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# Northern Arizona Water Affordability Study

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## Introduction

Access to safe, reliable, affordable drinking water is the foundation of public health, economic opportunity, and quality of life in any community. Yet, significant challenges associated with providing and maintaining this access exist across Arizona, perhaps most acutely on Native American reservations and in small, physically isolated rural communities across the state. Northern Arizona in particular is known for its isolated, rural areas and for the challenges faced by the Navajo Nation, Hopi Tribe, and other tribal and rural communities in developing and maintaining access to safe, reliable drinking water.

Much work has been done to document the challenges associated with **physical** access to safe, reliable water in this region, including by the Ten Tribes Initiative, the federal government, tribal governments, and the larger cities and towns in the region. Yet, little is known in this area about **financial** access to safe, reliable water, or in other words, the affordability of water.

In Northern Arizona water affordability is a significant challenge for many rural, small, and tribal communities. According to US Economic Research Service reports, the poverty rate in rural Arizona is nearly 22%, compared with 12.4% in urban areas of the state, and nearly 35% in tribal areas, leaving many struggling to pay their water bills[1]. Tribal communities are particularly vulnerable to water affordability issues due to the limited economic resources and high unemployment rates.

Recently the federal government pledged billions of dollars for tribal and non-tribal water and wastewater infrastructure, but often this investment does not cover the ongoing cost of operations. While such investment is helpful, in many isolated communities the ongoing costs of maintenance are spread over so few inhabitants as to render the cost of water service unaffordable. In addition, small, isolated towns, both tribal and non-tribal, may have difficulty recruiting and retaining operators and managers of water systems, making the process of applying for grants difficult to navigate and implementation problematic.

In addition to the local water utilities themselves, many groups are working to help communities in Northern Arizona achieve access to affordable, safe, clean water, including the Navajo Nation Water Access Coordination Group, Moenkopi Development Corporation, Native Builders, and the Northern Arizona Municipal Water Users' Association, among others.

In this paper water affordability is described and analyzed for tribal and non-tribal communities across Northern Arizona with the hope that the information can be useful to these utilities and groups.

1 Health Resources and Services Administration (HRSA) "Rural Health for Arizona Overview," Rural Health Information Hub, October 28, 2021, https://www.ruralhealthinfo.org/states/arizona.

# Why Measuring Water Affordability is Important

Water insecurity occurs when households do not have sufficient access to affordable and safe water. Measuring water affordability allows policymakers and utility managers to identify households and communities that are experiencing water insecurity or are at risk of falling into it. Water insecurity can be the result of disconnection due to inability to pay water bills as well as inadequate premise-based plumbing. Awareness of the characteristics and location of those who are experiencing or are at risk of water insecurity in a community can inform policies and programs to increase affordability and access to water.

A strong understanding of water affordability is helpful for utilities seeking grants and aid from state or federal programs. Many federal grant and loan programs prioritize projects that benefit low-income communities and address water affordability concerns. Hence utilities that can clearly evidence the water affordability challenges facing their customers may have a higher chance of securing funding for projects that address them.

Moreover, a strong understanding of water affordability is crucial in formulating effective water rate structures. Knowledge of the extent and severity of affordability challenges in the community enables utilities to strike a balance between covering costs and customers' ability to pay for water services. By examining affordability data, utilities can gain valuable insights into the financial obstacles faced by various customer segments, particularly those with low incomes, and make necessary modifications to their rate structures as well as design customer assistance programs.

Last, measures of affordability can help utility managers gauge the ability to increase water rates to support investment in the rehabilitation and replacement of aging water infrastructure while maintaining acceptable levels of affordability in the community.

# Northern Arizona

Northern Arizona is defined differently in varying contexts. In this study Northern Arizona includes the land area within the jurisdictions of Apache, Coconino, and Navajo counties. This selection is informed by the area represented by the Northern Arizona Council of Governments (NACOG) with the exception of Yavapai County, as it does not fall within the Colorado Plateau, an important geological feature often used to define the region in scientific contexts (Figure 1), and due to its smaller tribal land area relative to neighboring counties in the region (Figure 2). Mohave County is also not included in this study's definition of Northern Arizona. It is instead generally considered "Western Arizona" as it is represented by the Western Arizona Council of Governments (WACOG).

Colorado Plateau
Physiographic Region


Figure 1: The Colorado Plateau (https://files.cfc.umt.edu/cesu/NPS/CSU/2012/12_15Kuhn_-IMR_NNL_evaluate%20Colorado%20Plateau_rpt.pdf)

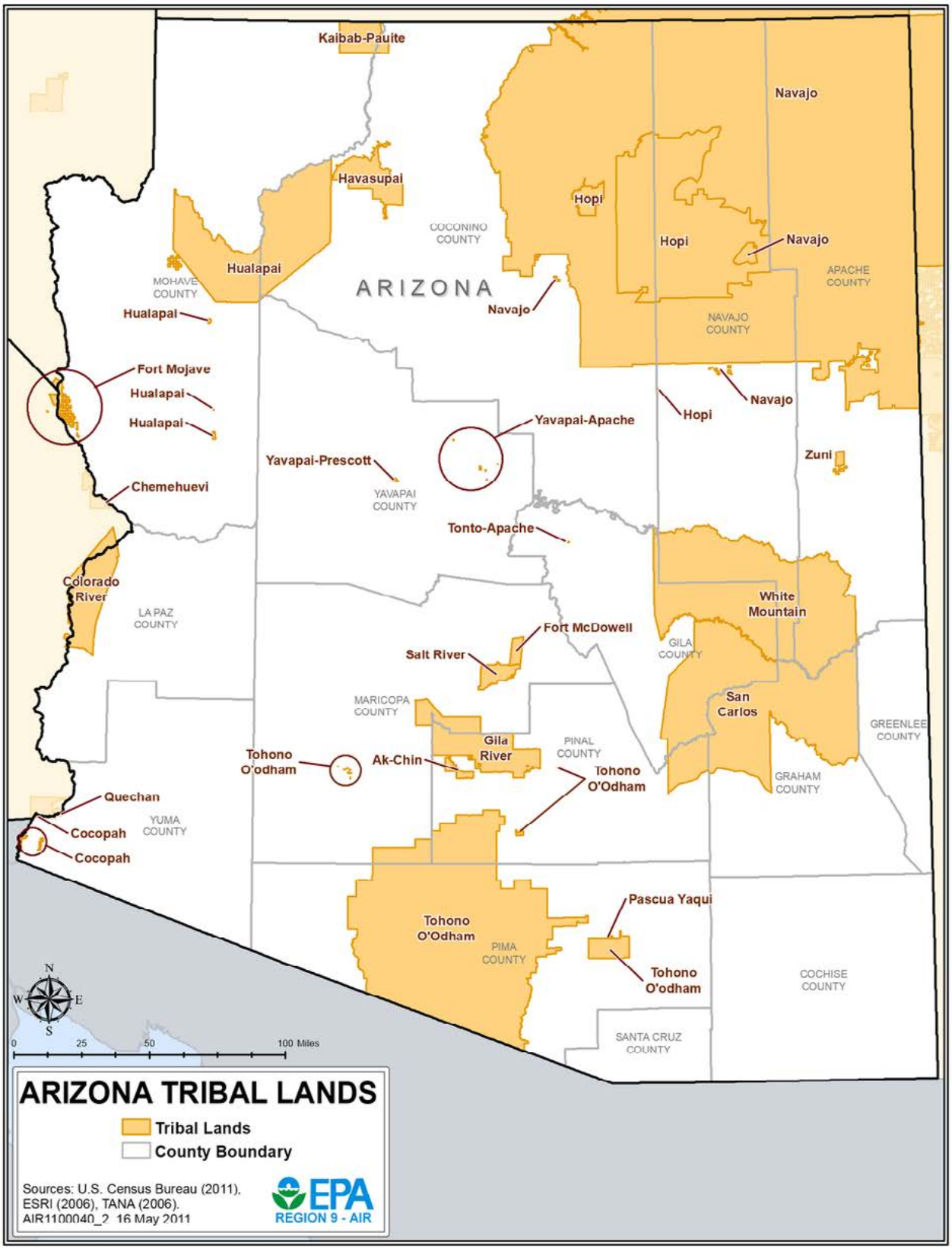


Figure 2: Arizona Tribal Lands

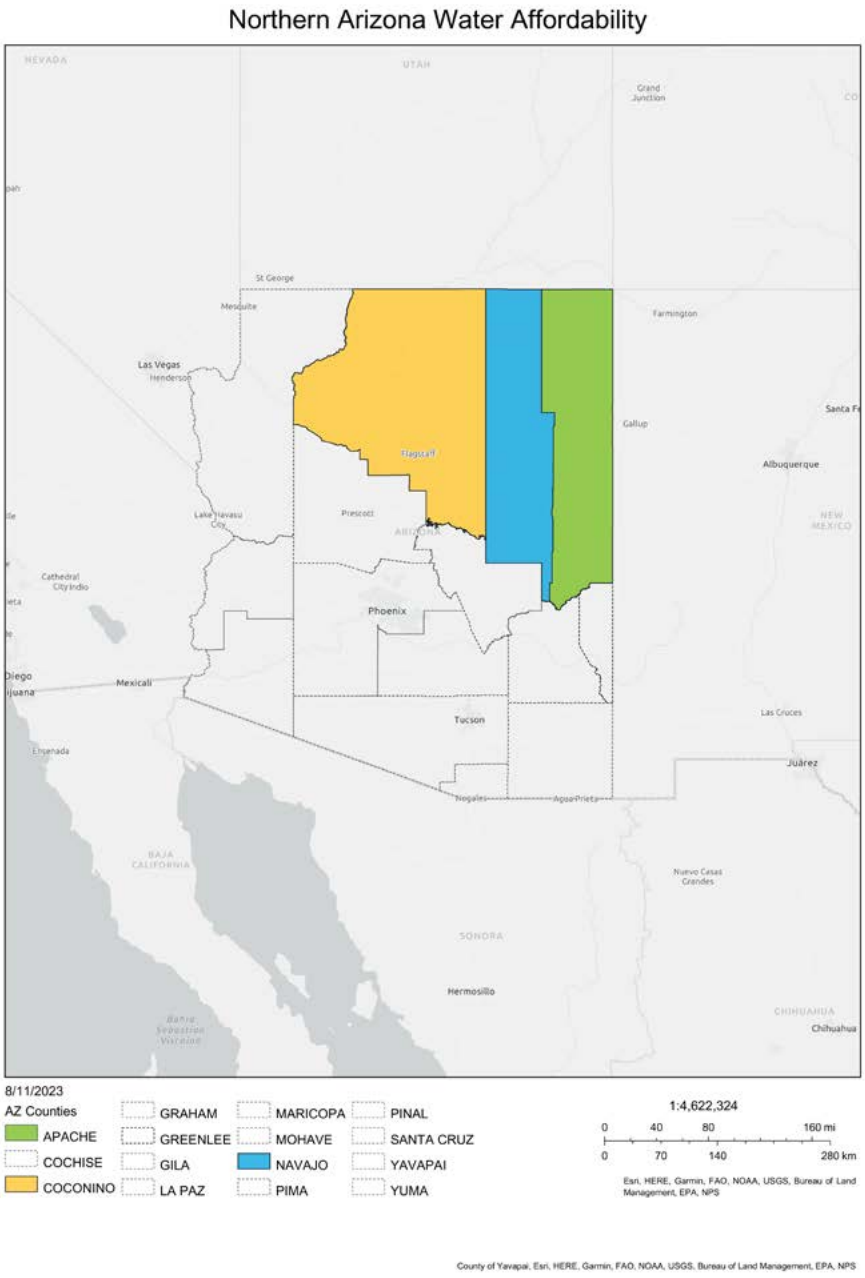


Figure 3: Coconino, Navajo, and Apache Counties (Arizona Water Blueprint)

Northern Arizona is special. This region is known for iconic landscapes of the West, such as the Grand Canyon National Park, Canyon DeChelly National Monument, and Monument Valley as well as for its isolated rural communities and the long distances between them.

Several Native American tribes call this area home, including the Hualapai Tribe, the Havasupai Tribe, the Kaibab Band of Paiute Indians, the Navajo Nation, the Hopi Tribe, the White Mountain Apache Tribe, and the Pueblo of Zuni. The San Juan Southern Paiute Tribe is a federally recognized tribe with traditional lands in Northern Arizona within the boundaries of the Navajo reservation.

Larger non-tribal communities include the cities of Flagstaff, Pinetop-Lakeside, Winslow, Williams, Eager, Tusayan, and Page.

# Water Systems in Northern Arizona

People and businesses in Northern Arizona gain access to drinking water in many different ways. Some households and businesses develop and maintain their own wells, while others rely on a well formally or informally shared with others. Still others lack piped water access and rely on water hauling stations (standpipes) that are physically distant from the home or business and haul the water over this distance to a holding tank on their property. Some have no household plumbing infrastructure and rely on bottled or hauled water. The Indian Health Service estimated at the beginning of the COVID-19 outbreak that nearly 10,000 homes on the Navajo Nation lacked piped water in their homes, and the Navajo Tribal Utility Authority reports that 30% of Navajo Nation homes lack access to piped water service[2]. Unless a private well is nearby, occupants of these homes must rely on hauled water.

2 Navajo Nation COVID-19 Water Access Coordination Group (WACG), "Navajo Safe Water: Protecting You and Your Family's Health," Navajo Nation COVID-19 Water Access Coordination Group, February 16, 2023, https://storymaps.arcgis.com/stories/1b4dc0d978c74d97a559e615730d4cd4.

