canopy in Tucson, AZ (data from Pima Association of Governments, PAG)

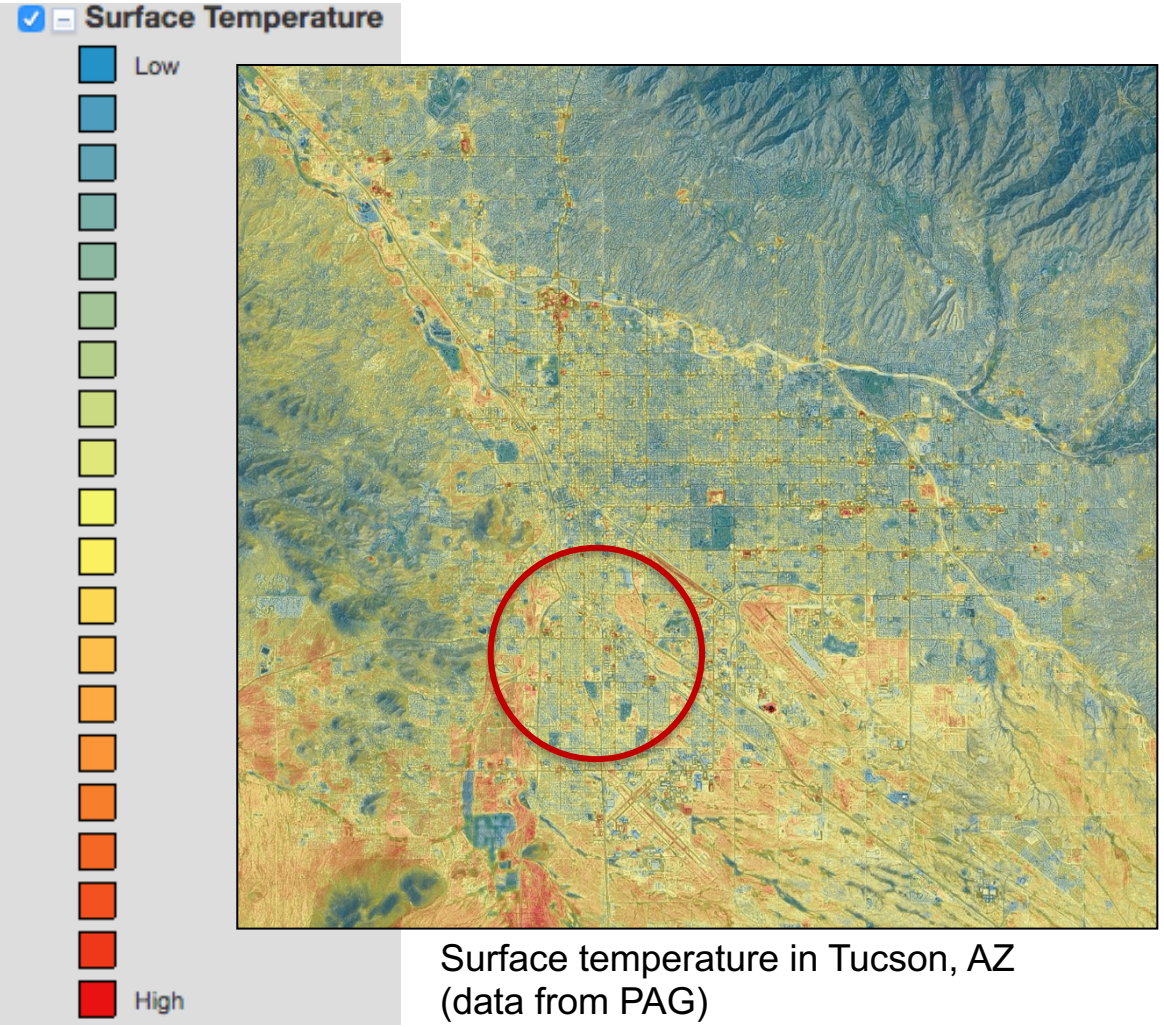
Street in the south side of Tucson

- Predominantly Hispanics
- Low income
- Younger population
- Larger households



Insecurities and vulnerabilities

- The south side of Tucson is vulnerable to flood and extreme heat



Surface temperature in Tucson, AZ
(data from PAG)

