**Small Drinking Water Systems in North Carolina:**
An assessment of small drinking water providers to understand challenges and opportunities for capacity building

A report for the University of North Carolina School of Government
Environmental Finance Center

Duke Nicholas School of the Environment
Master's Project, Spring 2019

Jizhen Zhong, Daniel Ramirez-Cisneros, Reed Perry, Yukun Xu

## Public Drinking Water Systems

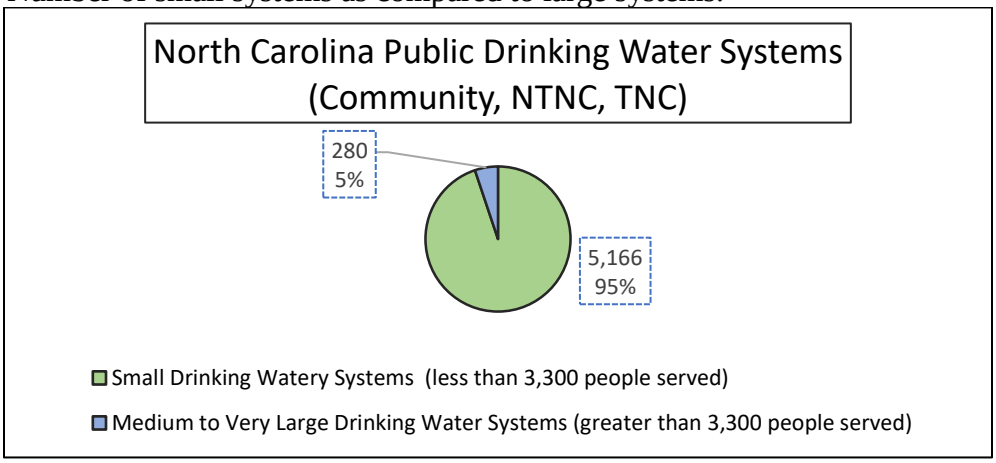
*Imbalance Leads to System Technical, Managerial, and Financial Capacity Challenges*

In North Carolina, there is an imbalance between the number of public drinking water systems and the size of populations served by individual systems. Of the nearly 5,450 public drinking water systems in the state, 95 percent (5,166 systems) serve fewer than 3,300 people each (Table 1 and Figure 2). This imbalance mirrors national-level statistics which show that over 97 percent of the nation's public water systems serve fewer than 10,000 people each (U.S. Environmental Protection Agency, 2016). Around 80 percent of U.S. public drinking water systems serve fewer than 3,300 people each (Kline, 2017).

**Table 1:** Distribution of NC Public Drinking Water Systems by type and by service population (range of persons served by system).[1]

| **Broad classification** | **Small** | | **Medium[2]** | **Large** | | |
|---|---|---|---|---|---|---|
| **System Type (EPA category)** | **Very Small (0-500)** | **Small (501-3,300)** | **Medium (3,301-10,000)** | **Large (10,001 – 100,000)** | **Very Large (100,000+)** | **Total** |
| **Community** | 1,377 | 340 | 141 | 123 | 15 | 1,996 |
| **Non-Transient, Non-Community** | 292 | 52 | 1 | 0 | 0 | 345 |
| **Transient, Non-Community** | 3,075 | 30 | 0 | 0 | 0 | 3,105 |
| Total | 4,744 | 422 | 142 | 123 | 15 | 5,446 |

**Figure 2:** Number of small systems as compared to large systems.




[1] Data on NC Public Drinking Water System counts was collected from the U.S. EPA Safe Drinking Water Information System. https://iaspub.epa.gov/enviro/sdw_form_v3.create_page?state_abbr=NC

[2] The EPA has categorized small systems as those serving a population fewer than 3,300 persons, and also those serving a population fewer than 10,000 persons. For the purposes of this study, we classify small systems as those serving fewer than 3,300 persons.

The Safe Drinking Water Act and related state laws require public drinking water systems to comply with safe drinking water standards; however, the size of a system's service population directly affects a system's ability to achieve compliance (McFarlane & Harris, 2018). Since the Safe Drinking Water Act's passage and implementation, small systems have experienced significant challenges in achieving compliance, and on a state and a national level they continue to show higher rates of drinking water violations as compared to large systems (North Carolina Department of Environmental Quality, 2018; U.S. Environmental Protection Agency, 2011).

Our research on small drinking water systems (specifically, mobile home parks and schools), shows that there is a difference in the occurance of drinking water violations between our sub-group, small drinking water systems, and all community and non-transient, non-community water systems in North Carolina. We looked at both the absolute number of violations committed, and also the number of systems with at least one violation over the past five years. We found that in absolute number of violations, mobile home park drinking water systems had a higher rate of non-compliance as compared to other small drinking water systems. We also found that for schools and absolute number of violations, schools had a lower rate of non-compliance as compared to other small drinking water systems. In examining the number of systems with at least one violation over the past five years, we find that there are a higher percentage of mobile home park and school drinking water systems with at least one violation as compared to other drinking water systems in the state.