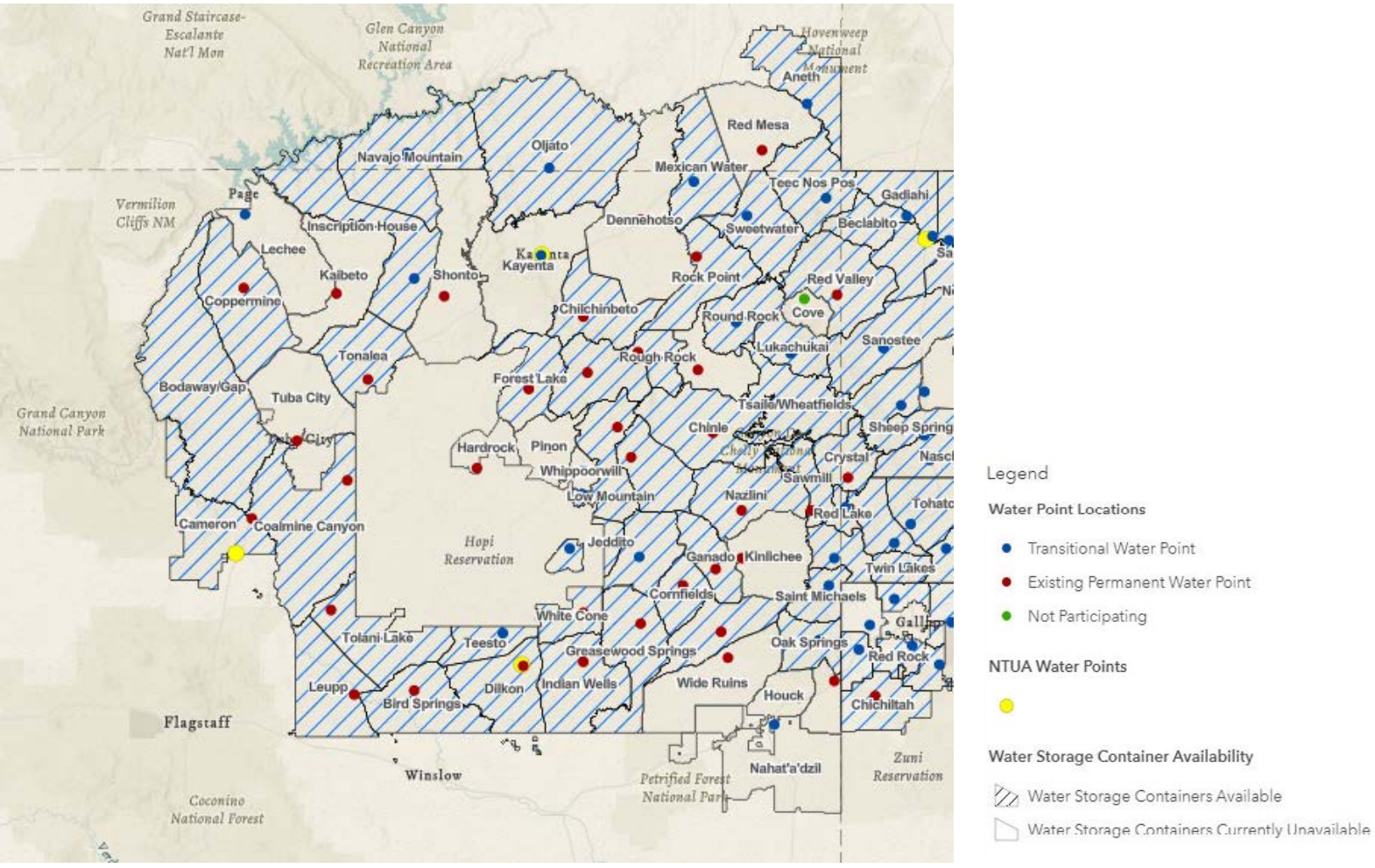


Figure 4: temporary, permanent, and Navajo Tribal Utility Authority water points on the Navajo reservation.
Source: Navajo Nation COVID-19 Water Access Coordination Group (WACG).

However the majority of the people and businesses in Northern Arizona gain access to drinking water via piped water delivered through community water systems, usually through formal, municipal water providers such as a private water company, a tribal utility authority, a domestic water improvement district, or a city-owned water utility.

A **community water system** is a water system which supplies drinking water to 25 or more of the same people year-round in their residences.

- The majority of people in Northern Arizona rely on community water systems. There are approximately 214 of them in the study area.
    - According to self-reported data, community water systems in the study area serve over 400,000 people, but this number includes schools, second-home communities, and tourist attractions that either count non-residents or that cause the number of people served to be double-counted in some cases. For comparison, according to the U.S. Census, the combined population of Apache, Coconino, and Navajo Counties is approximately 320,000.
    - The Hualapai, Havasupai, White Mountain Apache, and Hopi Tribes operate community water systems, as do the Navajo Nation and the Kaibab Band of Paiute Indians and some Hopi Villages. These tribal utilities offer access to a community water system in many population centers on reservations.
    - According to self-reported data, community water systems on tribal lands within the study area serve approximately 147,000 people, but this number includes schools and tourist attractions that either count non-residents or that cause the number of people served to be double-counted in some cases. For comparison, according to the U.S. Census, there are approximately 120,000 people living on tribal lands in the study area.
        - According to the Navajo Tribal Utility Authority, "Historically, Navajo people have a traditional economy based upon farming, hunting and grazing of livestock. This practice has continued into modern times, especially among the elders. A consequence of this practice is that Navajo people often live on large parcels of land, creating significant distances between neighboring homes, producing the lowest number of utility customers per mile in the U.S. and a high cost of providing service. As a result, it is often cost-prohibitive to provide utility services to individual homes on much of the Navajo Nation." Instead, community water systems exist in "...regional communities which primarily consist of housing developments built around schools, hospitals, and governmental centers.[3]"

Other than on the Navajo Nation there appears to be relatively broad access to community water systems in Northern Arizona. Although issues of water quality are beyond the scope of this report, it is important to note that the Hopi Tribe has long struggled with water systems that include levels of arsenic higher than allowed under the Safe Drinking Water Act. The federal government is in the process of completing the Hopi Arsenic Mitigation Project to improve water quality within Hopi lands.

There are different types of water systems other than community water systems and these differences are particularly important when considering access to drinking water in Northern Arizona, because there are many seasonal communities such as campgrounds and resorts, as well as enterprises that are very physically dispersed from more-populous communities, such as travel centers and boarding schools.

A **non-transient non-community water system** (NTNC) is a water system that supplies water to 25 or more of the same people at least six months per year in places other than their residences. Examples include schools, businesses, and hospitals that have their own water systems.

A **transient, non-community water system** (TNC) is a water system that provides water in a

3 Walter W Haase, "Navajo Tribal Utility Authority - About the NTUA," Navajo Tribal Utility Authority, May 2018, https://www.ntua.com/assets/5-2018-ntua-white-paper---about-ntua.pdf.

place such as a gas station or campground where people do not remain for a long time.

Of note, it appears as though several of the water systems labeled as "NC" in the Arizona Department of Environmental Quality Safe Drinking Water Information System database serving municipal purposes on non-tribal lands could potentially qualify as community water systems because they appear to supply at least 25 people in their residences on a permanent basis. Classifications are self-reported and not separately confirmed by the Arizona Department of Environmental Quality (ADEQ) unless fraud is reported. There are significant implications in the difference between the classifications since non-community water systems are not required to test for water quality.

There are approximately 170 NTNC and TNC water systems in the study area. These serve various purposes, such as lodging, remote business enterprises, and campgrounds,

Community water systems generally charge for water service because of the need to cover capital and operating expenses. Non-transient, non-community and transient, non-community water systems do not typically charge for water service separately from the business services provided. For example, mobile home and recreational vehicle facilities typically charge rent but do not charge for water separately from the rent.

Based on collected qualitative evidence, some small, private water systems operate under widely varied and informal well-sharing agreements. For example, one mobile home park owner reported that he billed users by dividing his monthly well meter by the number of hookups at that time, which varied seasonally. Another reported that the water rate was included in tenants' rent, but that this rate varied according to the number of tenants per month and their own unspecified determination. Based on this information, it can be reasonably assumed that in smaller rural communities some well sharing agreements are so informal they do not fall into any typical water rate structure and may operate as agreements sealed with just a word and a handshake.

Although the challenge of water affordability is likely most acute for those in Northern Arizona who are not connected to a community water system and must haul water from a standpipe, and may also be a challenge for those who rely on their own well or an informal, well-sharing arrangement, measuring water affordability in these instances is beyond the scope of this paper due to challenges with data collection. It is hoped that this study can be extended to include issues of affordability related to these challenges in a future phase.

The focus in this report is on water affordability associated with access to a functioning community water system that delivers piped water.

### Basic characteristics of community water systems on non-tribal lands

According to self-reported data in the ADEQ Safe Drinking Water Act database, in Northern Arizona, over 141,000 people are served by city-owned community water systems. The City of Flagstaff alone serves nearly 80,000. Nearly 70,000 people are served by private water companies, and around 23,000 by district systems, such as a domestic water improvement district or homeowner association. Essentially all of these water systems charge for water service under a broad range of rates, ranging from a low of $7.50 to over $100 for monthly consumption of 4,000 gallons of water.

### Basic characteristics of community water systems on tribal lands

On Navajo Nation lands, many people are served by more than 90 separate community water systems operated by the Navajo Tribal Utility Authority and/or the Navajo Nation. As of 2021, the Navajo Tribal Utility Authority has "approximately 39,000 (metered) customers and has 18 water-loading stations that serve an unknown number of additional customers who do not have

access to a piped water system".[4] The Navajo Tribal Utility Authority charges for water, but notably offers a discounted rate program for Senior Citizens or those on Lifeline/Life Support. The Navajo Tribal Utility Authority operates several utilities (communications, electric, natural gas, etc) and thus may have the flexibility to subsidize some water deliveries out of earnings from other utilities.

On White Mountain Apache Tribe lands, many of the twelve-thousand members are served by water systems at Miner Flat (Whiteriver), Hon Dah/McNary, Carrizo, and Cibecue. The White Mountain Apache Tribal Utility Authority charges for water, but notably offers discounted rates based on a number of different socio-economic and environmental factors: (a) a Senior Citizen Discount program for customers sixty years and older, (b) a Lifeline/Life Support Discount based on a physician's certification, (c) a Low Income Discount Program of 40%, and (d) a special rate discount applicable to users of the Carizzo water system, based on water quality.

The Kaibab Band of Paiute Indians Tribe is located on the Kaibab Paiute Indian Reservation in northern Arizona and split into five villages: Six-Mile, Kaibab, Juniper, Red Hills and Steamboat villages. The Kaibab Public Water System serves Kaibab, Red Hills and Juniper villages, while Steamboat Village is served by the Town of Fredonia, but still metered and billed by the Kaibab-Paiute Department of Public Works[5]. In total, around one-hundred meters are serviced, primarily homes and a few Tribally owned municipal buildings. The Kaibab-Paiute population is estimated to be around three-hundred individuals, indicating that the majority of households are served by these community water systems.

Pueblo of Zuni lands in Arizona do not appear to be occupied and no community water system appears to be available.

The San Juan Southern Paiute Tribe does not operate a community water system. Members living within the boundaries of the Navajo Nation are presumed to use the community water systems operated by the Navajo Tribal Utility Authority.

On Hualapai Tribe lands, the main source of water supply for the community of Peach Springs consists of three water wells located to the west of the community.[6] Spring water is also available on tribal lands. The Hualapai Tribal Utility Authority operates a community water system in Grand Canyon West. The Hualapai Tribe charges for water service.

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4 Deenise Becenti, "NTUA REQUESTS VOLUNTARY WATER CONSERVATION PRACTICES FROM ALL NTUA WATER CUSTOMERS," Navajo Tribal Utility Authority, July 9, 2021, https://www.ntua.com/assets/ntua-water-restrictions----.pdf.

5 Meghann Olson, "Kaibab Band of Paiute Indians Tribe Water Meter Replacement Project ," US Bureau of Reclamation, 2018, https://www.usbr.gov/watersmart///swep/docs/2019/applications/SWEP-081%20Kaibab%20Band%20of%20Paiute%20-ARC_extract_508.pdf.

6 Donald J. Bills and Jamie P. Macy, "Hydrogeologic Framework and Characterization of the Truxton Aquifer on the Hualapai Reservation, Mohave County, Arizona," Scientific Investigations Report, December 30, 2016, https://pubs.er.usgs.gov/publication/sir20165171.

The Havasupai Tribe relies on well water to meet its domestic needs. Spring water is also available on tribal lands. The Tribe operates a community water system that serves approximately 500 people in the village, as well as a community water system that serves its famous campground. The Havasupai Tribe does not charge for water service.

Lands of the Hopi Tribe in Northern Arizona are split into twelve villages that are located in three regions: First Mesa, Second Mesa and Third Mesa village. Forty-five minutes west of the Third Mesa is the village of Moenkopi "located at the western gateway to Hopi adjacent to the Navajo community of Tuba City"[7]. Many tribal members are served by community water systems at Keams Canyon, Upper and Lower Moencopi, Kykotsmovi, Polacca, Sipaulovi, Shungopavi, Mishongnovi, Bacavi, Yu Weh Loo Pahki, and Hotevilla. Some Hopi Villages and the Hopi Utilities Company charge for water service and there are ongoing discussions about how to charge for operational costs associated with the tribe's new arsenic mitigation project.

The characteristics and end-uses of all water systems in Northern Arizona are presented below in Figure 5, which shows the number of systems by their ownership and their end purposes. While tribal and private water systems are most numerous, it is notable that the city of Flagstaff serves the largest number of customers at more than 75,000 (customer counts are not shown in chart).

7 Hopi Education Endowment Fund, "About Hopi," Hopi Education Endowment Fund, 2023, https://www.hopieducationfund.org/about-hopi#:~:text=The%20villages%20of%20Moencopi%20are,a%20satellite%20community%20of%20Oraibi.

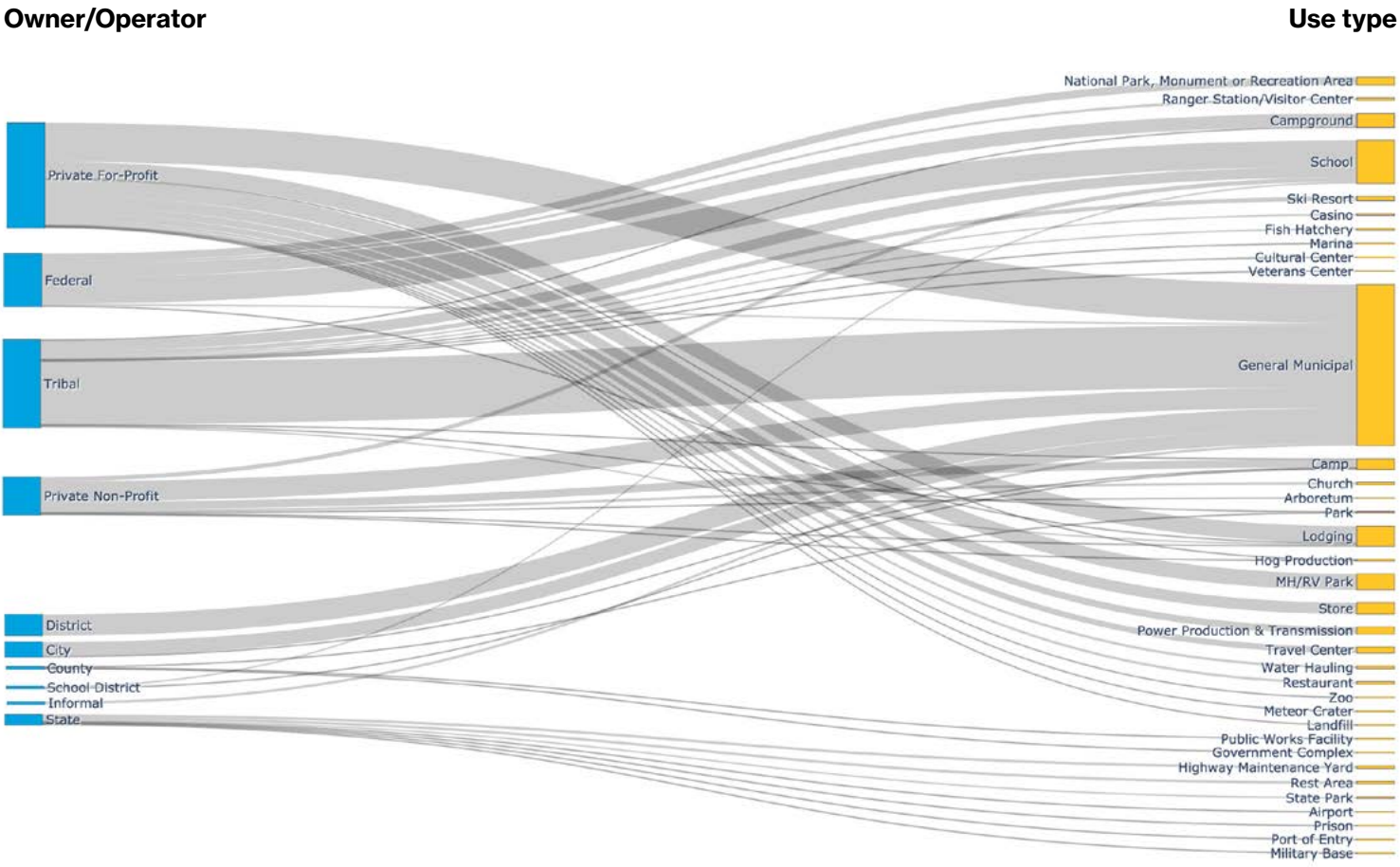



Figure 5: Characteristics and end-uses of all water systems in Apache, Coconino, and Navajo Counties, Arizona.

