Drivers of Declining Water Access in Alaska

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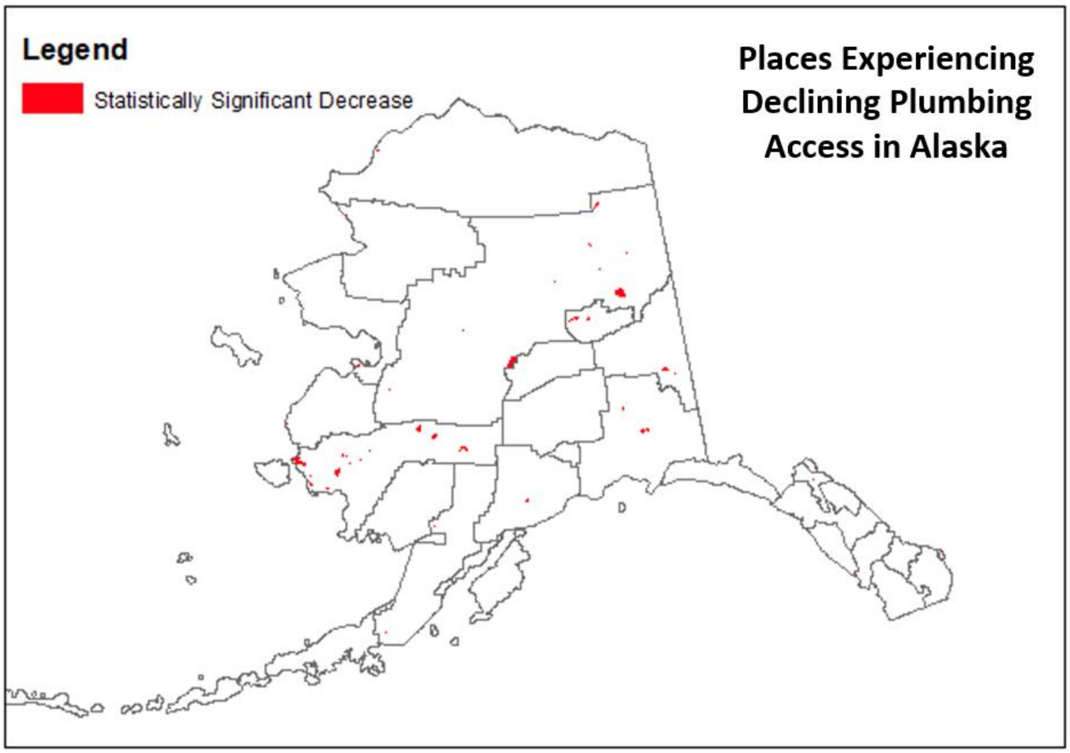
SYNOPSIS: This study determined where plumbing access is declining in Alaska and identified sociodemographic parameters associated with this change.

ABSTRACT

A majority of homes in the United States (U.S.) receive household water services via complete in-home plumbing. Observers tend to assume that in the U.S. there is an upward trend in plumbing access; yet in some Alaska communities, the rate is in fact a downward trend. This study seeks to identify, while considering the spatiotemporal variations in the region, the sociodemographic parameters that are correlated with the rates of in-home plumbing in Alaska communities. Equipped with American Community Survey data from 2011 to 2015, we employed a fixed-effects regression analysis. Our findings show that, concerning complete in-home plumbing, there was a statistically significant decrease ($p < 0.05$) in close to a quarter (23% percent) of census-designated places in Alaska. Access to complete plumbing is correlated to multiple sociodemographic

characteristics, including the percentage of households that 1) receive social security, 2) are valued under $150,000, and 3) are renter-occupied units paying for one or more utilities. Our results help decision-makers efficiently allocate government funds by showing where service is deteriorating as well as the potential predictors of such decline. Our study reveals the pressing need to invest in not only new water systems, but also maintenance, operations, and capital improvements.

ABSTRACT ART



1. INTRODUCTION

Most Americans enjoy the convenience of complete in-home plumbing (defined as having a flush toilet, hot and cold running water, and a bathtub or shower[1]). For some Americans, though, complete in-home plumbing is not a reality. In Alaska, for instance, 2016 Census data estimates that approximately 12,000 people did not have complete in-home plumbing.[2] In these un-piped homes, water may be delivered by a vendor, or residents may collect and carry water to the home by vehicle or hand.[3] These non-piped water services (e.g., water hauling, washaterias) can negatively impact people's health and quality of life. Non-piped water services can expose individuals to various disease-causing pathogens; for instance, studies have revealed that water contamination occurs during water hauling.[4-10] Additionally, hauled systems can require walking long distances, which often limits water use within a home. This is particularly true in households with older or disabled populations that are physically unable to complete this task.[9,11] In fact, some Alaskan residents consume about 1.5 gallons per capita per day (GPCD) as compared to the broader U.S. average of approximately 100-156 GPCD for in-home water use and lawn irrigation.[9,12] Limited water use in Alaska has been linked to a series of concerns, including higher pediatric rates of lower respiratory infections,[5] increased consumption of alternative unhealthy beverages (e.g., soda[8]), and increased stress levels, particularly amongst Alaskan women, who tend to feel the impact of restricted water more strongly than males do.[11] Further, research has shown that school children who regularly gather water tend to have lower test scores due to the time intensity required and health impacts of poor water services.[13] In sum, the lack of in-home plumbing in Alaska burdens many areas of life. The presence of these challenges in Alaska is surprising because complete in-home plumbing is still considered to be the standard in the U.S. Therefore, we are interested in understanding why some communities in Alaska deviate from this standard.

Alaska is not the only geography in the United States that experiences poor plumbing conditions. In a review of water access at the state level, it was found that some states, including

Delaware, Idaho, Nevada, South Dakota, and Puerto Rico saw decreases in water access between 2000 and 2014.[14] At the more granular level, rural and isolated communities often lack access to in-home plumbing. For example, some counties on the Texas-Mexico border, referred to as Colonias, lack basic utilities, including in-home plumbing.[15] While some policy changes have aimed to improve water services in this region and had some success, localized water service is still needed. The region of Appalachia is another example of a community that has limited water services. A lack of in-home plumbing often causes residents in Appalachia to practice similar water-hauling methods as Alaskan residents, using private wells or local surface water. Further, the lack of adequate wastewater systems has caused public health concerns, such as if the surface water is safe for human consumption.[16] Beyond these regional crises, affordability is also a threat to water infrastructure in the United States. Water rates continue to rise while household incomes are relatively stagnant, creating the risk of low-income households losing access.[17] In sum, while this study focuses on Alaska, this problem is not unique to this region and is cause for concern throughout the United States.