Flooding in the south side of Tucson

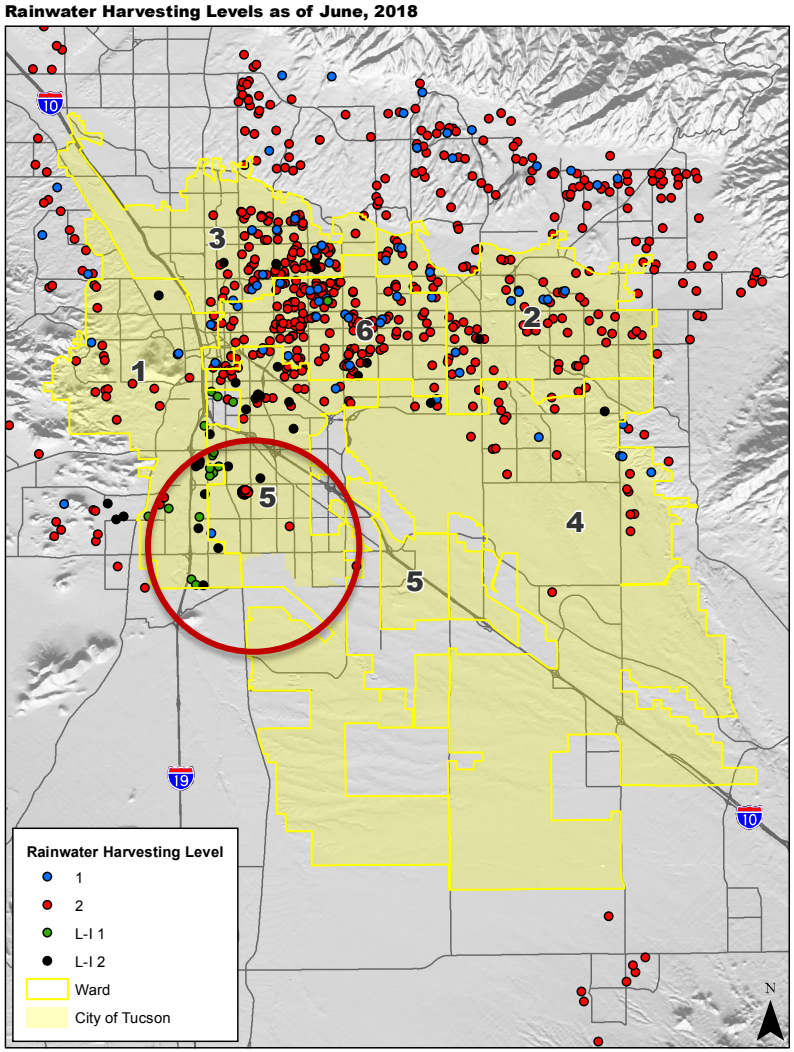
Rainwater Harvesting Rebate Program

Funded by Tucson Water through a conservation fee

- Gives $2,000 back to water customers who apply.
- Targeted to property owners.
- Participants are required to attend a workshop for training.
- Program funds the installation of active rainwater harvesting systems, which require maintenance.

Active rainwater harvesting system

Distribution of the Rainwater Harvesting Rebate Program



June 2018 Data from Tucson Water

Programs and incentives to harvest rainwater have rarely been implemented in the south side of the city.

Tucson Water is taking action to address this issue in the next iteration of the program.

Low-income Rainwater Harvesting Program

Funded by Tucson Water (fee) and managed by the Sonora Environmental Research Institute, Inc

- Designed to address equity issues by giving grants and loans to low-income families to be able to apply to the rebate program.

Active rainwater harvesting system

Socioeconomic challenge – Community engagement

Community engagement is a key factor in the long term benefits of green infrastructure – Ensures maintenance.

Roundabout where neighbors worked together to install artwork and vegetation, and have maintained it

Roundabout in a neighborhood where neighbors were not engaged

Governance, collaboration and agency

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Environment: Science and Policy for Sustainable Development

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/venv20

Green Infrastructure: Lessons in Governance and Collaboration From Tucson

Andrea K. Gerlak, Alison Elder, Timothy Thomure, Catlow Shipek, Adriana Zuniga-Teran, Mitch Pavao-Zuckerman, Neha Gupta, Marissa Matsler, Lena Berger, Adam Douglas Henry, Bo Yang, Joaquin Murrieta-Saldivar & Thomas Meixner

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Agency and governance in green infrastructure policy adoption and change

Andrea K. Gerlak, Alison Elder, Mitch Pavao-Zuckerman, Adriana Zuniga-Teran & Andrew R. Sanderford

Greenspace Justice

Socio-Ecological Practice Research (2020) 2:149–159
https://doi.org/10.1007/s42532-020-00052-5

PERSPECTIVE ESSAY

Addressing injustice in green infrastructure through socio-ecological practice: What is the role of university–community partnerships?