The characteristics and end-uses of community water systems in Northern Arizona are presented in Figure 6. Tribes, districts (mostly domestic water improvement districts), cities, and private water companies are the predominant suppliers of water through community water systems. Note that the federal government through the Bureau of Indian Affairs operates a number of community water systems that serve boarding schools.

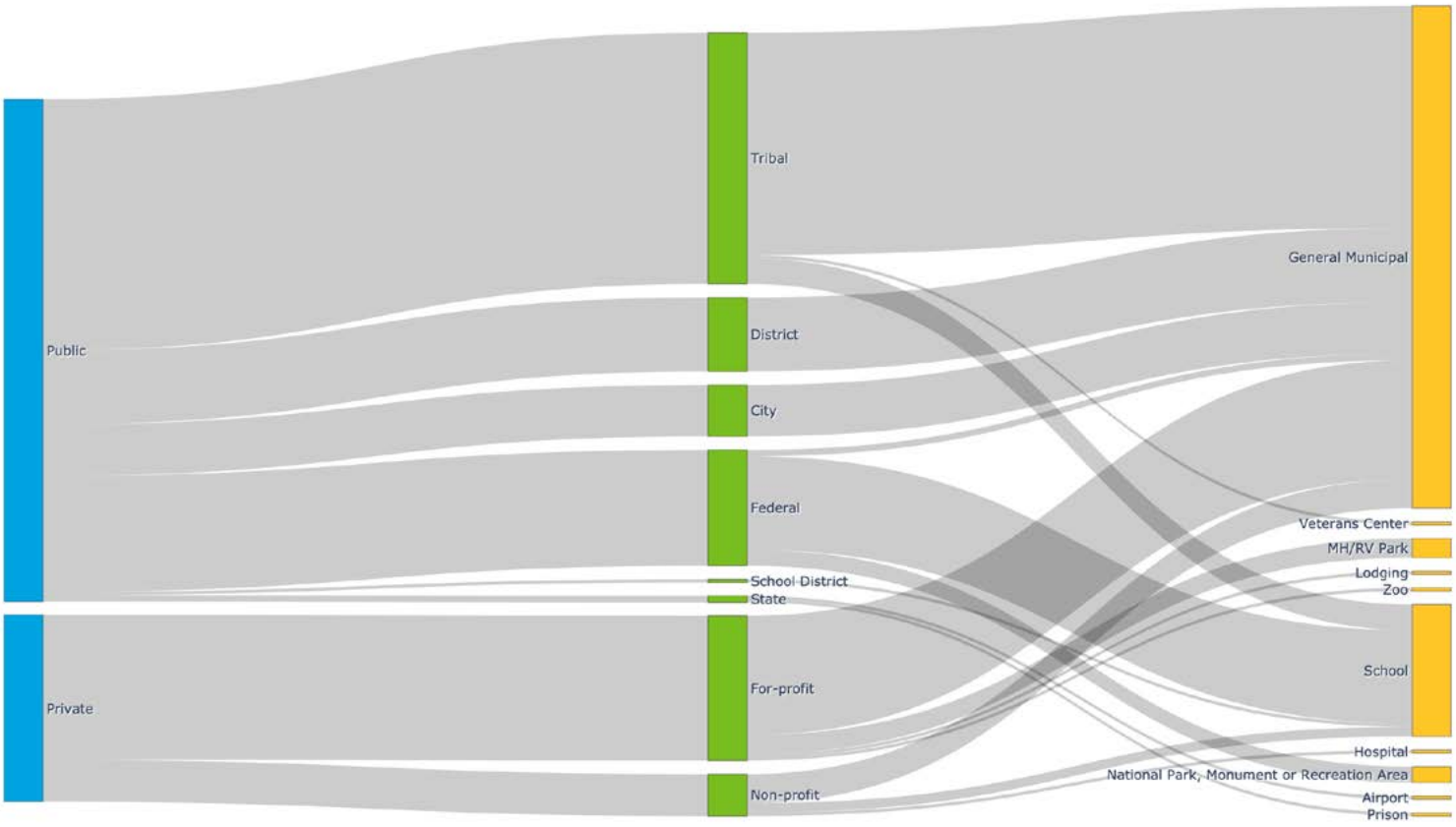



Figure 6: Characteristics and end-uses of community water systems in Apache, Coconino, and Navajo Counties, Arizona.

The Characteristics and end-uses of non-community water systems in Northern Arizona are presented below in Figure 7. End uses are extremely varied and represent the need to develop water systems in areas that are very geographically remote.

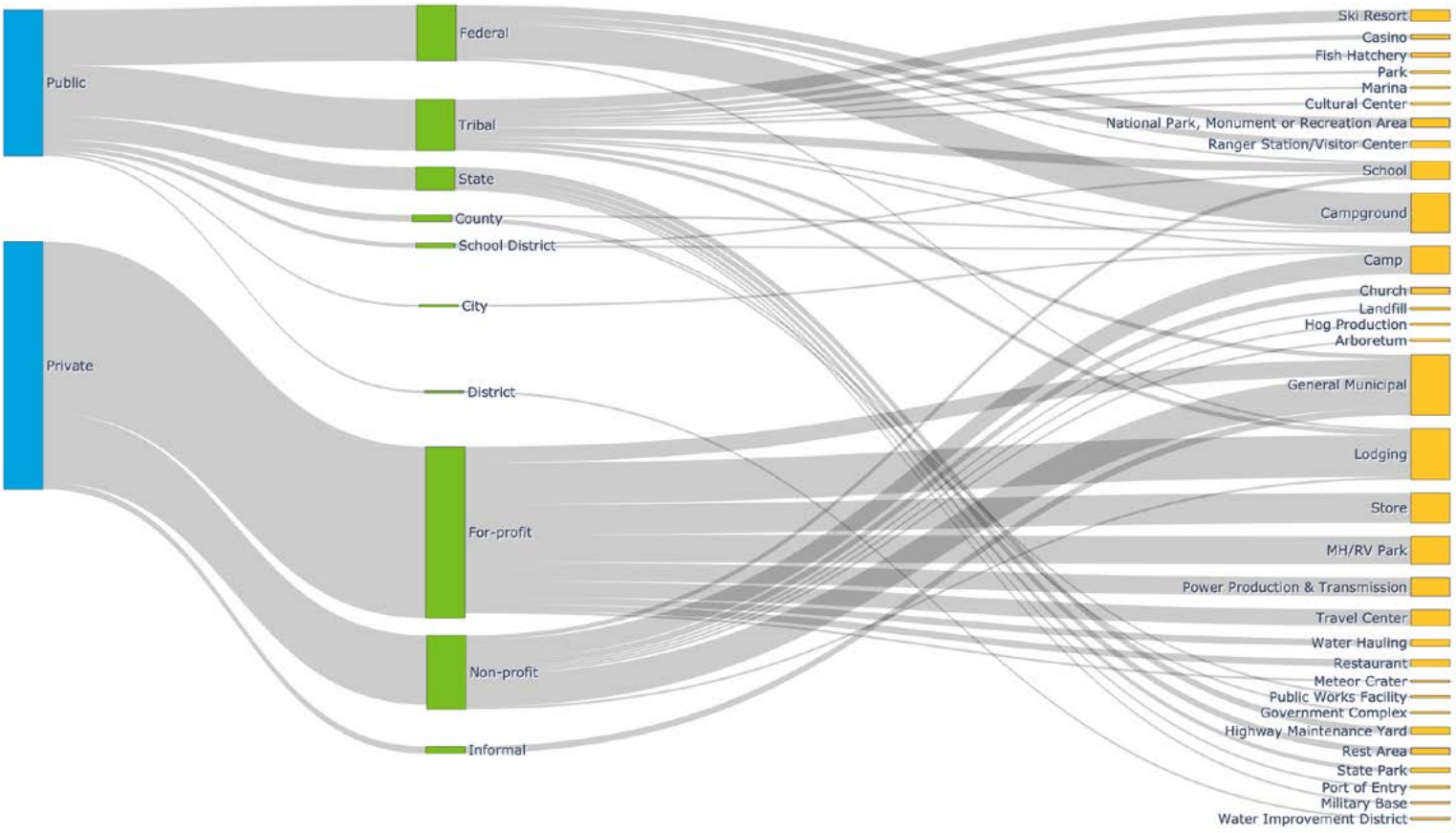



Figure 7: Characteristics and end-uses of non-community water systems in Apache, Coconino, and Navajo Counties, Arizona.

# Defining Water Affordability

The United Nations Office of the High Commissioner of Human Rights defined the human right to water as a universal entitlement to "sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses". The only clarification provided for what constitutes "affordable" is that the direct and indirect costs and charges associated with securing water must not, "compromise or threaten the realization of other Covenant rights".

**There is no standard definition of water affordability.** What is perceived to be an affordable water bill to one person may be perceived by another as completely unaffordable. These perceptions of affordability may change based on water consumption levels, relative incomes, and on the relative costs of other goods and services in an economy.

Instead, there are diverse definitions applied in different contexts that describe a measurable threshold to the point at which water is, or is not, "affordable." Definitions of water affordability often consider a ratio of the cost to the user of accessing piped water relative to measures of the user's financial capacity to cover that cost.

Because water affordability can mean so many different things to so many different people, policymakers and utility managers can benefit from examining water affordability through several different measures.

# Measuring Water Affordability

Decades ago the EPA established an approach for evaluating a community's financial wherewithal to fund required investment in water and wastewater infrastructure. The Residential Indicator uses median household income (MHI), to represent financial capability. The measurement defines affordability at the threshold of **4.5% of MHI** allocated to total water costs, with 2% allocated for wastewater and the remaining 2.5% for water costs.

Although not developed for the purpose, the EPA's **Residential Indicator** came into common usage for measuring household water affordability, likely for ease of computation and lack of ready alternatives. Discourse since this time has focused not only on the shortcomings of using the 4.5% of MHI affordability definition but also on the validity of using MHI to measure affordability at any threshold because it is not representative of the economic burden water costs place on a household below a "middle" income level. Many believe MHI thresholds ignore the hardships of the lowest income earners in a community, who are often at the highest risk of water utility disconnection due to non-payment.[8] This can result in a poor representation of water affordability for those that may have the largest affordability challenges.

Mindful of these criticisms, several income-based affordability frameworks have emerged that use techniques other than just median household income.

The **Household Burden** (HB) is found by calculating the percentage of income spent on water costs by users earning the **lowest quintile of income**, which makes the framework more representative of the burden placed on low-income households[9].

Some advocate for the use of **expenditure-based** measurements of water affordability, which evaluate water costs while also considering other essential expenses in the calculation of financial capability. These frameworks recognize that in an area where, for example, water rates may be low, other essential costs such as heating or healthcare may be significantly higher than

8 Manuel Teodoro, Measuring Household Affordability for Water and Sewer Utilities, American Water Works Association, February 6, 2018, https://awwa.onlinelibrary.wiley.com/doi/full/10.5942/jawwa.2018.110.0002.

9 Robert Raucher and Janet Clements, "Developing a new framework for household affordability and financial capability assessment in the water sector," American Water Works Association, April 17, 2019, https://www.awwa.org/Portals/0/AWWA/ETS/Resources/DevelopingNewFrameworkForAffordability.pdf?ver=2020-02-03-090519-813.

average, and the percentage of **available** income for water services will be relatively low. The most notable measurement approach based on this understanding is the **Affordability Ratio ($AR_{20}$)**[10]. It is the ratio of the cost of basic water service over income net of other essential costs of living for a family at the 20th percentile of income.
The $AR_{20}$ measures affordability

- At basic water needs associated with cooking, cleaning, and sanitation, as opposed to average water consumption-levels that often include outdoor use,
- For low-income households, rather than average- or median-income households, and
- In relation to other essential costs of living.

A complementary measure of affordability displays the cost for basic water service represented as the **hours at minimum wage**[11], meaning the number of hours worked at the area's respective minimum wage required to cover basic water costs.

To summarize, water affordability in this study is measured in the following ways:

- Residential Indicator – the percentage of the median household's income that goes towards paying a monthly water bill.
- Household Burden – the percentage of income spent on monthly water bills by households earning the 20th percentile of income.
- $AR_{20}$ – the cost of monthly water service over income net of other essential costs of living for a household at the 20th percentile of income.
- Hours at minimum wage – the number of hours worked at minimum wage necessary to cover basic water costs.

The monthly water cost for each method and for each community water system is measured at 4,000 gallons of consumption, an amount generally adequate for indoor cooking and cleaning, and not usually adequate for outdoor irrigation. That is, the intent is to represent the cost of drinking water for indoor purposes, not the cost of outdoor water use for landscape irrigation.

All four of these methods are employed in this paper to measure water affordability across Northern Arizona for households with access to piped water via a community water system. Notably, this study does not include the impact of any customer assistance programs offered directly through the water utility or indirectly through religious and other non-profit organizations in the community. Obviously, to the extent a third-party pays a customer's water bill, water for that customer is much more affordable. However, determining which systems have assistance programs, their structure, and how many customers are able to take advantage of them is beyond the scope of this study.

Also of note, the study area bisects the Hualapai and Kaibab Band of Paiute Indian reservations. The Hualapai Tribe and the Kaibab Band of Paiute Indians operate community water systems, but the population centers served lie outside of the study area, so affordability results for these tribes are not included. Pueblo of Zuni lands in Arizona do not appear to be occupied and no corresponding community water system could be found.

# Context for Results

In the study area and across the U.S., water utilities commonly employ a fixed monthly charge that is meant to recover the cost of meter reading, billing, and other activities for which cost does not vary with water consumption. Water utilities also typically employ a variable charge per unit for water consumed. Beyond this, there is no standard rate structure and they vary widely depending on the goals each community intends to achieve through its water charges as well as the business model of the entity providing water service. These goals can be contradictory, and commonly include revenue adequacy, conservation, affordability, economic development, transparency, and simplicity. It is common that state, county, and city taxes are levied against the sale of water in non-tribal areas.

10 Manuel Teodoro, Measuring Household Affordability for Water and Sewer Utilities, American Water Works Association, February 6, 2018, https://awwa.onlinelibrary.wiley.com/doi/full/10.5942/jawwa.2018.110.0002.

11 ibid

In addition, it is common for city-owned water utilities to be assessed various charges from the city, such as payment in lieu of taxes and payment for services provided centrally by the city such as information technology, human resources, and legal. Such costs get passed on to rate-payers and may further hinder affordability.

Of the water systems in the study area for which rate information could be found, nearly all charge a fixed, monthly fee. Approximately 76 percent use an increasing variable rate structure in which the cost of water per unit increases with consumption. Around 14 percent employ a variable rate structure in which the cost per unit remains flat as consumption rises, and 10 percent use a flat, monthly fee with no variable charge per unit of water consumed. Flat structures are more common with very small and informal systems as well as some tribal systems.