Regarding engineering projects, Alaska is a uniquely challenging location, which contributes to the state's water vulnerability.[18] Construction is costly and maintaining water systems is particularly difficult because of the extreme and changing climate.[19-22] In addition, un-piped Alaskan homes are typically isolated from other towns by both geography and climate-induced transportation challenges.[3,18] This sort of isolation brings a unique set of logistical and workforce challenges for engineered systems of any kind. In fact, for portions of the year, rural communities have little to no access to materials and external expertise/labor.[18, 22-24] Additionally, Alaska's Arctic environment (e.g., permafrost) poses many challenges for water infrastructure.

Typical subterraneous piping techniques are difficult with freeze-thaw cycles and general permafrost instability. Alternative plumbing methods, like the Portable Alternative Sanitation Systems (PASS), are already being deployed in rural regions,[25] and decentralized systems like in-home water reuse technologies are being explored.[26-28] Furthermore, climate change impacts Arctic regions by reducing sea ice, erosion, and increasing flooding, threatening water infrastructure state-wide.[29] Additionally, water shortages in growing urban areas in Alaska threaten water availability.[30] These technical issues are coupled with trends of historical disenfranchisement of Indigenous populations that reside in many rural Alaskan communities; part of the disenfranchisement includes governmental bodies granting limited funding and exhibiting general neglect.[31] The literature contains a large body of work focused on household water service inequalities in the U.S.[32-34] Nevertheless, we argue that Alaska's unique operating environment justifies targeted research and policy attention.

Research has explored and documented water challenges in Alaska and recommended interventions to improve services.[18,22] Although many studies have focused on the social and public health implications of these water-sector challenges (e.g., increased illness, water conservation[5-6, 9-10]) to our knowledge, researchers have not documented how access to water services has changed over time in Alaska. This information would help inform studies about the health impacts of poor water services (e.g., do places with declining services experience more health disparities) and provide policymakers with data to advocate for funding. In addition to documenting changes in water services, it is important to understand how community sociodemographic characteristics are related to such changes. This information will help researchers and policymakers target their interventions and reflect on previous decisions, ultimately improving water services in Alaska.

While we often assume that developed nations continually improve their water services, this is not always the case. In parts of these countries, for example, areas of Alaska (the location of the current study), water services are actually in decline thanks to operations, management, and maintenance challenges (e.g., workforce issues, lack of technical expertise, and financial limitations[3,18,22-23]). A fire in Tulusak, Alaska, for instance, destroyed the community's water treatment plant.[35] Repairs and emergency services were hindered by weather, leading to community-wide service disruptions for 45 days. Water systems in Alaska are, on average, 20 to 30 years old, creating concerns about aging systems that are threatened further by the region's extreme and changing climate.[3] It is critical to understand such service decline in Alaska and build on past literature that has explored Alaskan plumbing access at the larger county level[33] and cross-sectional work that focuses on plumbing rates at a single moment in time.[32] Rates of complete plumbing are significantly associated with sociodemographic characteristics (i.e., related to or involving a combination of social and demographic factors) we believe, based on studies carried out in other contexts (Africa;[36-39] Lower 48/contiguous U.S. [32-33,40]). For example, in one of the few studies that analyzed the sociodemographic drivers of water access over time, Desphande and colleagues found that, in low- and middle-income countries, urbanized areas typically experienced more increases in water access than rural regions.[38] Such sociodemographic drivers can help policymakers create targeted policies to counteract the decline in plumbing access. Water systems are constructed and maintained by governmental bodies;[41] it is critical, then, that allocation of this funding be efficient and equitable. By understanding sociodemographic characteristics associated with access to complete plumbing, we make practical recommendations that can inform policy and funding decisions (e.g., increased funding for regional health corporations if facing declining plumbing).

1.1 RESEARCH QUESTIONS AND HYPOTHESES

Here, we use the American Community Survey (ACS)[42] data to answer the following research question: What are the key community-level sociodemographic characteristics that affect access to complete plumbing in Alaska, while considering the spatiotemporal effects that exist throughout the state? Based on existing literature, we construct four hypotheses.

Hypothesis 1: In Alaska, access to water plumbing is correlated with spatiotemporal variations.

Previous research has indicated that access to complete plumbing varies according to geography, such as shown in Alaska[18,43] and developing countries.[38] In Alaska, we know that many small, rural villages face operations and construction challenges due to the extreme climate, a small labor pool, and general isolation. Previous literature has shown that these conditions work in tandem to exacerbate water challenges in these regions.[11,18] While this study looks at the entire state of Alaska, we expect that rural regions will face the strongest decline. Additionally, subterraneous water infrastructure is subject to damage via melting permafrost, a spatial phenomenon that fluctuates with local climate and infrastructure,[44] indicating that water services will vary based on geography Such challenges can lead to service deterioration, over time reducing levels of access.

Hypothesis 2: In Alaska, measures of economic vulnerability positively correlate with access to water plumbing.

Previous research tends to show that people of lower economic status—in both developed[18,32-33,43] and developing countries[36-37,39]—have disproportionately less access to in-home plumbing. Previous studies have measured economic vulnerability in different ways, basing it on such measures as income, home ownership, and education.[36,38-39] Additionally, a review of the United States showed that poverty was a key obstacle to water access, with economic status encompassing income, educational attainment, and unemployment. This review found that census tracts with higher incomes had lower percentages of households with complete plumbing.[14] Therefore, we hypothesize that as measures of economic vulnerability (such as income level, percent of people receiving public assistance, home value, rate of employment, and poverty level) increase, so do levels of in-home plumbing.