Andrea K. Gerlak[1] · Adriana Zuniga-Teran[2]

sustainability

MDPI

Review

A Multidisciplinary Approach to Analyzing Questions of Justice Issues in Urban Greenspace

Adriana A. Zuniga-Teran [1,2,*] and Andrea K. Gerlak [1,3]

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Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Review

The unjust distribution of urban green infrastructure is just the tip of the iceberg: A systematic review of place-based studies

Adriana A. Zuniga-Teran [a,*], Andrea K. Gerlak [b], Alison D. Elder [c], Alexander Tam [d]

Tucson – Innovation challenge

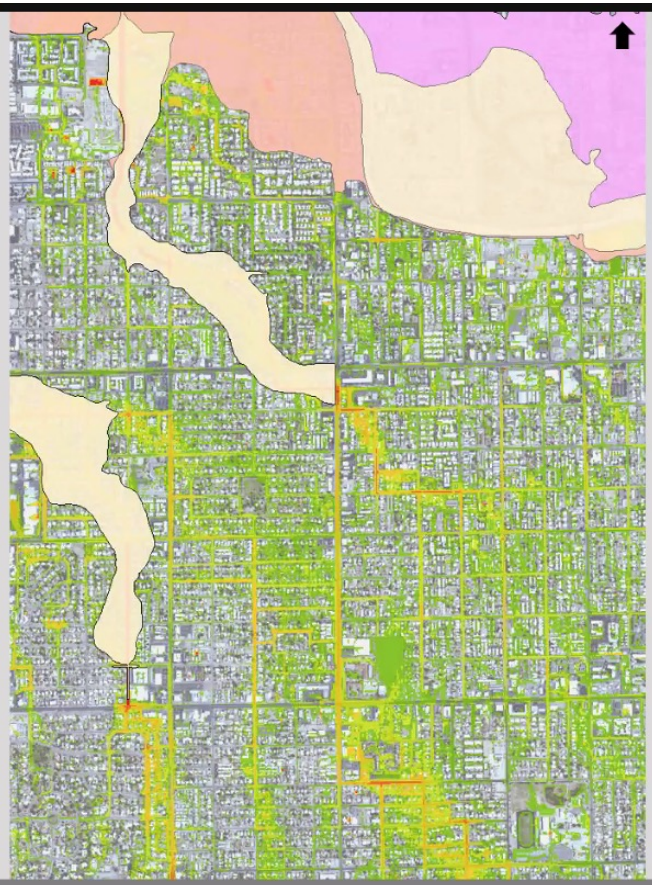
A community of practice (Low Impact Development Group) gets together every month to share lessons learned and expedite learning and implementation.

Pima County Regional Flood Control District (PCRFCD)

PCRFCD aims to retrofit older neighborhoods to restore flood plains that were developed.