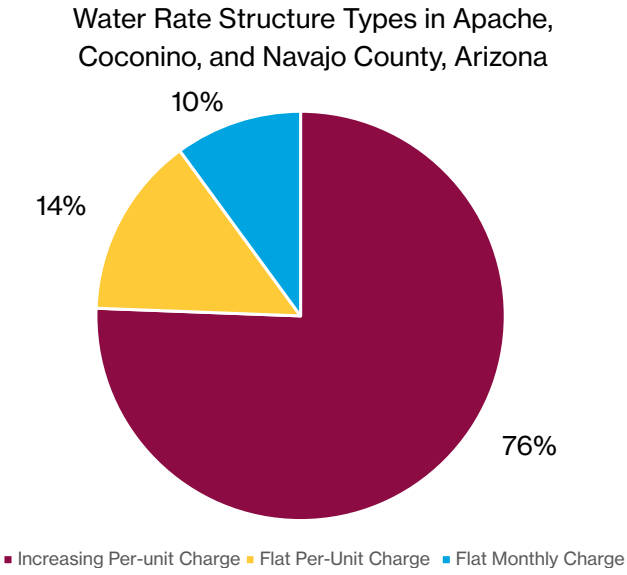



Figure 8: Water rate structure types in Northern Arizona

## Water rate structure matters for affordability

- Smaller fixed monthly fees enhance affordability since the fixed fee is a charge that cannot be avoided by using less water. In general, larger fixed monthly fees are proportionately more expensive for households in the bottom quintile of income.
- The presence of an "allowance" of water consumption that is included in the fixed monthly fee can help make water access more affordable. Around 16% of the water systems for which rate information could be found include allowances.
- Smaller unit charges enhance affordability, all else equal, but must be balanced with the need to charge more for water as consumption increases to encourage water conservation in Arizona's arid environment.

## Water rate structure matters for financial viability of the community water system

- If monthly fixed fees and variable charges are set too low, revenue generation may not be adequate to fund operations or necessary investments in rehabilitation and replacement of aging infrastructure.[12]
- Monthly fees that are small compared to variable consumption rates may increase revenue volatility during economic downturns or as customers conserve water.
- Affordability increases access to drinking water, but water affordability concerns must be balanced with the need to generate revenue adequate to ensure the continued viability of the community water system. Water systems are extremely expensive to operate, maintain, and improve. The costly need to invest in the rehabilitation and replacement of aging infrastructure increases over time.

Without financial viability, physical deterioration of the community water system occurs, access to safe, clean water declines, and concerns about affordability become moot.

12 David Tucker, "Key Financial Indicators for Water Systems: Revenue Stability," Environmental Finance Blog, February 8, 2016, https://efc.web.unc.edu/2016/02/08/revenue-stability/.

# Results

### Monthly Water Costs at 4,000 gallons of Consumption

In Northern Arizona, the median monthly cost of water at 4,000 gallons of consumption is approximately $32.50.

The monthly cost of water at 4,000 gallons of consumption varies from a high of near $100 in Tusayan to a low of zero for the Havasupai Tribe. Water problems are well documented in Tusayan, which is the town nearest Grand Canyon National Park. Tusayan struggles with water supply stress, a growing population, and the need to accommodate the many millions of visitors to the Grand Canyon each year.

Given the expansive geography and large differences between the number of people served in different water systems, as well as large differences in water quality, monthly water costs in the study area at 4,000 gallons of consumption are remarkably similar (mean $37.57, standard deviation $15.16, & coefficient of variance .4). This may be because of similarities in cost recovery needs and rate structures, or a sense of the politically-acceptable level of water costs that is broadly applicable across the region.

As can be seen in Figure 9 below, the average private water system monthly water cost is higher than the average public water system cost. Private water systems in this context include not just private water companies but also private and informal water associations, such as homeowners' associations and water users' associations. It is important to keep in mind that lower water costs, while potentially enhancing water affordability, are not necessarily desirable if cost recovery is not adequate to pay for continual investment in the rehabilitation and replacement of aging water infrastructure.

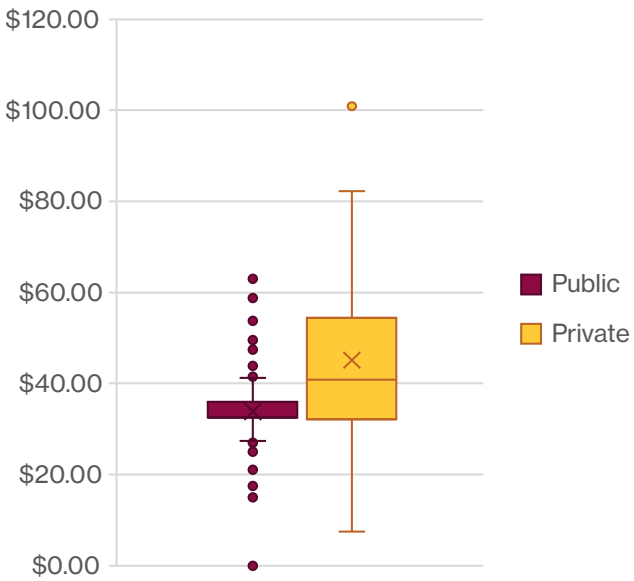



Figure 9: Monthly Water Cost at 4,000 Gallons of Consumption in Apache, Coconino, and Navajo Counties, Arizona, grouped by Utility Type (Public versus Private)

The average tribal monthly water cost is lower than the average non-tribal cost.

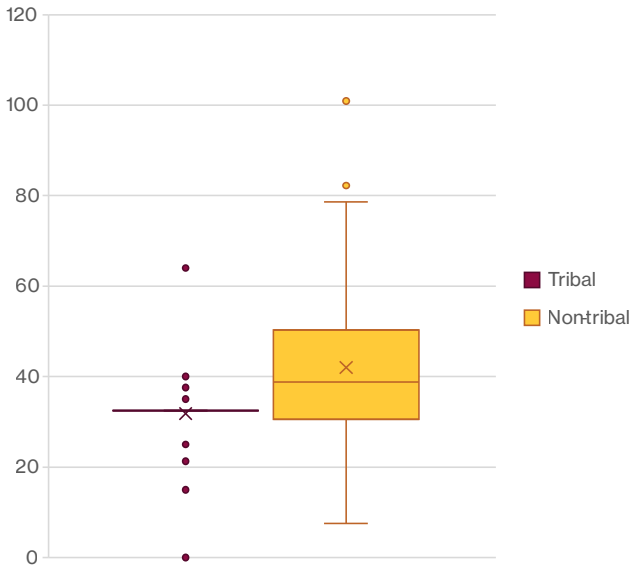



Figure 10: Monthly Water Cost at 4,000 Gallons of Consumption in Apache, Coconino, and Navajo Counties, Arizona, grouped by Utility Type (Tribal versus Non-tribal)

## Residential Indicator Results

Water affordability as measured by the Residential Indicator is calculated as the monthly cost of water consumption at 4,000 gallons of consumption divided by median household income and gives a general picture of the percentage of income that must be dedicated to a water bill for a household of median income. The Residential Indicator will be higher when water costs are high relative to income. In Northern Arizona, the average Residential Indicator score is .94, meaning that on average just under one percent of median household income is necessary to pay monthly water costs.

Average Residential Indicator scores for public and private utilities are similar, and each category has a broad range of results.

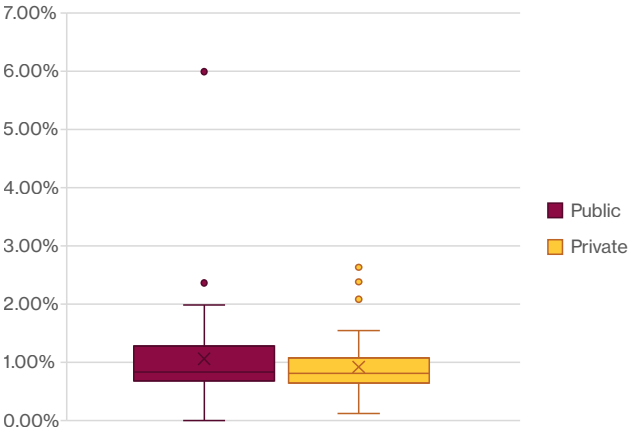



Figure 11: Residential Indicator scores in Apache, Coconino, and Navajo Counties, Arizona, grouped by Utility Type (Public versus Private)

Generally, median household income in the study area is lower on tribal lands. The average Residential Indicator score on tribal lands at 1.09% is more that on non-tribal lands at .85%.

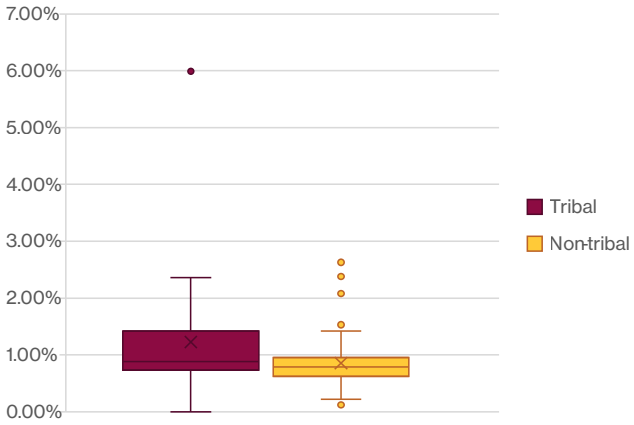



Figure 12: Residential Indicator scores in Apache, Coconino, and Navajo Counties, Arizona, grouped by Utility Type (Tribal versus Non-tribal)

## Household Burden Results

Water affordability as measured by the Household Burden is calculated as the monthly cost of water consumption at 4,000 gallons of consumption divided by lowest-quartile household income and gives a general picture of the percentage of income that must be dedicated to a water bill for a low-income household. The Household Burden will be higher when water costs are high relative to income. In Northern Arizona, the average Household Burden score is 2.34%, meaning that on average low-income households must dedicate over two percent of their income to pay monthly water costs.

Household Burden scores are very similar for public and private water utilities in the study area. However, there is a much wider range of results for public water utilities.

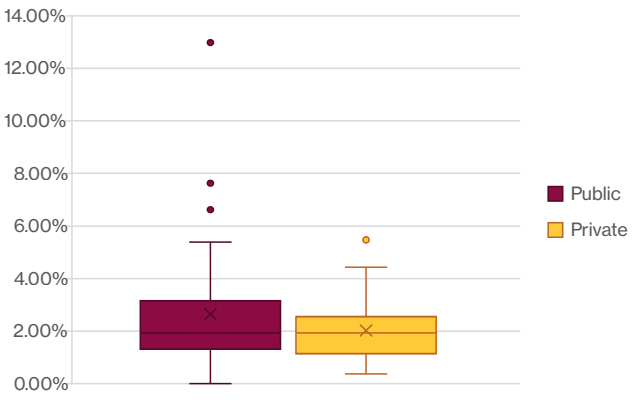



Figure 13: Household Burden scores in Apache, Coconino, and Navajo Counties, Arizona, grouped by Utility Type (Public versus Private)

It is when comparing Household Burden scores for tribal versus non-tribal systems that larger differences appear. Generally, lowest-quintile household income in the study area is lower on tribal lands, and in many cases, much lower. The average tribal Household Burden score at 3.02% is around one-and-a-half times that on non-tribal lands at 1.92%.

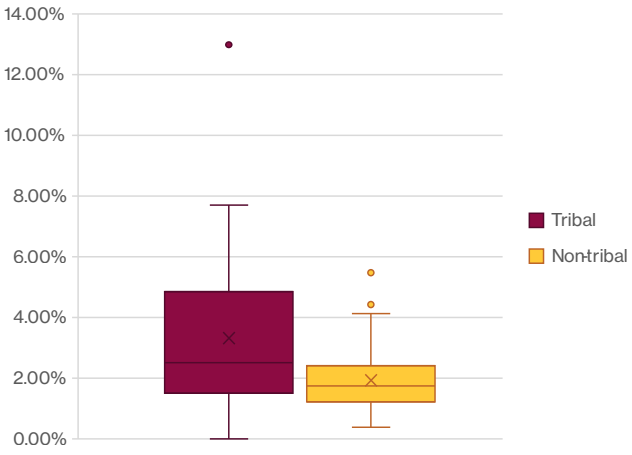



Figure 14: Household Burden scores in Apache, Coconino, and Navajo Counties, Arizona, grouped by Utility Type (Tribal versus Non-tribal)

## $AR_{20}$ Results

$AR_{20}$ measures the cost of monthly water service over income net of other essential costs of living for a household at the 20th percentile of income. On non-tribal lands in this study, 'other essential costs of living' include housing, healthcare, food, utilities other than water, fuel, and taxes.

Native Americans living on tribal lands have some advantages in terms of expenditures in that they do not pay state, county, or local property taxes, do not pay state income taxes, and do not pay for medical services provided by the Indian Health Service. On tribal lands in this study, 'other essential costs of living' include housing, food, utilities other than water, and fuel, but do not include healthcare or state and local taxes. Nonetheless, because lowest-quintile household income in the study area is lower on tribal lands, and in many cases, much lower, $AR_{20}$ results are generally much higher on tribal lands, with the exception of lands of the Havasupai Tribe, where there is no charge for water service.

There is a much broader range of $AR_{20}$ results for public systems compared to private water systems, mainly because of the range of results on tribal lands. In contrast, the $AR_{20}$ results for public and private systems outside of tribal lands are very similar to each other, with an average of 3.92% and 3.99% respectively.

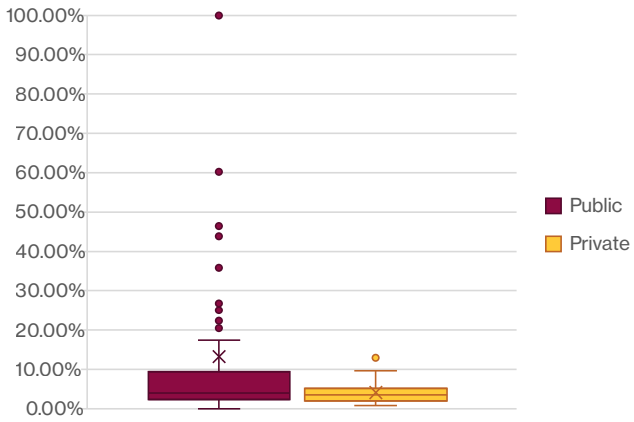



Figure 15: $AR_{20}$ scores in Apache, Coconino, and Navajo Counties, Arizona, grouped by Utility Type (Public versus Private)

The differences between $AR_{20}$ results between tribal and non-tribal lands are shown in Chart 16 below.

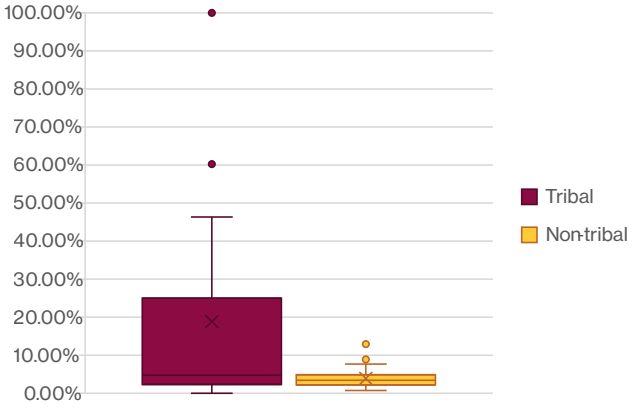



Figure 16: $AR_{20}$ scores in Apache, Coconino, and Navajo Counties, Arizona, grouped by Utility Type (Tribal versus Non-tribal)

Note that in some tribal communities, $AR_{20}$ results reach 100%, meaning essentially that all income net of other essential expenses must be dedicated to paying for water service. This happens in extremely poor communities.