Additional support for this hypothesis comes from the Center for Disease Control's "Social Vulnerability Index" (SVI).[45] This index is a measurement of relative vulnerability of each area (i.e., census tract) and is used to identify locations that may need additional support in case of disaster. The SVI is a scale that goes from 0 to 1, with 0 indicating low vulnerability and 1 indicating high vulnerability. This index is based on 15 questions from the ACS, broken down into four themes—Socioeconomic Status, Household Composition & Disability, Minority Status & Language, and Housing Type & Transportation.[45] This index shows that populations without large financial resources are more vulnerable in disaster situations. We assume a similar case for vulnerability to water service decline.

Hypothesis 3: In Alaska, the level of access to water plumbing is correlated with a community's gender makeup.

Another aspect that may impact access to in-home water plumbing is gender (i.e., proportion of the population that is female). Previous research has shown that genders differ in their attitudes towards water services.[11,46-47] For instance, Wutich[47] found that men and women in a household experience water scarcity differently, with women expressing more fear and anger and men more annoyance. This study also showed that men are less likely to be burdened with water responsibilities than women. Some of these responsibilities may include childcare, cooking, and cleaning. Additionally, menstrual hygiene requires access to clean water, according to UNICEF, creating unique conditions that may stress a female population, and in turn, spur women to advocate for water services.[48] Knowing this, we hypothesize that communities with higher proportions of women will experience higher rates of complete plumbing.

Hypothesis 4: In Alaska, access to water plumbing is correlated with a community's racial makeup.

Lastly, we expect access to plumbing to be impacted by race. In research that has measured sociodemographic characteristics related to water access in the US, findings show a disparity in plumbing access between white households and households of color.[32-33,40] Since the state of Alaska is 18% Indigenous and rural Alaska is 79% Indigenous, a historically disenfranchised population,[31] this poses unique challenges to provide water services, as water infrastructure is typically constructed by the government for its constituents. In fact, a previous study noted that Native Alaskans may distrust the government,[49] and as such, this mistrust may be extended to government funded water services. For example, some villages may trust ancestral sources of water, like rainwater and ice melt, rather than water from their in-home plumbing.[11] This disconnect may lead to decreased use and maintenance of existing water infrastructure. Additionally, disenfranchised groups have historically lower investment in their water infrastructure, in both the initial investment and continued maintenance.[14] In turn, we hypothesize that communities with a larger proportion of native residents will exhibit lower levels of water access.

2. DATA AND METHODS

In this study, we seek to identify sociodemographic characteristics associated with declining plumbing rates. To do so, we use a panel regression analysis of data from the ACS[42] between 2011 and 2015. Our unit of analysis is Alaskan census-designated and incorporated places. A *census-designated place* is a population concentrated in a region recognized by the census for statistical reasons; an *incorporated place* is defined as a town or village with a legal border.[50] Additionally, this study includes a temporal unit, as we look at plumbing rates over time (i.e., yearly census data from 2011 to 2015). For this study, both census-designated and incorporated places are referred to as *places*; this is the most granular resolution of ACS data available statewide. Places were chosen over census tracts to focus on concentrations of the population rather than physical delineation.[51]

2.1 DATA

This study is enabled by ACS data spanning from 2011 to 2015,[42] focusing on sociodemographic information and the survey question pertaining to "complete plumbing facilities." Complete plumbing facilities are defined as having a flush toilet, hot and cold running water, and a bathtub or a shower.[1] This metric measured the number of households with complete plumbing in each place, allowing us to use a variable that represents the percentage of households without complete plumbing (i.e., rate of complete plumbing). It is important to note that this metric is different than that used by the Alaska Department of Environmental Conservation (i.e., a “served” community where more than 55% of homes are served by a piped, septic tank and well, or covered haul system). Here, we look at the rate of plumbing access over time instead of the binary “served” or “unserved” commonly used, allowing us to understand the trends at a more granular level. In the current study, alternate methods of bringing water into a household that bypass plumbing (e.g., water hauling) are considered incomplete access, as the ACS does not acknowledge water hauling as complete access. Further, the need to use complete plumbing as the standard is underscored by the documented concerns with hauled water.[4-8,10] Figure S1 in the Supplemental Information (SI) shows the 355 places in Alaska that were included in this study.

Sociodemographic data is used in the modeling process to predict drivers of complete plumbing access (see Table 1). Each independent variable is calculated as a percentage of its respective population or number of total households within a place. When choosing sociodemographic characteristics, we referenced the Center for Disease Control’s Social Vulnerability Index (SVI; discussed in our second hypothesis). Our research hypothesis and the sociodemographic characteristics that make up the SVI helped determine the independent variables used in the current study (see Table S1 in the SI for a comparison between SVI variables and the current study). The CDC’s Social Vulnerability Index was selected over other vulnerability indices in the United States, such as the National Risk Index because this index is not hazard-specific,[52] and therefore is better suited for non-disaster contexts, such as the context studied here. Additionally, two variables are directly related to plumbing access: *Percentage of households without complete kitchen facilities* and *Percentage of renter-occupied units that pay extra for one* *or more utilities*. Complete kitchen facilities are defined as having three of the following operational features—(1) a sink with a faucet, (2) a stove or range, and (3) a refrigerator (1). The definition of complete plumbing facilities also requires a functioning sink, so both variables share this characteristic. We also assume that households that pay extra for a utility would indeed receive the service. Therefore, to account for this effect, we model these variables as control variables (*Percentage of households without complete kitchen facilities* and *Percentage of renter-occupied units that pay extra for one or more utilities*).

For several years (2011 to 2015), the ACS could not determine the number of impoverished individuals or the number of citizens with a high school or bachelor's degree and listed these values as "Not Applicable." Therefore, these variables were removed from our analysis.