Existing Conditions

- City of Tucson Priority Watersheds
- FLO-2D rainfall/runoff models



PIMA COUNTY
FLOOD CONTROL

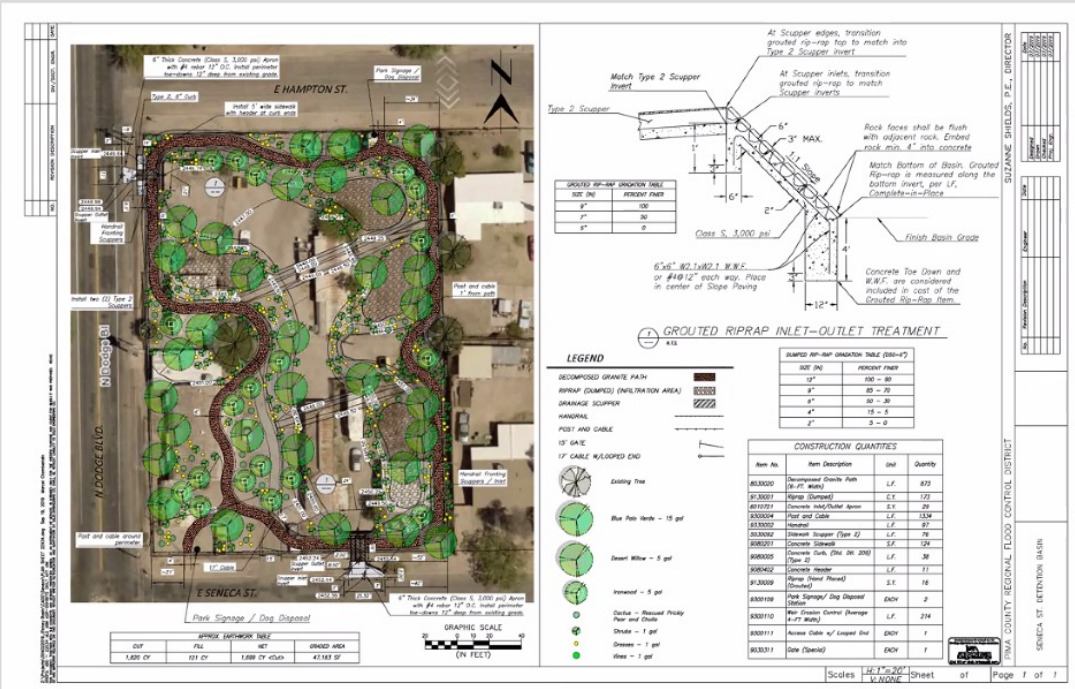
Jacob Prietto, CFM
Chief Hydrologist
Pima County Regional Flood Control District

Pima County Regional Flood Control District

Seneca Park (2019)

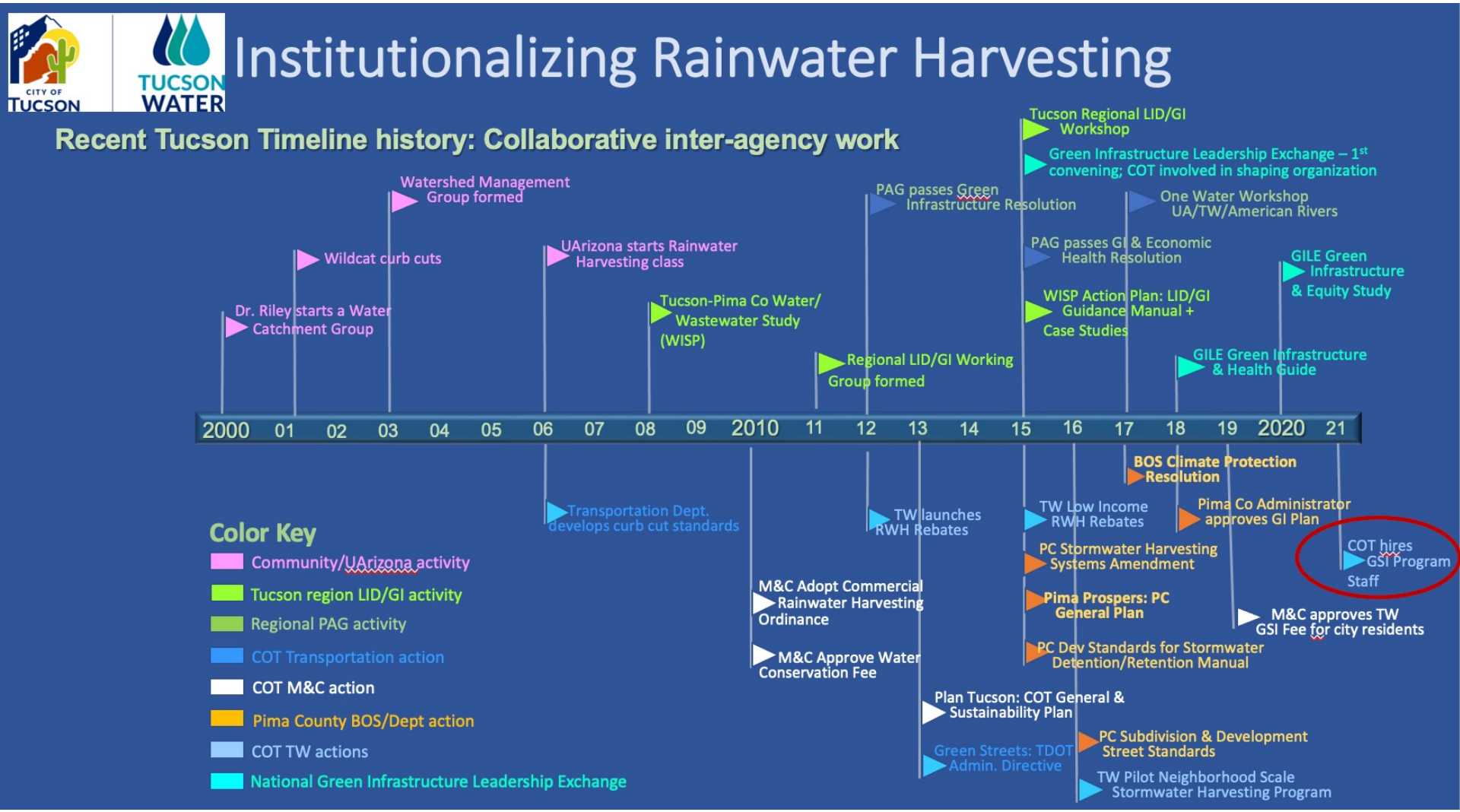
- State of Arizona
- Tax Lien Acquisition