*Small Systems but Less Capacity*

The fundamental problem is that while small systems require less infrastructure and resources to operate, they also have less capital, revenue, and staff available to achieve the same level of safe drinking water rule compliance as large systems (McFarlane & Harris, 2018). By definition, small systems have a customer base around or smaller than one-hundredth of a large system; furthermore, these systems often employ just one to two staff on a part time basis (U.S. Environmental Protection Agency, 2011). These characteristics represent a few of the fundamental technical, managerial, and financial (TMF) capacity differences as compared to larger systems (Blanchard & Eberle, 2013). Other challenges include greater cost of scale, aging infrastructure, poor management, less regulatory expertise, and a lack of long-term planning as compared to larger systems (U.S. Environmental Protection Agency, 2011).

*State Level Research is Needed*

In North Carolina, there is limited research investigating the challenges faced by small drinking water systems. Studies on small drinking water systems in other states have used owner surveys and have analyzed state level data to generate more nuanced understanding about the challenges of owning, operating, and managing a small system (Blanchard & Eberle, 2013). For example, a 2011 survey conducted by Washington's Office of Drinking Water revealed that small system owners were relatively confident about technical capacity but were less confident about the financial capacity of their systems (Blanchard & Eberle, 2013). Similar research on small drinking water systems in North Carolina is needed to fully understand the challenges and potential solutions to improve capacity and safe drinking water compliance.

North Carolina has launched a statewide water and wastewater infrastructure "Master Plan" (North Carolina DEQ Division of Water Infrastructure, 2017). The Master Plan seeks to put drinking water systems on a path to being "viable systems" (Durso, Solomon, & Colson, 2019). According to the Master Plan, a viable system is "one that functions as a long-term, self-sufficient business enterprise, establishes organizational excellence, and provides appropriate levels of infrastructure maintenance, operation, and reinvestment that allow the utility to provide reliable water services now and in the future" (North Carolina Department of Environmental Quality, 2017). A viable system must meet the state criteria for infrastructure management, organizational management, and financial management; these are akin to the aforementioned technical, managerial, and financial capacity characteristics (Durso, Solomon, & Colson, 2019).

The Master Plan focuses almost solely on utility systems and overlooks a variety of other small systems that currently supply drinking water in the state. Although these other small systems do not operate like a drinking water utility, they do face similar challenges regarding operations, finances, and infrastructure. Research on non-utility, small drinking water systems could help North Carolina and other states incorporate these systems into statewide planning efforts for public drinking water.

**Research Objective**

The purpose of our research is to improve understanding about the specific characteristics and the challenges associated with small drinking water systems in North Carolina and to test assumptions about the current status of these systems. By analyzing data on drinking water violations, individual system characteristics, and community demographics, and by speaking with system owners directly, we seek to enhance current knowledge about these systems and help to lay the groundwork for future research on capacity-building and system consolidation.

*Subgroup: Mobile Home Parks and Schools*

Within the small system category, we limited our scope of research to include mobile home parks and schools that own and operate a public drinking water system. These system types represent both community (mobile home parks) and non-transient, non-community (schools) water systems as defined by the EPA. On average, the systems in our study serve populations far fewer than 500 persons. The median population served by mobile home parks is 86 persons per park, and the median population served by schools is 303 persons per school (Table 3).

Our study includes 339 mobile home parks and 159 schools (Table 2). Collectively, the systems in our study serve just under 90,000 people (less than 1% of the state population) (Table 3). The mobile home parks in our dataset represent the total number of mobile home parks that own and operate a public drinking water system. Mobile home parks meeting this classification represent about 20 percent of all small community water systems in North Carolina (Table 2). About 39,000 people rely on drinking water from the mobile home parks in our study, which is less than 0.4% of the state population (Table 3).

The schools in our dataset represent the estimated total number of schools that own a drinking water system. Many of the schools in our dataset are public schools owned by a county

government; however, these schools operate a drinking water system that is not connected to a local government system. The schools in our dataset represent over 45 percent of all small non-transient, non-community water systems in North Carolina (Table 2).