Table 1: Average Values of Select 2015 Sociodemographic Variables for All Places based on Data from the ACS[42]

Variable (*Percentage of…*)	**Average Percent across all Places Studied**
Population	
White	42.1%
Native Alaskan	43.6%
Over 3 years old enrolled in school	23.2%
Over 25 years old with at least a bachelor's degree	15.8%
Over 65 years of age	10.4%
Male	51.5%
Living in poverty (for those whose poverty status is determined)	18.6%
25 years or older that graduated high school or higher	80.0%
Civilians in the workforce that are employed	48.7%
Only speak English (5 years old and over)	78.3%
Households (HH)	
Making < $30,000 per year	29.8%
Receive social security income	24.1%
Receive supplemental security income	5.8%
Receive public assistance income or food stamps	31.8%

Without telephone service available	5.0%
Receive retirement income	15.5%
Housing units that are built after 2000	15.5%
Owner-occupied homes valued under $150,000	45.4%
Renter-occupied units where the gross rent is 30% or more of HH income	19.8%
Without complete kitchen facilities*	17.7%
Renter-occupied units that pay extra for one or more utilities*	70.2%
Without Complete Plumbing Facilities	**23.6%**

* Control Variables

2.2 FIXED EFFECTS MODEL

To identify parameters that are correlated with a change in access to complete plumbing in Alaska places, the current study used a fixed effects regression model. This model employed panel data (i.e., data gathered over time from the same respondents). In this case, the respondents were the census-designated and incorporated places. The fixed effects (FE) model for each place (unit) can be expressed as follows:

$$y_{it} = \alpha_i + \sum_{p=1}^{P} x_{it,p}\beta_p + \varepsilon_{it} \text{ where } i = 1, 2, \ldots, I, \text{ and } t = 1, \ldots, T. \qquad \text{(Equation 1)}$$

where y_{it} represents the percentage of households without complete plumbing facilities in place i at time t, and $x_{it,p}$ is a sociodemographic factor p for place i at time t. Then β is the vector of coefficients that are estimated for the sociodemographic characteristics by the FE model.[53] The sociodemographic characteristics are shown in Table S1. For this study, $I = 355$ places and $T = 5$ years (i.e., 2011 to 2015). The error is captured by α_i and ε_{it}, where α_i is the unobserved spatial fixed effects of each place (see Table S2 in the SI) and ε_{it} is the error term. By incorporating spatiotemporal effects into the estimated coefficients and considering place-specific effects in the error, the FE model provides more reliable estimates in comparison to a conventional pooled model.[53] In addition, on the FE model, the research team carried out a stepwise regression using AIC to reduce model complexity and, to address issues of multicollinearity, the team used a variance inflation factor (VIF) < 5.[53] Note that, to determine if a fixed effects or random effects model was a best fit for our data,[53] the team used the Hausman Test, with a p-value of 2.2×10^{-16}, which indicated that a fixed effects regression model was more consistent.

3. RESULTS & DISCUSSION

3.1 SPATIOTEMPORAL VARIATIONS IN PLUMBING ACCESS

To demonstrate the effects of spatiotemporal variations in the data, we spatially mapped the Alaskan places with significant fixed effects. Figures 1-3 show the areas that experienced significant ($p < 0.05$) decline, increase, or no change in access to plumbing. It is important to note that significant (or insignificant) changes were computed after accounting for the sociodemographic characteristics. As expected, we found that there were significant geographic and temporal variations in complete plumbing, supporting Hypothesis 1. Alaska is separated by census areas, delineated by the lines in Figures 1-3.

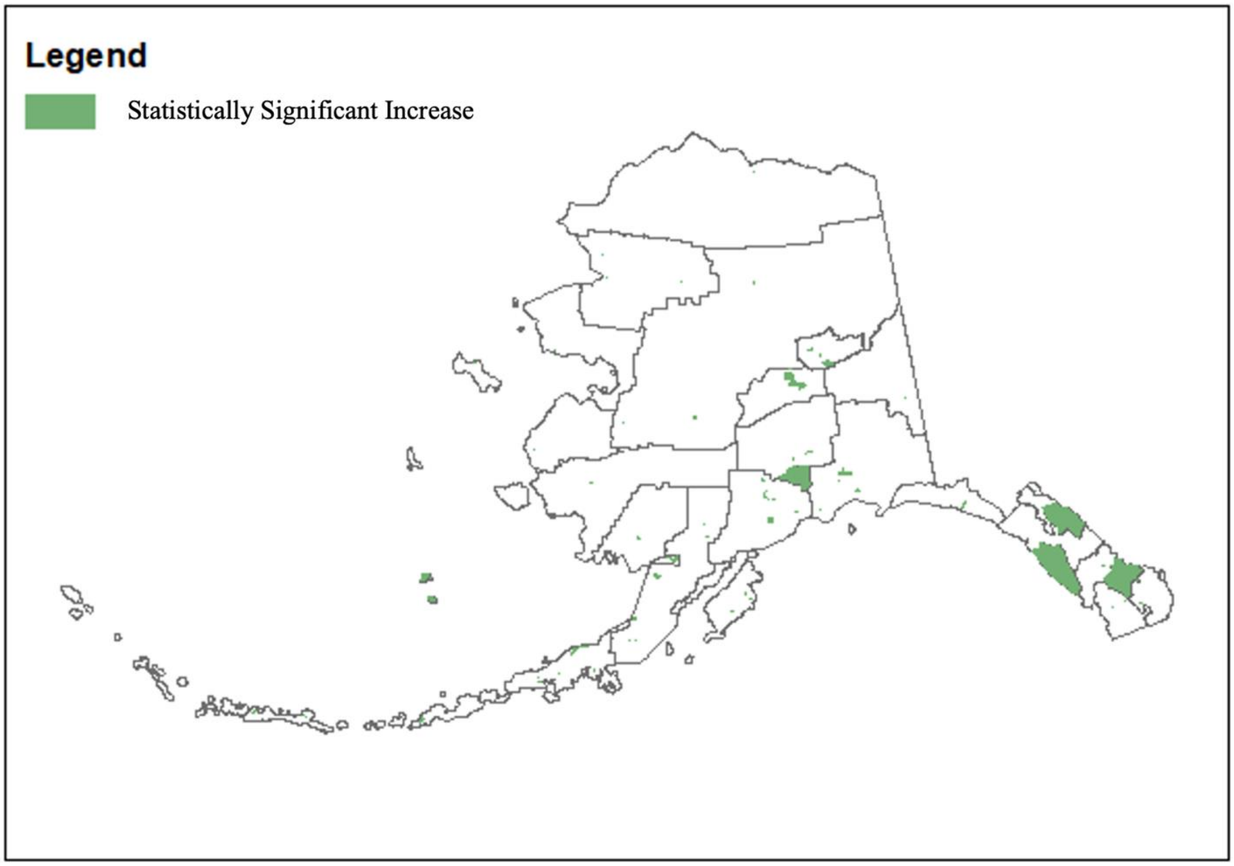


Figure 1: Places in Alaska with Statistically Significant Increases in Plumbing Access