PIMA COUNTY
FLOOD CONTROL



Credit: Jacob Prieto, Pima County Regional Flood Control District

Institutionalization of GI in Tucson

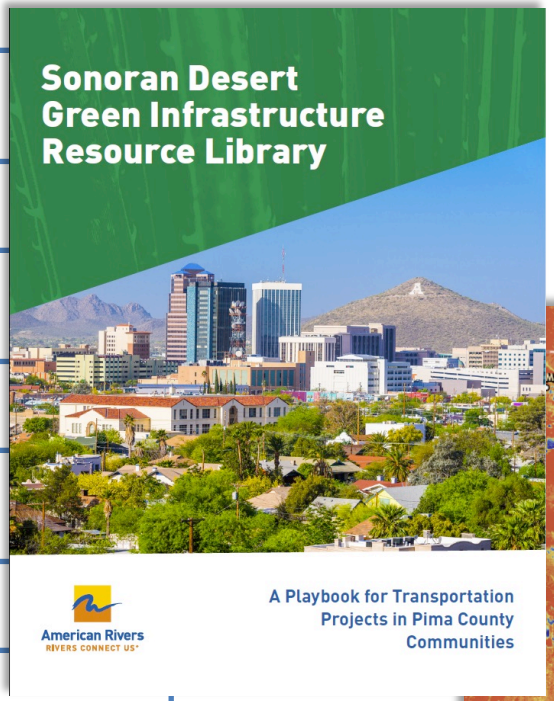


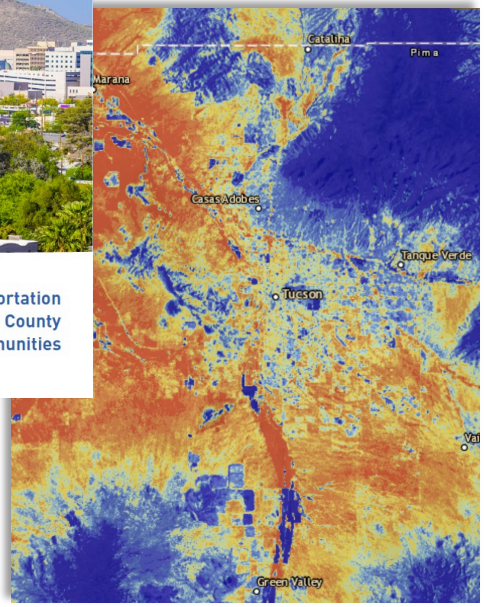
Credit: Irene Ogata, Tucson Water, City of Tucson

Regional GI Collaboration

Pima Association of Governments – oversees regional collaboration around GI

- Planning Tools and Collaborative Data Investments
- Data Driven Goals Setting, Assessment and Metrics
- Regionally Cohesive Outreach Messaging
- Regional Consistency & Guidance
- Learning from Models and Examples