## Hours at Minimum Wage Results

On average, households in the study area can pay for 4,000 gallons of monthly water consumption by performing 3.6 hours of labor at minimum wage. There is a small difference in this result between public and private water systems (3.79, and 3.3 hours, respectively).

A comparison of tribal versus non-tribal results is more interesting. The minimum wage in Arizona is $13.85 per hour (at the time of writing). Because tribes are sovereign nations not subject to state laws, they can either set their own minimum wage or follow the federal minimum wage of $7.25 per hour. Most tribes in the study area have elected to follow the federal minimum hourly wage, except the Hualapai Tribe, where workers are paid $15.00 per hour. On most tribal lands, workers earn less in minimum wage than workers in the remainder of Arizona, yet even counting for this, in some communities on tribal lands, fewer hours at minimum wage must be worked to pay for 4,000 gallons of monthly water consumption because within those communities the cost of water is relatively low. Nonetheless, on average workers on tribal lands must work 4.39 hours at minimum wage to afford this level of water consumption, compared to only 3.06 hours on non-tribal lands.

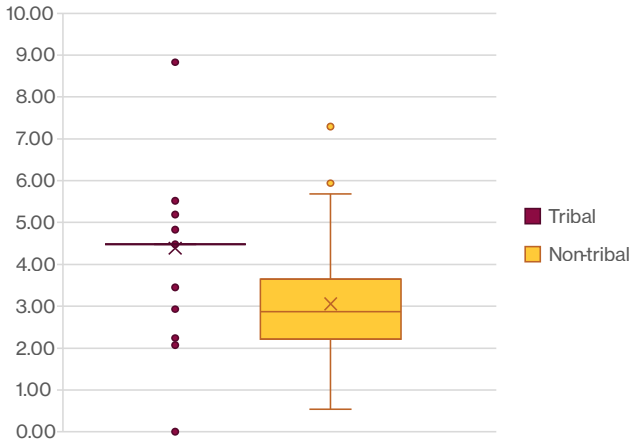
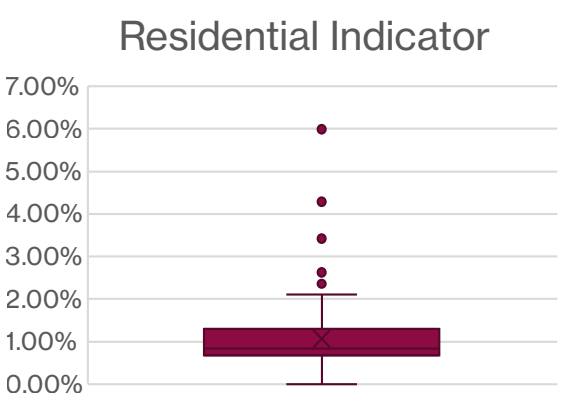


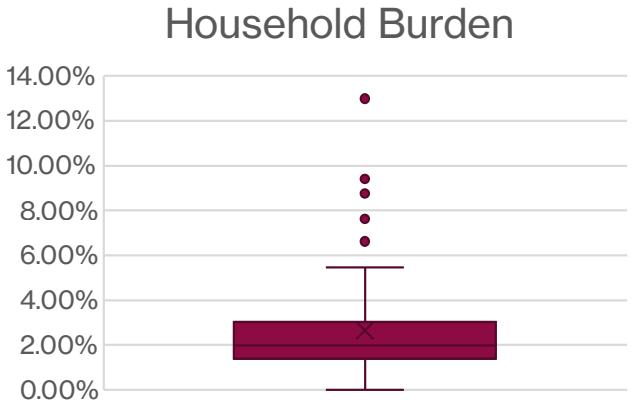

Figure 17: Hours at Minimum Wage scores in Apache, Coconino, and Navajo Counties, Arizona, grouped by Utility Type (Tribal versus Non-tribal)

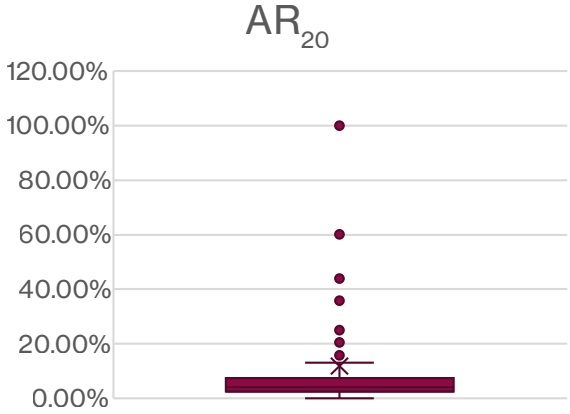
# Conclusions

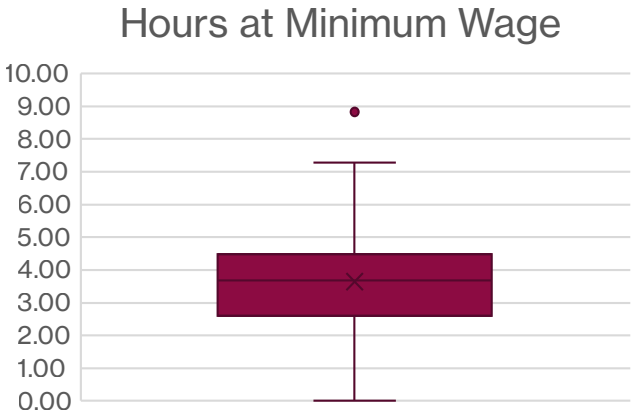
The median Residential Indicator score in the study area is .82%, the Household Burden 1.94%, and $AR_{20}$ 4.04%. In general, households in Northern Arizona can pay for 4,000 gallons of monthly water consumption by performing 3.6 hours of labor at minimum wage. A table of results for each community with a community water system is presented in Appendix A.

Results summarized are shown below in figures 18 through 21.




Not surprisingly given Northern Arizona's vast landscape, varied water utility sizes, and different socio-economics, measures of affordability vary widely.

Within each community, Residential Indicator measures of affordability are lowest (meaning more affordable) because they represent the income that the median-income household must dedicate to monthly water service. As such, Residential Indicator measures are likely a better measure of the ability of the entire community to collectively pay for water service and may be useful as a measure of the ability of the entire community to increase water rates to pay for rehabilitation and replacement of aging water infrastructure. This interpretation is similar to the EPA's intent in creating residential indicator scores to assess the ability of communities to pay for consent decrees under the Clean Water Act. Only in tribal communities and in Tusayan do Residential Indicator scores top 2.5%, the threshold originally used by the EPA to determine whether water service in a community was "affordable."

Household Burden measures of affordability

within each community are next-lowest. While the Household Burden more accurately represents the relative cost of monthly water service for a low-income household, this measure does not take into account the size of the water bill relative to the income left to a low-income household after paying for other essential services. It is for this reason that Household Burden scores within a community are lower than $AR_{20}$ scores, which assess the affordability of monthly water service relative to income and the cost of other essential goods and services. Both Household Burden and $AR_{20}$ scores are generally much higher (meaning less affordable) on tribal lands where some communities are extremely impoverished. For contrast, in six tribal communities the $AR_{20}$ score reaches 100%, and in twenty-six tribal communities the $AR_{20}$ score is larger than 10%, the threshold set by the city of Phoenix Citizens' Water and Wastewater Rate Advisory Committee as "affordable[13]." In only one non-tribal community, Tusayan, does the $AR_{20}$ exceed this level.

The monthly cost of 4,000 gallons of water consumption in the study area on tribal lands varied from $0.00 to $64.00, but are generally lower than the cost on non-tribal lands, where the cost varied from $7.50 to over $100.00. Nonetheless, because all of the tribes in the study area other than the Hualapai tribe adhere to federal minimum wage laws of $7.25 rather than the Arizona state minimum of $13.85, in many tribal communities more hours of work at minimum wage must be performed to afford this level of water consumption than on non-tribal lands. Measures of affordability through Hours at Minimum Wage varied from zero to 8.83 on tribal lands, and from .54 to 7.29 on non-tribal lands.

No 2023 national results are available for monthly water consumption of 4,000 gallons. However, national results for 2019 for combined water and sewer costs for monthly water consumption of 6,200 gallons exist. While these results are not directly comparable because they are less up-to-date, include sewer costs, and entail a higher level of monthly water consumption, they can give context to results presented here. Figures from Manny Teodoro's publication "Water and sewer affordability in the United States: a 2019 Update[14]" are included as figures 23 and 25, below.

13 City of Phoenix Water Services Department, "Water Equity Initiative," City of Phoenix, June 23, 2020, https://www.phoenix.gov/waterservicessite/MediaAssets/WSD%20Home%20Page/EquityPaper_2020-06-23_Final.pdf

14 Manuel Teodoro and Robin Saywitz,"Water and sewer affordability in the United States: a 2019 update," April 14, 2020, https://doi.org/10.1002/aws2.1176.

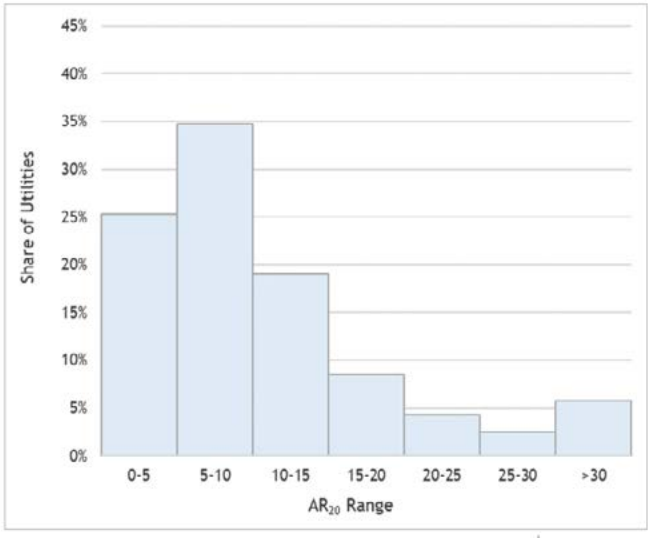



Figure 23, Single-family $AR_{20}$ in the United States per Teodoro, 6.2kgal monthly consumption, water and sewer combined costs

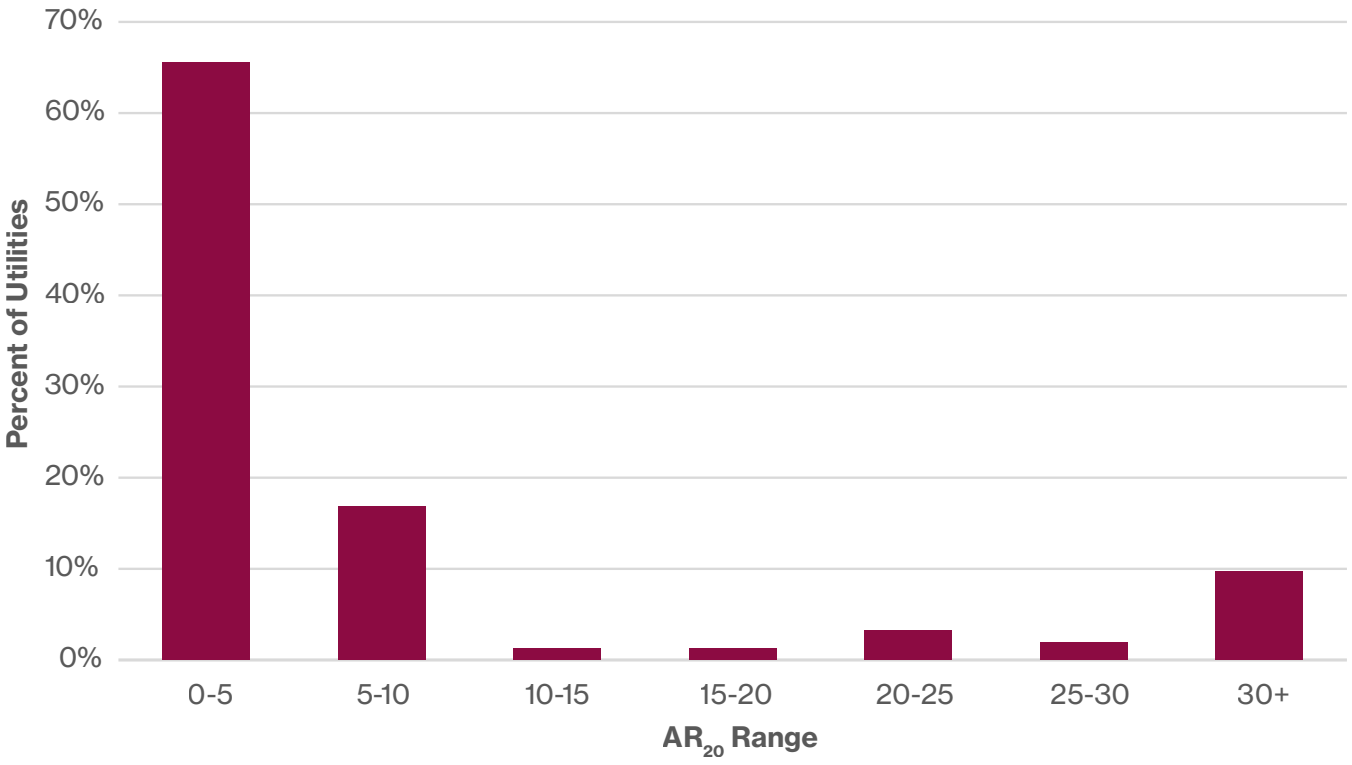



Figure 24: Single-family $AR_{20}$ in Northern Arizona (4 kgal monthly consumption, water costs only)

When considering Teodoro's $AR_{20}$ results as context, a couple of things stand out. First, average $AR_{20}$ values in Northern Arizona at 4.04% seem to be roughly in-line with national measures of $AR_{20}$. Even assuming that drinking water bills are forty percent of combined water and sewer bills, and adjusting for an increase from 4,000 to 6,200 gallons of monthly water consumption, it is unlikely that average $AR_{20}$ values in Northern Arizona would increase much beyond 10%, which would put values in the same range as 35% of utilities nationwide. Second, in national results for water and sewer costs only around 6% of utilities surpass $AR_{20}$ of 30%. By contrast in Northern Arizona nearly 10% of utilities surpass $AR_{20}$ of 30% for drinking water only and at a lower volume of monthly consumption. Water affordability in Northern Arizona is a study in extremes.