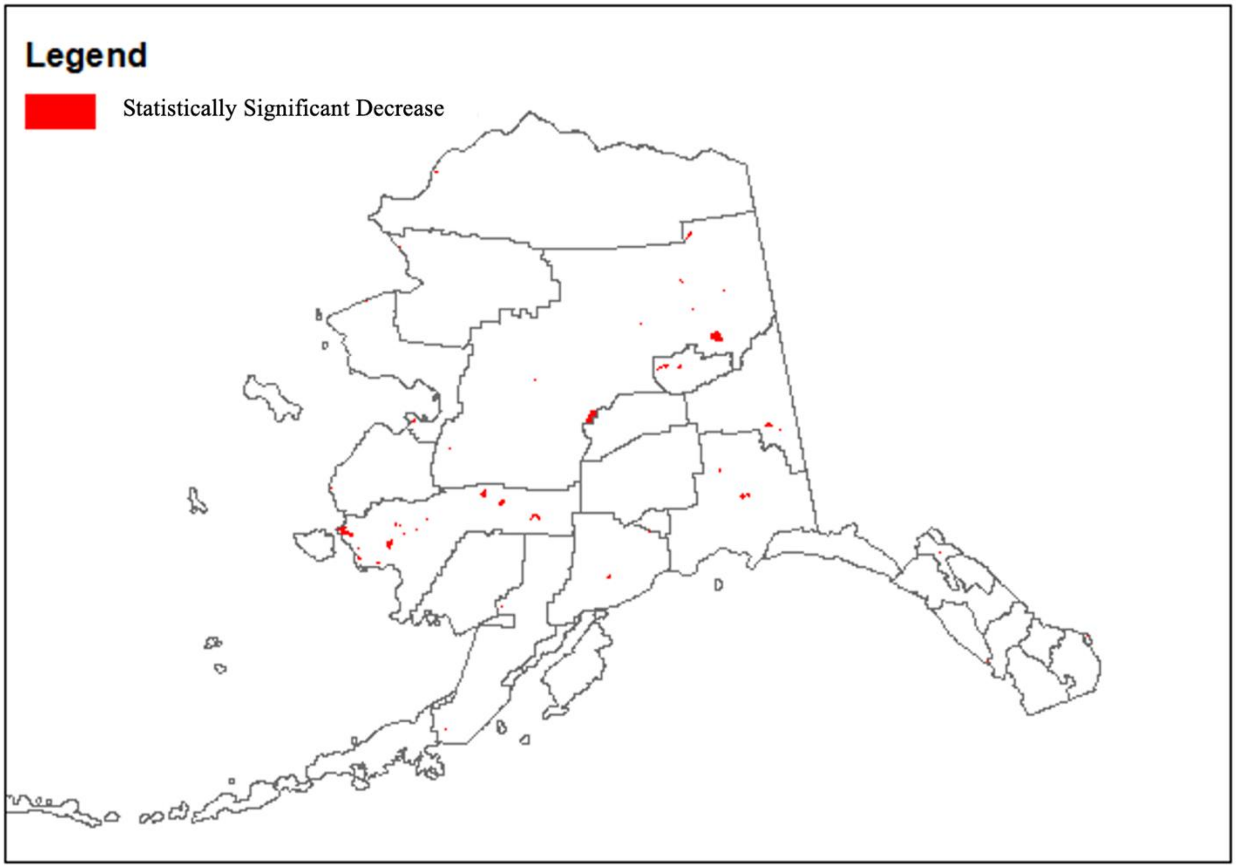


Figure 2: Places in Alaska with Statistically Significant Decreases in Plumbing Access