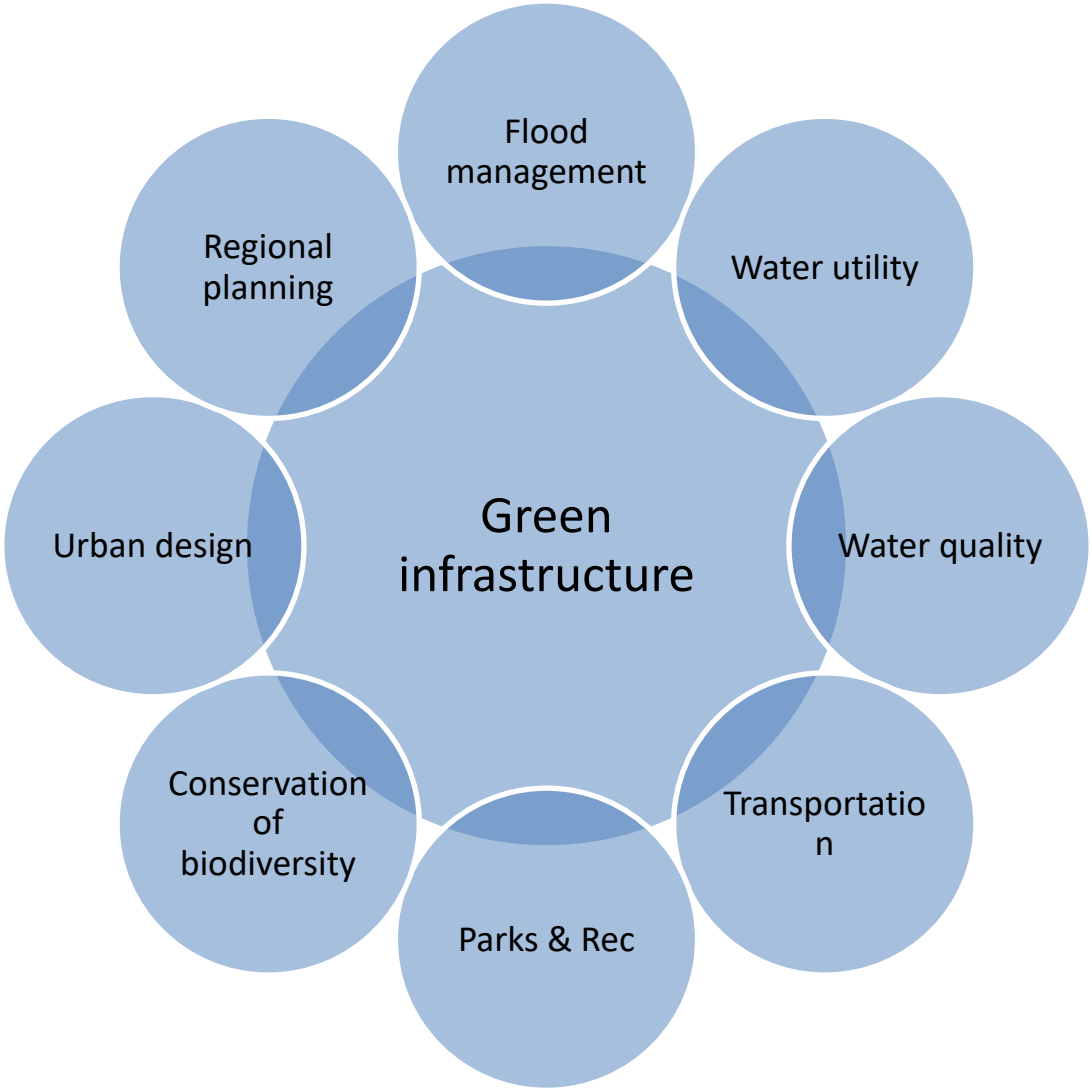
Credit: Mead Mier, Pima Association of Governments

Conclusion

GI has **broken siloes** in water management and has engaged other organizations.

Through GI, **equity issues become visible** – either you have it, or you don't.

Sustained engagement and maintenance are challenging and affect equity.



Conclusions

Community engagement is critical to address maintenance and equity issues in GI, but resources are needed to do this work.

Bottom line – it takes a village! Water managers need to collaborate with each other and other organizations to invest in community engagement efforts for greening to ensure water security for all.

Thank you!

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