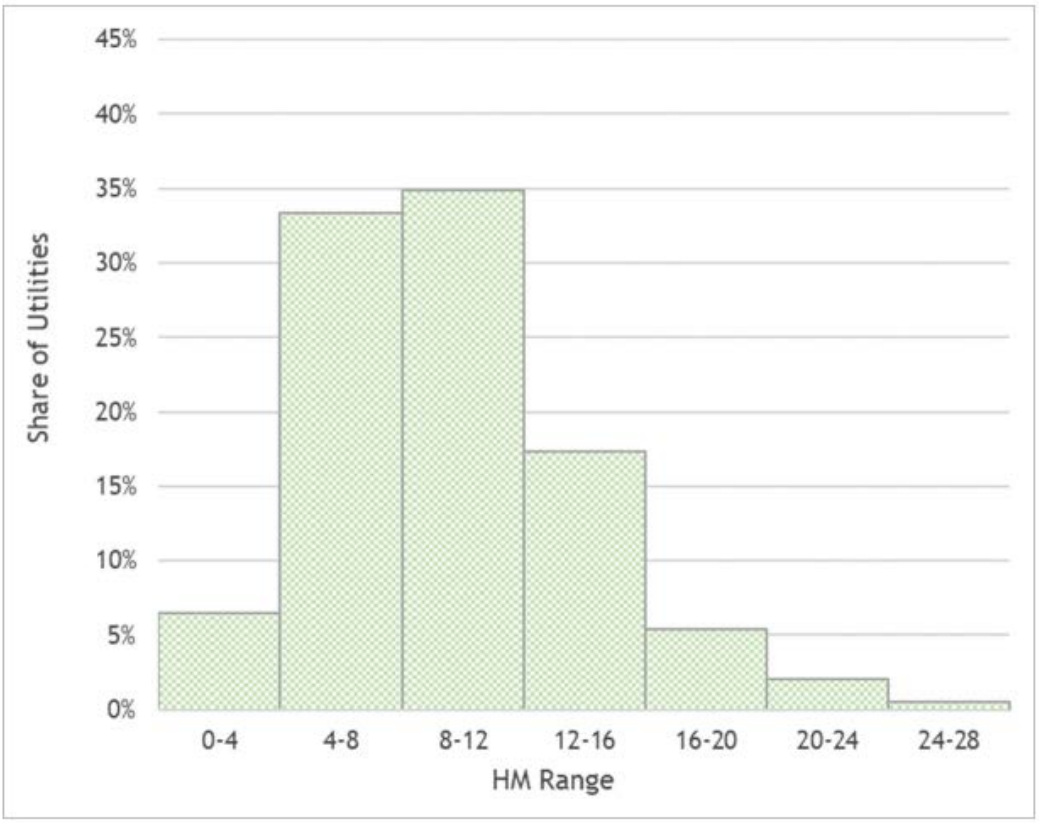



Figure 25: Single-family Hours at Minimum Wage in the United States per Teodoro (6.2Kgal monthly consumption, water and sewer costs combined)

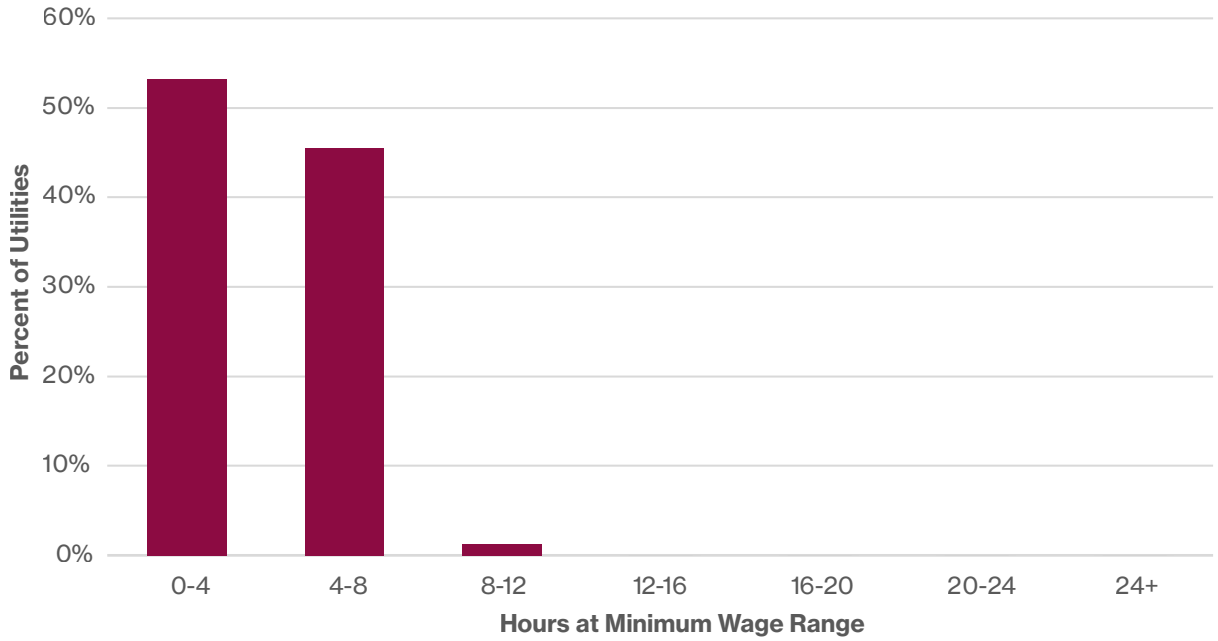



Figure 26: Single-family Hours at Minimum Wage in Northern Arizona (4 kgal monthly consumption, water costs only)

When considering Teodoro's Hours at Minimum Wage results as context, average Hours at Minimum Wage values in Northern Arizona at 3.6 seem to be lower than national measures. Even assuming that drinking water bills are forty percent of combined water and sewer bills, and adjusting for an increase from 4,000 to 6,200 gallons of monthly water consumption, it is unlikely that average Hours at Minimum Wage values in Northern Arizona would increase much beyond 8, which would put values in the same range as 34% of utilities nationwide. However, in national results for water and sewer costs nearly 60% of utilities surpass Hours at Minimum Wage of 8. By contrast in Northern Arizona in only two communities (1%) did Hours at Minimum Wage surpass 8 (for drinking water only and at a lower volume of monthly consumption).

# Discussion

To enhance affordability, decision-makers can consider the structure of their community's water rates. Higher fixed charges can present a barrier to those who are struggling to get by; while a person who is struggling financially can do their best to conserve water and avoid variable charges associated with water consumption, that person cannot avoid fixed charges. Thus, higher fixed charges make access to safe, clean water more problematic for those who are struggling to make ends meet. Decision-makers can also consider the inclusion of an "allowance" in water charges. These are designed to provide the customer a small amount of water without being assessed a variable charge for water consumption. These allowances typically fall within the fixed charge employed by the utility. That is, by paying the fixed charge, the customer also receives a small amount of water as an allowance for basic needs.

The deployment of low fixed charges and an allowance enhance broad access to basic water services for customers because water for basic needs becomes more affordable. However, it is important to weigh the level of fixed charges and any allowance against their implications for the water system's revenue sufficiency and stability. A water system with extremely low fixed charges that cannot earn sufficient or stable revenue serves no one in the community in the long-term. Community water systems must have a level of financial viability necessary for costly operations and investment in the rehabilitation and replacement of aging infrastructure. Otherwise, water access is undermined for everyone.

Communities in Northern Arizona can use the results presented here to better inform decisions regarding water access policies such as disconnects for non-payment, to adopt rate structures that enhance affordability, and to apply for federal and state grants.

# APPENDIX A—FULL RESULTS

| | RI | HB | $AR_{20}$ | Hours at MW |
|---|---|---|---|---|
| 303 DWID | 1.13% | 2.38% | 5.19% | 2.60 |
| A PETERSEN WATER COMPANY | 1.42% | 3.11% | 6.32% | 4.73 |
| ALPINE DWID | 1.04% | 2.55% | 4.48% | 4.55 |
| ALPINE ESTATES WATER COMPANY | 0.41% | 1.01% | 1.78% | 1.81 |
| ARIZONA WATER CO - LAKESIDE | 0.73% | 2.01% | 2.45% | 3.05 |
| ARIZONA WATER CO - OVERGAARD | 1.18% | 2.49% | 5.85% | 2.97 |
| ARIZONA WATER CO - PINETOP LAKES | 0.80% | 1.69% | 3.36% | 2.97 |
| ARIZONA WATER CO - PINEWOOD | 0.67% | 2.07% | 4.48% | 2.98 |
| ARIZONA WATER CO - SEDONA | 0.87% | 1.71% | 2.99% | 3.08 |
| BABY ROCKS NTUA | 2.36% | 6.62% | 100.00% | 4.48 |
| BACAVI VILLAGE | 0.59% | 1.63% | 4.34% | 2.07 |
| BUCKSKIN ARTISTS COMMUNITY | 0.78% | 1.56% | 4.06% | 1.96 |
| CAMERON NTUA | 0.97% | 2.46% | 4.65% | 4.48 |
| CARRIZO WMATUA | 0.71% | 0.73% | 1.13% | 2.24 |
| CEDAR GROVE WATER COMPANY | 0.99% | 2.05% | 3.56% | 3.88 |
| CHAPACHE WATER COOP | 0.45% | 1.10% | 1.93% | 1.96 |
| CHILCHINBETO NTUA | 3.42% | 9.41% | 100.00% | 4.48 |
| CHINLE-MANY FARMS-DEL MUERTO NTUA | 1.42% | 4.60% | 20.68% | 4.48 |
| CIBECUE WMATUA | 1.40% | 2.78% | 9.91% | 2.93 |
| CITY OF SHOW LOW | 0.95% | 1.99% | 4.01% | 3.05 |
| CLAY SPRINGS DWID | 1.17% | 2.62% | 6.39% | 3.43 |
| CLEAR CREEK PINES UNIT 2 | 0.41% | 1.26% | 2.71% | 1.81 |
| COAL MINE MESA NTUA | 0.68% | 1.55% | 2.48% | 4.48 |
| COPPERMINE NTUA | 0.74% | 1.42% | 2.15% | 4.48 |
| COTTONWOOD-TSELANI NTUA | 1.42% | 4.60% | 20.68% | 4.48 |
| COVE NTUA | 1.80% | 5.39% | 60.20% | 4.48 |
| CROSBY SPRING AT GREER | 0.25% | 0.61% | 1.07% | 1.08 |
| DENNEHOTSO NTUA | 2.36% | 6.62% | 100.00% | 4.48 |
| DILKON-INDIAN WELLS-GREASEWOOD-WHITE CONE NTUA | 1.00% | 2.29% | 4.09% | 4.48 |
| DONEY PARK WATER | 0.65% | 1.10% | 1.68% | 3.45 |
| EAGAR | 0.41% | 0.96% | 1.88% | 1.52 |
| FIRST MESA CONSOLIDATED VILLAGES | 0.84% | 1.62% | 2.54% | 4.83 |
| FLAGSTAFF | 0.82% | 2.03% | 4.25% | 2.99 |
| FLAGSTAFF (OUTSIDE) | 0.86% | 2.15% | 4.50% | 3.17 |
| FLAGSTAFF RANCH WATER COMPANY | 0.31% | 0.71% | 1.12% | 2.07 |
| FOREST HIGHLANDS WATER COMPANY | 0.44% | 0.79% | 1.23% | 2.32 |
| FOREST LAKE NTUA | 1.00% | 3.22% | 7.46% | 4.48 |
| FOREST LAKES WATER IMPROVEMENT DISTRICT | 0.64% | 2.00% | 4.31% | 2.87 |

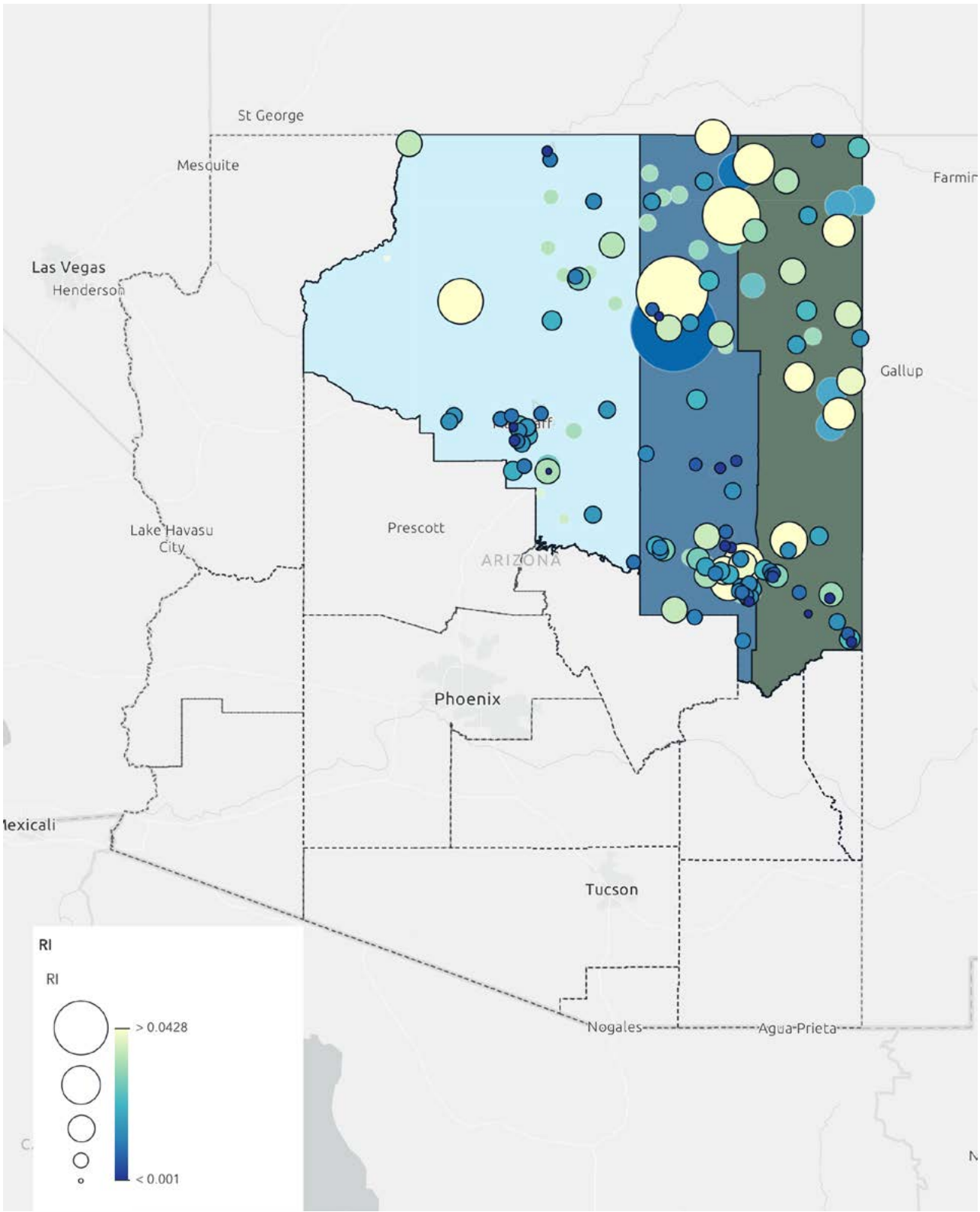
| | RI | HB | $AR_{20}$ | Hours at MW |
|---|---|---|---|---|
| FORT DEFIANCE-WINDOW ROCK-ST MICHAELS NTUA | 0.82% | 2.84% | 5.70% | 4.48 |
| FREDONIA | 1.39% | 2.94% | 7.76% | 3.64 |
| GANADO-BURNSIDE-CORNFIELD-STEAMBOAT NTUA | 0.88% | 2.51% | 4.85% | 4.48 |
| GAP-CEDAR RIDGE NTUA | 0.68% | 1.55% | 2.48% | 4.48 |
| GREENEHAVEN WATER COMPANY | 0.47% | 0.92% | 1.74% | 1.49 |
| HARD ROCK NTUA | 4.29% | 8.76% | 100.00% | 4.48 |
| HAVASUPAI VILLAGE | 0.00% | 0.00% | 0.00% | 0.00 |
| HEBER DWID | 0.74% | 1.54% | 3.93% | 1.95 |
| HECKETHORN WATER COMPANY | 0.94% | 2.01% | 4.71% | 2.70 |
| HIDDEN MEADOW RANCH | 0.64% | 1.57% | 2.76% | 2.80 |
| HIGH COUNTRY PINES WATER COMPANY | 0.96% | 2.07% | 5.17% | 2.65 |
| HOLBROOK | 0.44% | 1.25% | 2.87% | 1.30 |
| HONDAH - MCNARY WMATUA | 0.41% | 0.77% | 1.17% | 2.93 |
| HOUCK-QUERINO CANYON NTUA | 1.78% | 5.25% | 46.40% | 4.48 |
| HYDRO RESOURCES - TUSAYAN | 2.63% | 5.47% | 12.96% | 7.29 |
| INSCRIPTION HOUSE-NAVAJO MOUNTAIN NTUA | 0.82% | 1.23% | 1.93% | 4.48 |
| JEDDITO NTUA | 1.39% | 4.68% | 22.41% | 4.48 |
| JOSEPH CITY DWID | 0.55% | 0.98% | 1.63% | 2.24 |
| KACHINA VILLAGE DWID | 0.68% | 1.23% | 1.93% | 3.63 |
| KAIBETO NTUA | 0.74% | 1.42% | 2.15% | 4.48 |
| KAYENTA NTUA | 0.86% | 2.28% | 4.04% | 4.48 |
| KAYENTA SANDSTONE HOUSING | 0.86% | 2.28% | 4.04% | 4.48 |
| KINLICHEE NTUA | 0.88% | 2.51% | 4.85% | 4.48 |
| KITSILLIE-BLACK MESA NTUA | 1.26% | 4.79% | 25.04% | 4.48 |
| KLAGETOH NTUA | 1.68% | 7.70% | 100.00% | 4.48 |
| KYKOTSMOVI | 0.32% | 0.95% | 1.58% | 2.07 |
| LECHEE NTUA | 0.67% | 1.50% | 2.35% | 4.48 |
| LEUPP-BIRDSPRINGS-TELANI LAKE NTUA | 0.82% | 1.61% | 2.64% | 4.48 |
| LIVCO WATER COMPANY | 0.77% | 1.15% | 1.92% | 2.65 |
| LONG HOUSE VALLEY NTUA | 0.86% | 2.28% | 4.04% | 4.48 |
| LORD AZ WATER | 0.71% | 1.06% | 1.77% | 2.45 |
| LORD AZ WATER 2 - WINCHESTER TRAILS | 0.56% | 1.37% | 2.41% | 2.45 |
| LOWER MOENKOPI | 0.79% | 1.92% | 3.69% | 3.45 |
| LUKACHUKAI NTUA | 1.80% | 5.39% | 60.20% | 4.48 |
| MAJESTIC VIEW ESTATES | 0.64% | 1.45% | 2.30% | 4.24 |
| MEXICAN WATER NTUA | 0.61% | 1.06% | 1.55% | 4.48 |
| MINER FLAT WMATUA | 0.73% | 3.17% | 17.43% | 2.93 |
| MISHONGOVI | 5.99% | 12.98% | 20.52% | 8.83 |
| MISTY MOUNTAIN DWID | 0.82% | 1.14% | 1.93% | 2.60 |
| MOENAVE COMMUNITY | 0.68% | 1.55% | 2.48% | 4.48 |