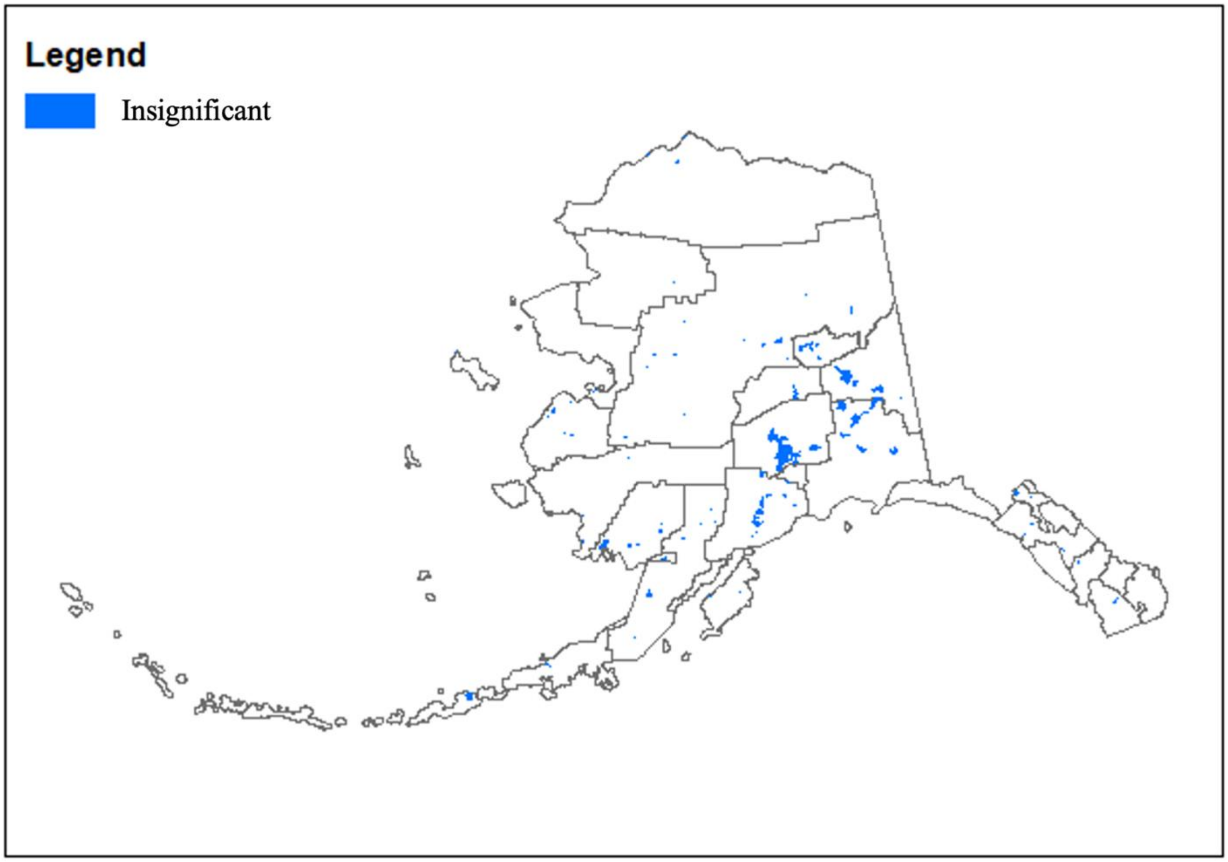


Figure 3: Places in Alaska with Statistically Insignificant Changes in Plumbing Access

Table 2 shows the number of places experiencing, from 2011 to 2015, significantly increasing, significantly decreasing, and insignificant changes in complete plumbing. Table 3 shows, for the same time period, the number and relative frequency of places in each census area that experienced significant decline, significant increases, and insignificant changes in plumbing. It is important to note that while this model examines 355 places, 52 places either (1) did not have sufficient data or (2) did not change over time; as such, the final sample includes 303 places. These 52 places are not included in Table 2, Table 3, and Figures 1-3.

Table 2: Change in Complete Plumbing based on 2011-2015 ACS data[42]

Change in Complete Plumbing	Number of Places	Percentage of Total Places
Statistically Significant Increase	91	30%
Statistically Significant Decrease	63	21%
Insignificant	149	49%

Table 3: Change in Complete Plumbing Aggregated by Borough/Census Area based on 2011-2015 ACS data.[42] Percentage Relative to Places across the State.

Borough/Census Area	Number of Places (Percentage of Total Places Relative to State)		
	Significantly Increasing	Insignificant	Significantly Decreasing
Aleutians East	5 (1%)	1 (0%)	0 (0%)
Aleutians West	5 (1%)	1 (0%)	0 (0%)
Anchorage	1 (0%)	0 (0%)	0 (0%)
Bethel	**2 (1%)**	**9 (3%)**	**22 (6%)**
Bristol Bay	2 (1%)	1 (1%)	0 (0%)
Denali	2 (1%)	2 (1%)	0 (0%)
Dillingham	2 (1%)	7 (2%)	0 (0%)
Fairbanks North Star	4 (1%)	11 (3%)	2 (1%)
Haines	0 (0%)	3 (1%)	1 (0%)
Hoonah-Angoon	2 (1%)	4 (1%)	1 (0%)
Juneau	1 (0%)	0 (0%)	0 (0%)
Kenai	12 (3%)	19 (5%)	3 (1%)
Ketchikan	2 (1%)	0 (0%)	0 (0%)
Kodiak Island	6 (2%)	4 (1%)	0 (0%)
Kusilvak	1 (0%)	9 (3%)	3 (1%)
Lake and Peninsula	6 (2%)	6 (2%)	3 (1%)
Matanuska	4 (1%)	19 (5%)	0 (0%)
Nome	6 (2%)	5 (2%)	5 (1%)
North Slope	3(1%)	4 (1%)	1 (0%)
Northwest Arctic	3 (1%)	6 (2%)	2 (1%)
Petersburg	1 (0%)	1 (0%)	0 (0%)
Prince of Wales	7 (2%)	3 (1%)	2 (1%)
Sitka	1 (0%)	0 (0%)	0(0%)
Skagway	1 (0%)	0 (0%)	0 (0%)
Southeast Fairbanks	2 (1%)	8 (2%)	3 (1%)
Valdez-Cordova	5 (1%)	10 (3%)	2 (1%)
Wrangell	1 (0%)	0 (0%)	0 (0%)
Yakutat	1 (0%)	0 (0%)	0 (0%)
Yukon-Koyukuk	**3 (1%)**	**16 (4%)**	**13 (4%)**

*Census areas in bold have the most places experiencing significant decline.
Note: In 2019, the Valdez-Cordova census area split into the Chugach census area and the Copper River census area. Since this study looks at data prior to this split, this census area is combined.

Alaska is organized into 19 boroughs and 11 census areas. These are similar geographic units and, for clarity, will all be referred to as “census areas”.[54] Between 2011 and 2015, 21% of places (63 places) experienced statistically significant declines in access to plumbing; 30% (91 places) experienced increased access (or improved access), and 49% (149 places) experienced insignificant changes. The largest portion of places facing a statistically significant decline in households with complete plumbing is found in the Yukon-Koyukuk Census Area and the Bethel Census Area, at 20% and 35%, respectively. Figure 4 shows a detailed view of places with significantly declining access in these census areas.