| | RI | HB | $AR_{20}$ | Hours at MW |
|---|---|---|---|---|
| MORMON LAKE LODGE | 1.33% | 4.13% | 8.92% | 5.94 |
| MORMON LAKE WATER COMPANY | 1.33% | 4.13% | 8.92% | 5.94 |
| MORMON LAKE-UPPER VILLAGE | 1.33% | 4.13% | 8.92% | 5.94 |
| MOUNTAIN DELL WATER | 0.75% | 1.94% | 3.97% | 2.93 |
| MOUNTAIN GLEN WATER - FALCON | 0.86% | 1.94% | 4.72% | 2.53 |
| MOUNTAIN GLEN WATER - LINDEN TRAILS | 0.75% | 1.49% | 2.99% | 2.53 |
| MOUNTAIN GLEN WATER - RICOCHET RANCH | 0.86% | 1.94% | 4.72% | 2.53 |
| NAVAJO WATER - CHAPARRAL PINES | 1.54% | 3.23% | 6.43% | 5.68 |
| NAVAJO WATER - LAGUNA ESTATES | 2.38% | 3.78% | 7.77% | 5.68 |
| NAVAJO WATER - SUMMER PINES | 2.08% | 2.66% | 4.68% | 5.68 |
| NAZLINI NTUA | 1.03% | 5.21% | 43.84% | 4.48 |
| NEW LANDS NTUA | 1.78% | 5.25% | 46.40% | 4.48 |
| OAK CREEK UTILITY CO. | 0.95% | 2.20% | 4.52% | 3.30 |
| OAK SPRINGS NTUA | 1.52% | 1.17% | 1.77% | 4.48 |
| OJO BONITO ESTATES DWID | 0.49% | 1.21% | 2.13% | 2.17 |
| OLD CONCHO WATER USERS | 2.11% | 4.43% | 9.66% | 4.84 |
| OLJATO NTUA | 1.98% | 2.22% | 3.86% | 4.48 |
| PAGE | 0.41% | 1.46% | 3.58% | 1.31 |
| PINE RIDGE ESTATES | 0.45% | 1.10% | 1.93% | 1.96 |
| PINE SPRINGS NTUA | 1.78% | 5.25% | 46.40% | 4.48 |
| PINECREST WATER COMPANY | 0.79% | 1.94% | 3.41% | 3.47 |
| PINEDALE DWID | 0.89% | 1.99% | 4.85% | 2.60 |
| PINEDALE ESTATES DWID | 1.32% | 2.97% | 7.23% | 3.88 |
| PINETOP WATER CFD | 0.72% | 1.98% | 2.42% | 3.00 |
| PINON - DISTRICT 4 NTUA | 1.00% | 3.22% | 7.46% | 4.48 |
| PONDEROSA DWID | 0.47% | 1.32% | 2.49% | 2.57 |
| PONDEROSA UTILITY CO. | 0.82% | 2.54% | 5.48% | 3.65 |
| PORTER CREEK DWID | 0.84% | 1.71% | 3.05% | 3.00 |
| PORTER MOUNTAIN DWID | 0.75% | 1.05% | 1.77% | 2.38 |
| RARE METALS NTUA | 0.68% | 1.55% | 2.48% | 4.48 |
| RED MESA NTUA | 0.61% | 1.06% | 1.55% | 4.48 |
| RED VALLEY NORTH NTUA | 1.80% | 5.39% | 60.20% | 4.48 |
| RETAW WATER COMPANY | 1.05% | 1.79% | 3.15% | 3.20 |
| ROCK POINT NTUA | 1.35% | 5.09% | 36.27% | 4.48 |
| ROUGH ROCK NTUA | 1.26% | 4.79% | 25.04% | 4.48 |
| ROUND ROCK NTUA | 0.88% | 4.31% | 15.81% | 4.48 |
| SAWMILL NTUA | 1.45% | 5.08% | 35.81% | 4.48 |
| SHONGOPOVI | 1.42% | 7.63% | 100.00% | 5.52 |
| SHONTO JUNCTION NTUA | 0.82% | 1.23% | 1.93% | 4.48 |
| SHONTO NTUA | 0.82% | 1.23% | 1.93% | 4.48 |

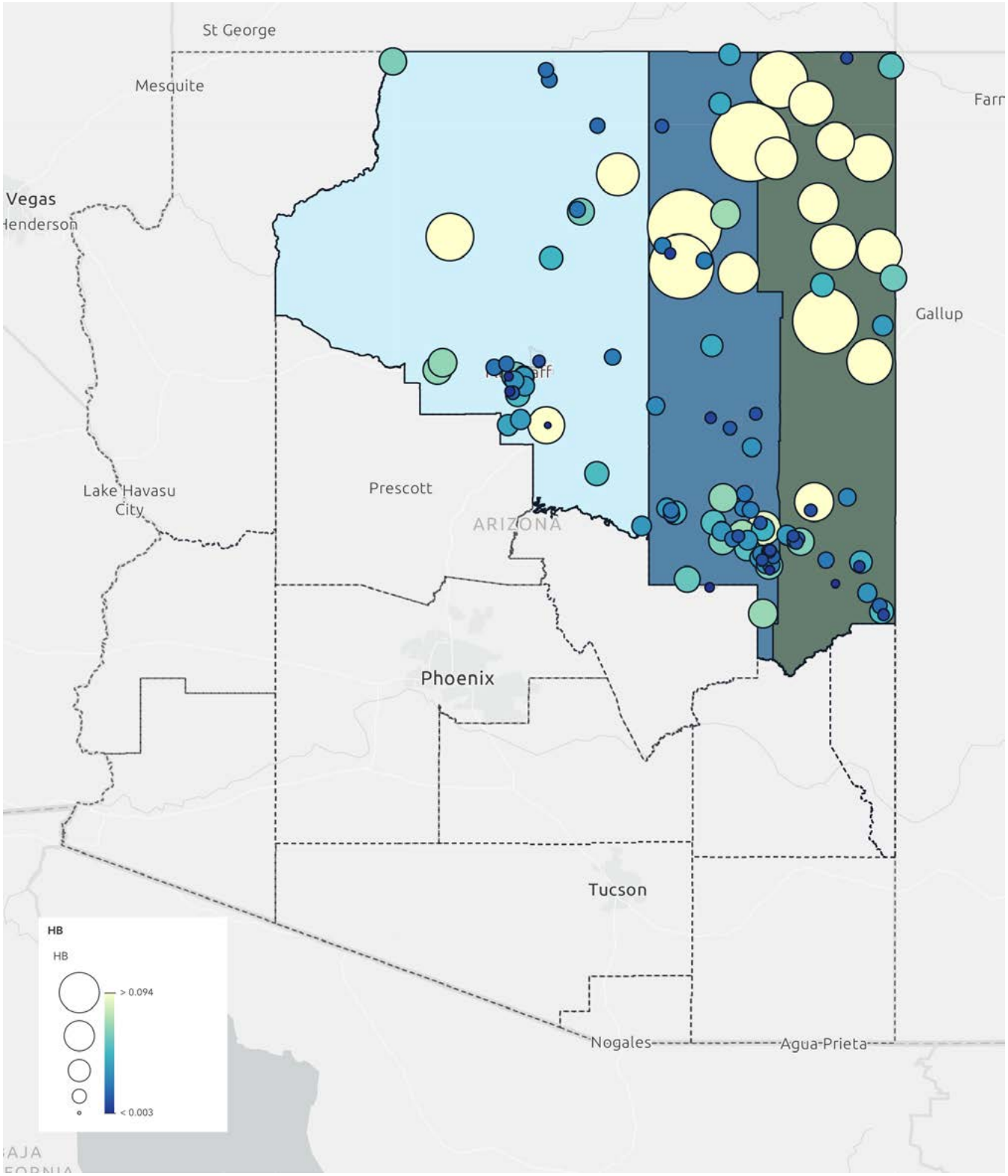
| | RI | HB | $AR_{20}$ | Hours at MW |
|---|---|---|---|---|
| SHOW LOW CROSSROADS HOA | 0.67% | 1.00% | 1.67% | 2.31 |
| SIERRA SPRINGS RANCH WATER CO. | 0.92% | 2.59% | 4.91% | 5.07 |
| SIPAULOVI | 5.99% | 12.98% | 20.52% | 8.83 |
| SKY HI DWID | 0.95% | 1.32% | 2.23% | 3.00 |
| SNOWFLAKE | 0.62% | 1.56% | 3.15% | 2.37 |
| SPRINGERVILLE | 1.28% | 2.35% | 4.75% | 3.58 |
| ST JOHNS | 0.91% | 1.75% | 3.47% | 2.98 |
| STARLIGHT WATER CO. | 0.83% | 2.56% | 5.53% | 3.68 |
| STONEMAN LAKE WATER CO. | 0.22% | 0.67% | 1.45% | 0.96 |
| SUN VALLEY UTILITIES | 0.46% | 1.12% | 2.35% | 1.26 |
| SWEETWATER NTUA | 1.31% | 3.81% | 11.68% | 4.48 |
| SWEETWATER RANCH - TAYLOR | 0.43% | 1.64% | 4.53% | 1.98 |
| TAL WI WI WATER USERS | 0.58% | 1.42% | 2.49% | 2.53 |
| TALL PINES ESTATES WATER | 0.12% | 0.38% | 0.81% | 0.54 |
| TAYLOR | 0.42% | 1.67% | 3.33% | 1.98 |
| TEEC NOS POS NTUA | 1.08% | 2.71% | 5.21% | 4.48 |
| TIMBER KNOLL DWID | 0.63% | 1.55% | 2.72% | 2.77 |
| TIMBERLAND ACRES DWID | 0.68% | 1.54% | 3.04% | 2.89 |
| TONALEA - RED LAKE NTUA | 1.36% | 4.85% | 26.75% | 4.48 |
| TUBA CITY NTUA | 0.68% | 1.55% | 2.48% | 4.48 |
| TWIN ARROWS NTUA | 0.82% | 1.61% | 2.64% | 4.48 |
| UPPER MOENKOPI | 1.18% | 2.89% | 5.54% | 5.19 |
| UTILITY SOURCE | 0.69% | 1.57% | 2.49% | 4.60 |
| VERNON VALLEY WATER SYSTEM | 1.21% | 2.98% | 5.24% | 5.32 |
| VOYAGER AT WHITE MOUNTAIN LAKES WATER CO. | 0.76% | 1.21% | 2.49% | 1.82 |
| WATCO WATER | 1.53% | 2.43% | 5.00% | 3.65 |
| WEST VILLAGE WATER CO. | 1.08% | 2.90% | 6.69% | 3.94 |
| WHEATFIELDS NTUA | 0.49% | 1.38% | 2.06% | 4.48 |
| WHITE MOUNTAIN SUMMER HOMES DWID | 0.86% | 2.96% | 7.05% | 3.93 |
| WHITE MOUNTAIN WATER CO. | 0.90% | 1.15% | 2.03% | 2.46 |
| WHITE POST MISSION NTUA | 0.82% | 1.23% | 1.93% | 4.48 |
| WILLIAMS | 0.80% | 3.12% | 7.71% | 2.78 |
| WINSLOW | 0.75% | 1.82% | 4.22% | 1.89 |
| WONDERLAND ACRES DWID | 0.64% | 1.09% | 1.92% | 1.95 |
| WOODRUFF DOMESTIC WATER COMPANY INC | 0.80% | 1.93% | 4.05% | 2.18 |
| YUWEHLOO PAHKI | 0.71% | 0.80% | 0.80% | 4.48 |
| **For Comparison** | | | | |
| PHOENIX | 0.14% | 0.33% | 0.66% | 0.6 |
| TUCSON | 0.88% | 2.06% | 5.08% | 2.66 |

# APPENDIX B

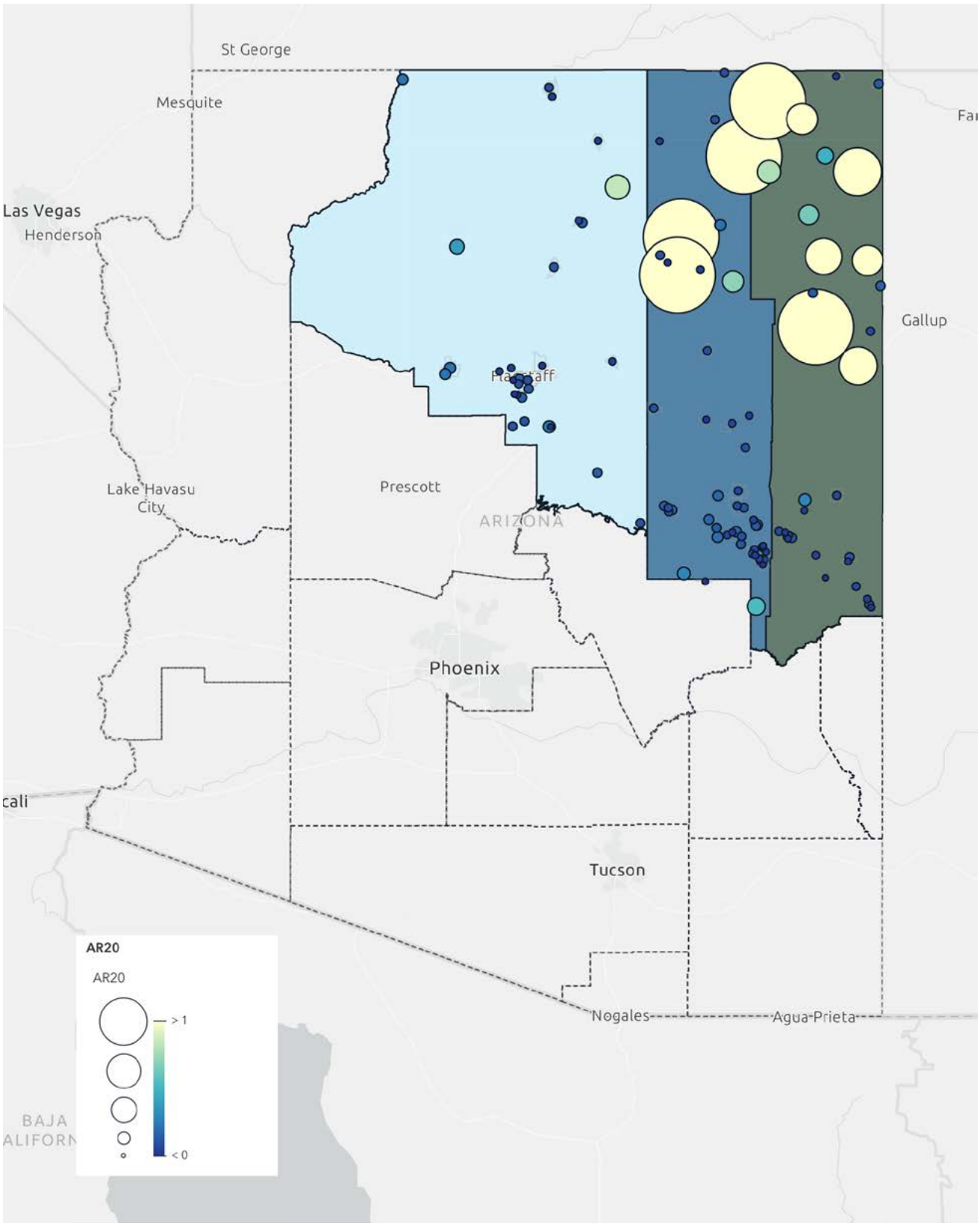
Heat map of Residential Indicator Results



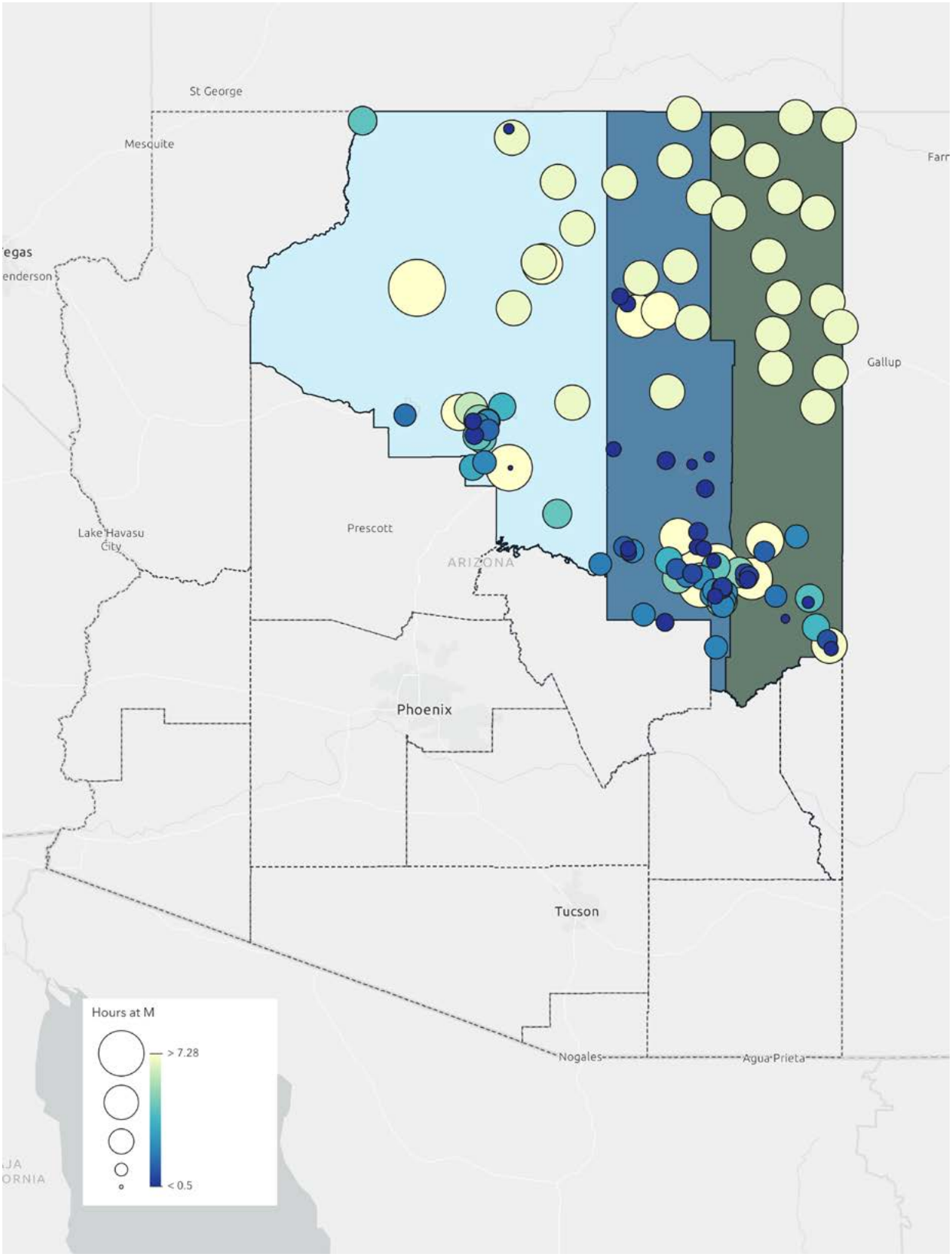
Heat map of Household Burden Results



Heat map of Affordability Ratio at 20th Percentile Results



Heat map of Hours at Minimum Wage Results



# APPENDIX C—METHODOLOGY

## Water Rates

Publicly posted tariff schedules outlining fixed costs and service charges per thousand gallons were used when available. Private water companies are also required to disclose water tariffs to the Arizona Corporation Commission, and through ACC databases and assistance from commission staff additional rates were collected. Outreach to individual systems without publicly accessible rate information was also conducted. Rate information was found for nearly every system identified, with the following exceptions:  A1 Ranch HOA, Five Oaks Water Owners, Oak Creek Estates, Pine Flats HOA, Vernon DWID, and Hotevilla Village.

Water service costs were calculated in all systems assuming a single-family residential customer using 4,000 gallons per month with a 5/8 in. meter connection (or smallest meter size for which a charge was listed), billed monthly. A value representing the monthly cost of water under these assumptions was calculated individually for every system included in the study including the fixed charge, usage charges at all relevant usage tiers, and all applicable taxes. It was assumed that city-operated and private water company utilities charge state and local taxes on the sale of water, but that districts, private water associations, and tribal utilities do not. Where community water system physical boundaries crossed both city and county boundaries, city sales taxes were applied if half or more of the community water system boundaries was in the city.

## Minimum Wage

The minimum wage in each area was ascertained through the Industrial Commission of Arizona data and corroborated with local sources to confirm any local minimum wage ordinances established by the respective municipality or tribe.

## Median Household Income

The median household income for each area was obtained from the United States Census Bureau's American Community Survey (ACS) 2021 5-year estimates. The ACS provides estimates for the median household income for the population over five years of data collection. Where a tribal community water system existed but no corresponding Census Designated Place could be located, the data from the Census Designated Place physically closest and on the same reservation was used.

**Hopi Reservation and Off-Reservation Trust Land, AZ**

Source: 2017-2021 American Community Survey 5-Year Estimates

| Income and Benefits (In 2021 inflation-adjusted dollars) | Estimate | ACS Margin of Error |
|---|---|---|
| Total households | 2,335 | ( +/-177) |
| Less than $10,000 | 363 | ( +/-104) |
| $10,000 to $14,999 | 120 | ( +/-56) |
| $15,000 to $24,999 | 208 | ( +/-80) |
| $25,000 to $34,999 | 223 | ( +/-82) |
| $35,000 to $49,999 | 340 | ( +/-95) |
| $50,000 to $74,999 | 594 | ( +/-156) |
| $75,000 to $99,999 | 185 | ( +/-55) |
| $100,000 to $149,999 | 222 | ( +/-96) |
| $150,000 to $199,999 | 57 | ( +/-36) |
| $200,000 or more | 23 | ( +/-27) |
| Median household income (dollars) | $46,484 | ( +/-4,689) |

## 20th percentile Income

The 20th percentile Income (TPI) represents the income of a household making less than 80 percent of households within the designated area. The Census Bureau ACS and My Tribal Area data tools provide a breakdown of the number of households in an area earning within ten income groups, ranging from those earning less than $10,000 annually to those earning over $200,000. An example of ACS Tribal Area income group data for the Hopi Reservation is included:

Following the framework used in Patterson and Doyle's 2021 "Measuring water affordability and the financial capability of utilities", incomes were randomly generated for every household in the census tract or CDP, within their respective income range. For instance, if there were 50 households in the $25,000 to $34,999 income range and 20 households in the $35,000 to $49,999 range, 50 random incomes between 25,000 and 34,999 and 20 random income values between 35,000 and 49,999 would be generated. These values are then compiled into a single list, representing the incomes of all households in the area, ordered, and the 20th percentile value is calculated. Prior research by Cardoso & Wichman (2020) has demonstrated the robustness of this approach[55].

These values were calculated using the following python code, where they were calculated 5 times for each area, and the average of which taken to avoid outliers. This value is used as the 20th percentile income in further calculations.

20th Percentile Income: 2021 5-year estimate Household Income Data

```
import pandas as pd
import numpy as np
import random

# Load the csv file containing the number of values to be generated
df = pd.read_csv('/content/Census Income Data Analysis - 2021 Hoseholds Counts (7).csv')

# Define the constant ranges
ranges = [(0, 9999), (10000, 14999), (15000, 24999), (25000, 34999), (35000, 49999),
          (50000, 74999), (75000, 99999), (100000, 149999), (150000, 199999), (200000, 500000)]

# Initialize the list to store the percentile values
percentile_values = []

# Loop through each row in the csv file
for i in range(len(df)):
    # Get the number of values to be generated for each range from the csv file
    num_values = df.iloc[i].tolist()

    # Generate the required number of random values within each range
    values = []
    for j in range(len(ranges)):
        for k in range(num_values[j]):
            value = random.randint(ranges[j][0], ranges[j][1])
            values.append(value)

    # Calculate the lower 20th percentile value of the generated values
    percentile_value = np.percentile(values, 20)

    # Store the percentile value in the list
    percentile_values.append(percentile_value)

# Output the list of percentile values separated by commas
print(','.join(map(str, percentile_values)))
```

There is no data on the maximum earner in any given area; $500,000 was used as the upper bound in the greater than 200,000 range for all systems.

## Essential Expenditure Data

$AR_{20}$ calculation necessitates an estimate for a water user's average monthly expenditures for essential goods and services. This study defines non-water essential expenses as housing, health care, food, non-water utilities, and taxes, consistent with Teodoro's 2018 analysis accompanying the framework's publication. The study utilizes data from the Bureau of Labor Statistics Consumer Expenditure Survey (CES) to approximate average expenditures for each expense category.

However, the CES does not provide data geographically specific to the areas of study, and therefore, certain estimates and approximations are needed to represent user's essential non-water expenditures.

The calculations in this study utilizes data that is reflective of expenditures for households within the income range that includes the 20th percentile income for the study area. While not necessarily reflective of localized pricing and product availability, the value is reasonably reflective of the average level of spending by category for households earning at or near the 20th percentile income of the census tract, city/town, reservation, or census designated place being measured.

The following CES "items" were used to represent the combination of essential non-water expenditures:

- Housing, Owned dwellings OR Housing, Rented dwellings
- Healthcare
- Food
- Utilities, fuels, and public services
  - (Water and other public services)
- Federal income taxes
- State and local income taxes

Healthcare and state and local taxes are not included when calculating essential expenditures for tribal lands in this study.

## Water Systems Serving Multiple Census Tracts

When a water system's service area expands to multiple census tracts, one of two methods are used to ensure reliability of data used in calculations:

When a multi-tract system adheres largely to the boundaries of a city, town, or similar grouping of households, ACS Census household income data is collected directly at the city, town, village or Census Designated Place (CDP) level, as opposed to the census tract, and every other subsequent process and calculation is unchanged. This helps ensure that households within the relevant census tracts but outside of the water system are not included.

When a system falls within multiple census tracts but is not largely consistent with the boundaries of a city town or CDP, a combination of the relevant census tract's data is used to represent the water system. This is done by calculating the percentage of the water system's service area contained in each census tract and using that percentage to perform a weighted average of the tracts' median household income and 20th percentile incomes. Expenditure data for these combined tracts is informed by the income group designated by the newly calculated TPI.

## Data Limitations

The study relied on databases available through the Arizona Department of Environmental Quality (Safe Drinking Water Act Information System) and the Environmental Protection Agency (Enforcement and Compliance History Online) to identify community and non-community water systems on both tribal and non-tribal lands, and to identify the number of customers served by each system. These databases may hold inaccurate information and may not accurately capture all community and non-community water systems in the study area.

As referenced, when calculating data-intensive affordability metrics such as the $AR_{20}$ for a large number of systems, approximations are sometimes necessary in place of specific and localized

data. In this study, the calculation of the 20th percentile income relies on a calculated estimate that, while there is existing research to support confidence, still may not be reflective of the actual 20th percentile as a result of ACS surveying limitations, and the necessity to make assumptions for a “maximum income” level for calculation.

Further, while expenditure data may be reflective of average spending tendencies at a certain income level nationally, localized pricing and availability factors for essential costs of living has significant impact on the expenditures a household undertakes and could therefore affect the accuracy of the $AR_{20}$ in any given area.