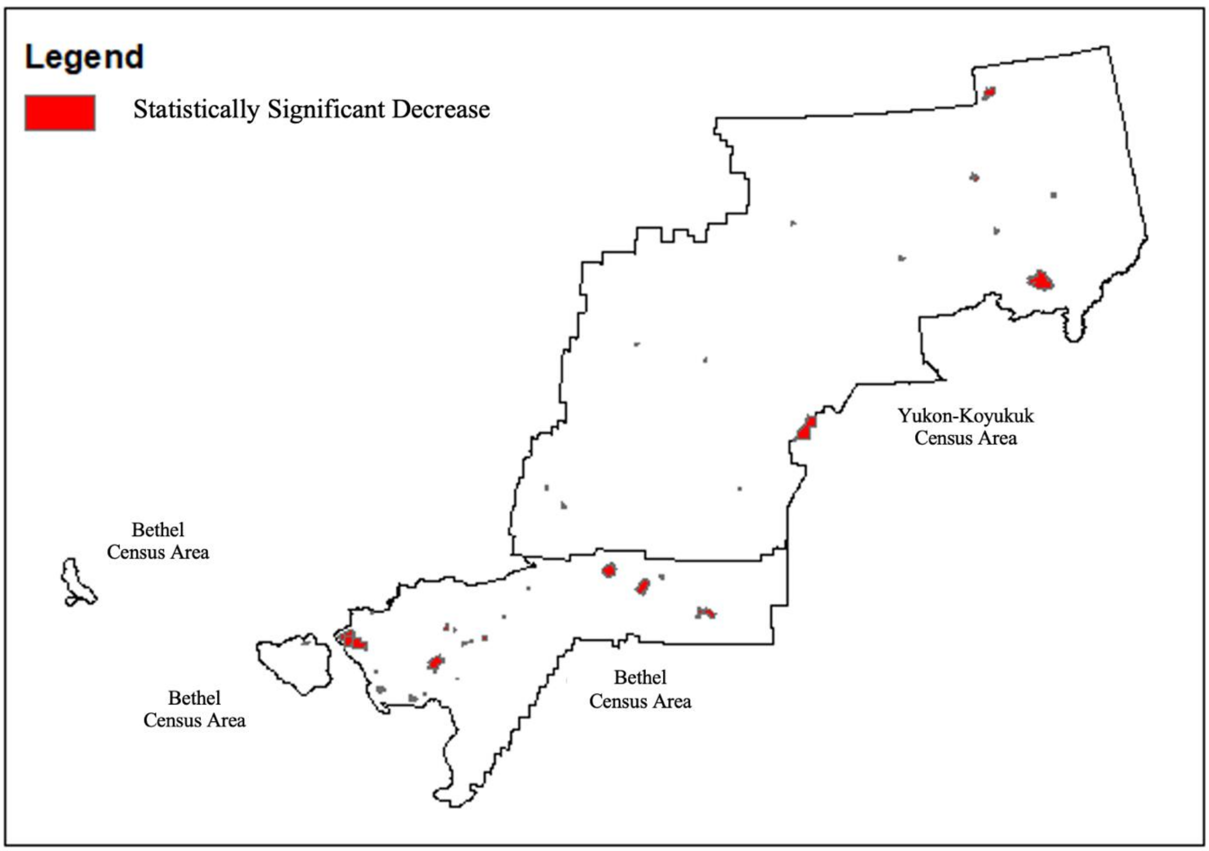


Figure 4: Places with Statistically Significant Declines in Plumbing within the Bethel and Yukon-Koyukuk Census Areas

Places with the greatest decline are isolated (see Figure 2) and sparsely populated—the Yukon-Koyukuk and Bethel census areas both have a population density of under 0.5 persons per square mile. In fact, while the Yukon-Koyukuk census area is the largest physical region of the census areas, it houses approximately only 5,000 Alaskan citizens.[42] This could be expected, as isolation and low population density can lead to challenges with funding (e.g., financial capacity of communities[18, 23]), construction (e.g., supply chain challenges[3]), and maintenance (e.g., operator certification[23]) of piped infrastructure systems. These findings align with previous literature that rural and isolated communities tend to have less widespread utility service connectivity than their larger and more urban counterparts.[38]

3.2 SOCIODEMOGRAPHIC DRIVERS OF ACCESS TO COMPLETE PLUMBING

Table 4 summarizes the parameters associated with rates of complete plumbing revealed through the FE model.

Table 4: Results from Fixed Effects Model

Sociodemographic Variables *(percentage of…)*	**Estimate**	**t-value**	**p-value (>|t|)**
INDEPENDENT Variables			
Population that is male	0.062	1.667	0.095
Households receiving social security	0.066	2.660	0.0079
Owner-occupied homes valued under $150,000	0.043	2.634	0.0086
Population that is native	0.049	1.466	0.143
Households receiving supplemental security income	0.057	1.483	0.138
CONTROL Variables			
Households without complete kitchen facilities	0.744	30.902	< 2.2e-16
Renter-occupied units that pay extra for one or more utilities	-0.030	-1.763	0.078
TOTAL SUM OF SQUARES	5.2806		
RESIDUAL SUM OF SQUARES	2.198		
R-SQUARED	0.583 **		
F-STATISTIC	172.828 on 7 and 863 DF		
OVERALL P-VALUE	$< 2.2e^{-16}$		

**This R-Squared value is for the within regression model after accounting for fixed effects.

Hypothesis 2: Measures of economic vulnerability

The model revealed that as the percentage of homes with a value under $150,000 increases, so does the percentage of households that lack complete plumbing. A home of lower value may be capturing economic vulnerability or a homeowner with lower income. This connection between having complete plumbing and economic vulnerability is not surprising. Financial challenges are often a barrier to repair plumbing in the household and to pay water bills.[55] Low-income families may forgo paying for expensive repairs to pay more immediate or pressing bills like medical expenses, mortgage payments, or grocery bills. Further, if customers are unable to pay for water provision, utilities may struggle—with the consequent decreased financial capacity—to continue providing quality services.

We found that as the percentage of total households that receive social security increases, the number of households without complete plumbing increases as well. In order to receive social security income, a person must be 62 years of age or older or have a disability that disqualifies him or her from work.[56] Our finding is not surprising as aging populations and disabled persons have been found to have lower access to potable water.[9] Access to potable water in Alaska is strengthened by strong social networks; often a group of males will haul water for the rest of the community.[11] However, studies have shown that older and disabled populations can face more social isolation than their able-bodied counterparts,[57] a unique vulnerability that may increase this population's odds of losing plumbing facilities. While the presence of a strong social network may delay an older or disabled individual from losing plumbing access, it is common for residents, seeking economic opportunity, to migrate from small towns, particularly from Native communities, to larger cities like Anchorage and Juneau.[58] As young families move to the cities, older family members who want to remain close to ancestral lands or disabled individuals who are unable to move to cities may lose their vital social networks, thus exposing this population to possible plumbing decline.

Hypothesis 3: Gender

As expected, the model revealed that access to plumbing is impacted by a community's gender makeup. As the percentage of the male population increases, so does the number of households without plumbing access. This trend expressed itself in census areas that experienced the lowest rates of plumbing in the state—in Allakaket, Alaska, a city in the Yukon-Koyukuk census area where the population is 65% male.[42] Indeed, other research supports that women may experience emotional distress in different ways than men do.[47] In general, women express more concern about irregular water availability in the household than men do.[11] In fact, Wutich[47] found that women reported economizing water in times of low availability while cooking, bathing, and cleaning, more often than the male household members did. This is not to say that women need more water than men but may suggest that women, more so than men, are acutely aware of their plumbing status.

Hypothesis 4: Race

In the model, the percentage of the population identifying as Native Alaskan was found to be, surprisingly, insignificant. Many places in Alaska are relatively homogeneous—urban areas tend to have predominately white populations, while rural villages have a predominantly Alaskan Native population. In fact, 82% of the rural Alaskan population are Alaskan Natives.[59] This lack of variation within each place may have led to the findings that race did not uniquely impact plumbing access. The thematic mapping (Section 3.1) shows that isolated geography indirectly reflects, perhaps, racial trends in complete plumbing access. Within Alaska, the Yukon-Koyukuk and Bethel census areas contain the most places with plumbing decline and high percentages of Alaskan Native residents (65.3% and 87.6%, in 2015); as a whole, Alaska's native population was 13.7% in 2015.[42] This is hardly surprising, given that, historically, Native populations in Alaska have received poor water services.[18]

4. PRACTICAL IMPLICATIONS

Between 2011 and 2015, 23% of Alaska places experienced a significant decline in the percentages of households with complete in-home plumbing. Practically speaking, this means that a growing percentage of people are without piped water and sanitation services such as a flush toilet or running water. We acknowledge the engineering, economic, and workforce challenges involved in piped water and sanitation in the extreme and changing Alaskan climate and context.[3,18,23] Nonetheless, we argue that this decline, because of its health and social implications, is a problem of equity. As such, here we outline urgent needs to improve access to water services in Alaska.

One critical need is for increased, external water infrastructure investment in Alaska. Water services in Alaska are typically funded by governmental institutions, such as the Indian Health Service and the Alaska Department of Environmental Conservation.[60] This, in part, stems from historical treaties and agreements in which the government pledged to support Native Alaskan communities (e.g., clean drinking water[61]). Estimates from the federal government suggest that Alaska's water infrastructure needs $987 million in additional funding before 2041.[62] Recently, promising steps have been taken to improve water services in Alaska, such as the Infrastructure Investment and Jobs Act.[63] Still, given that most funding comes from government agencies, it is critical that these agencies have access to tools to ensure funding is allocated efficiently and equitably. Tying water challenges to sociodemographic characteristics begins to frame the needed specific policy changes that could help to alleviate the water challenges in Alaska. Even so, funding equity does not imply funding equality. The recognition of clean water and sanitation as a human right does not require a certain expenditure per person or per community; instead, it requires the meeting of certain water quality and quantity standards. Accordingly, it seems clear that Alaska needs to fundamentally change its approaches to providing water services.

Our results show that funding agencies that select communities for water service investments should investigate the state of plumbing in the most rural and isolated regions. While urban places were included in this study, these regions did not appear to have declining water services. Communities experiencing declining access to complete in-home plumbing were typically rural and remote. This decline may be due to supply chain issues when maintaining systems or a lack of technical expertise to manage systems in rural communities.[18] Further, it is important that funding for Alaskan water systems is not isolated to new construction, a trend that was present in federal funding during the 1970s and 80s,[3] but can be used to support operations (e.g., paying operators, training operators) and maintenance (e.g., fixing issues before system failure) as operations challenges can lead to service decline and failures that contribute to the declining access levels.

Secondly, the sociodemographic drivers revealed in our model suggest possible leverage points to provide services to places with low levels of in-home plumbing, leverage points that could help inform funding decisions. Unfortunately, policymakers are unable to focus on serving each household that lacks in-home plumbing and must make large-scale decisions based on water access trends. Knowing the sociodemographic characteristics related to in-home plumbing will help policymakers make such decisions (e.g., funding) and reflect on previous decisions. For instance, the fact that spatiotemporal variations exist shows that funding decisions should be localized in the future. Further, the variable representing the percentage of homes with values under $150,000 suggests the need for more robust assistance for lower-income families and increased funding for programs like Village Safe Water[64] that develops and funds water services for rural Alaskan communities. Some examples include washeteria improvements and water infrastructure construction. To address the decline in the percentage of households with complete in-home plumbing in areas with high populations of people receiving social security, regulators may focus on providing older and disabled people resources for home repair and social connections to ensure plumbing access. Finally, while the gender variable is difficult to translate into policy, this variable does show policymakers where decreased rates of complete in-home plumbing may occur, allowing them to proactively monitor such locations.

Although our results did not capture access to decentralized systems (e.g., washaterias, systems providing partial access only), our data exploration revealed that there are notable geographic variations in water access. That is, isolated, rural regions experienced lower plumbing access. This trend shows that decentralized systems may be a useful mechanism to provide interim services before a piped system is funded or permanent services are established in communities that, at this point, do not want or cannot support a piped system. A cost-effective way to serve isolated communities may be decentralized services that provide partial plumbing. In such communities, complete plumbing is a challenge for the following reasons: the expensive upfront cost of constructing a distribution system, the inability of many customers to pay water bills and thereby sustain the financial capacity of utilities, supply chain challenges (e.g., transporting construction materials), and arctic weather conditions (e.g., the need to insulate water pipelines).

5. CONCLUSION

Historically, Alaska has been the U.S. state with the highest percentage of homes without in-home plumbing. While this percentage has improved overall since the 1960s (when this topic was initially identified), some places in Alaska are still experiencing declines in in-home plumbing access. Filling a gap in the literature, our study showed that plumbing access varies spatially and temporally in Alaska and identified the sociodemographic drivers of incomplete in-home plumbing. By understanding the sociodemographic characteristics that correlate to in-home plumbing rates, planners and municipal bodies are better equipped to reverse this decline or anticipate areas at high risk of plumbing decline. As this decline happens in certain places to select populations, policy must be localized to be effective. Additionally, this study reveals future research questions. For example, researchers may look at declines on a more granular basis instead of from a five-year dataset going through present day.

ASSOCIATED CONTENT

The following files are available free of charge.

Table S1: Comparison of Variables Used in this Study with the Social Vulnerability Index

Table S2: Fixed Effects of Alaska Census-Designated & Incorporated Places Used in Regression Model

Figure S1: Census-Designated and Incorporated Places in Alaska

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Author Contributions

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Notes

The authors declare no competing financial interests.

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