**Table 3:** (Count of systems included in our dataset) Number of Mobile Home Parks and Schools in North Carolina that own and operate a public drinking water system.

| System Type | Number of Systems | Number of Small Community Water Systems | MHPs as percent of Small Community Water Systems |
|---|---|---|---|
| Mobile Home Parks (MHPs) | 339 | 1,717 | 20% |
| | | **Number of Small NTNC Water Systems** | **Schools as percent of Small NTNC Water Systems** |
| Schools | 159 | 344 | 46% |

**Table 4:** Population served by Mobile Home Parks and Schools as a count and as a percent of total population in North Carolina.

| | Median Number of People Served per System | Total Population Served (All Systems) | Percent of NC Population |
|---|---|---|---|
| Mobile Home Parks (MHPs) | 86 | 38,963 | 0.38% |
| Schools | 303 | 50,579 | 0.49% |
| | | | |
| MHPs and Schools | N/A | 89,542 | 1% |
| | | | |
| North Carolina Population | 10,300,000 | | |

In North Carolina, the small system category also includes communities such as subdivisions, apartments, resorts; however, a significant portion of these systems are owned by water corporations like Aqua America (Aqua America, Inc., 2019) We excluded systems owned by water corporations. We selected systems that were not owned by a water corporation because system ownership is directly related to TMF capacity and we assume that water corporations have inherent advantages in ownership and operation (U.S. Environmental Protection Agency, 2011).

In addition, we excluded all transient, non-community drinking water systems which include entities like churches, camps, gas stations. Because transient, non-community systems do not serve a consistent population, they pose less of a threat of long-term exposure of contaminants to populations as compared to other system types. As a result, they are less regulated than other public systems and the regulations are limited to contaminants posing an immediate health risk (Tiemann, 2017).

*What did we do?*

We conducted a thorough literature review and collected background information on federal and state drinking water regulations, small drinking water systems, state funding programs for drinking water systems, groundwater and water quality in North Carolina, and mobile home parks and schools to provide context for our research. We employed a variety of datasets, including drinking water violations data, North Carolina sanitary surveys data, free & reduced meals data, and U.S. census data, to evaluate the TMF capacity of systems in our study. We also conducted a survey of mobile home park owners to understand the challenges small systems face from an owner's perspective. We analyzed this data to generate new knowledge about the TMF capacity of mobile home parks and schools in our subgroup.

*What did we learn?*

Our findings confirm and challenge our initial expectations about small drinking water systems. We find that the small drinking water systems in our study represent a majority of the drinking water rule violations over the past five years, which we expected given that small systems represent 95 percent of all drinking water systems. Looking at the number of systems with at least one violation and comparing against the total number of systems of that type (mobile home parks or schools), our study provides further evidence that small systems have a higher rate of non-compliance. We find that there are a higher percentage of mobile home park and school systems with at least one violation over the past five years (out of all mobile home parks and schools with drinking water systems) as compared to small drinking water systems and the total group of community and non-transient, non-community systems.

We also find that non-governmental systems like mobile home parks have no direct opportunities to apply for drinking water loan and grant programs offered by the state of North Carolina. Furthermore, our survey conducted with owners of mobile home parks confirms that small systems feel challenged by a regulatory burden in achieving safe drinking water rule compliance. In aggregate, our findings provide evidence that the small systems in our dataset have less TMF capacity than larger systems in North Carolina to achieve SDWA compliance.

However, we found some of our initial expectations were challenged. For example, we found that the systems are largely located in communities that are characterized by moderate to high household income and low poverty rates. Background research on mobile home parks confirms that residents tend to be poorer, and parks are typically located in more rural areas (Van Dam, 2017). Thus, we were surprised to see that mobile home parks in our study were located in areas with comparatively higher incomes. Our survey of mobile home park owners also reflects a relatively high degree of confidence among owners in the current TMF capacity of their systems.

*Where do we go from here?*

Our research raises questions about how system ownership influences TMF capacity and safe drinking water compliance, and about potential solutions to either build capacity among small systems or support consolidation of small systems with larger systems. Within the mobile home park sector, there is a growing trend of investment and corporate ownership of mobile home parks (Whoriskey, 2019). There is debate between scholars familiar with the topic about how corporate ownership may differ from local ownership in terms of investment in the park and attention to the needs of residents. For example, an anthropologist studying mobile homes has

stated that when deciding between park maintenance and repairs or profits, large corporations tend to pursue profits to maintain shareholder value (Whitford, 2018). A New York Times article exploring corporate-run mobile home parks provides evidence to the contrary and discusses how one investor improved the safety and living conditions of the park after purchasing it from a resident-owner (Rivlin, 2014).

Our conversations with mobile home park owners revealed that a substantial number of survey participants would be open to transferring their ownership of the drinking water system if it were financially feasible. This opinion among owners raises important questions about drinking water systems that are not the sole focus of the system owners.

The types of violations we see in schools with drinking water violations tend to be related to coliform and the Lead and Copper rule. If a high number of violations from the schools in our dataset are Lead and Copper, that could provide further evidence that all schools (not just those with drinking water systems) should be testing more regularly for lead and other contaminants.

Overall, our research helps to highlight a small and overlooked category of drinking water systems in North Carolina. For both schools and mobile home parks, there are a higher number of drinking water systems with at least one violation as compared to other drinking water systems (total and just small systems). It is evident that these small systems continue to struggle with compliance. As North Carolina seeks to improve capacity and upgrade the drinking water infrastructure of utilities, the state should also consider what the future operation of small "non-utility" systems should look like.

## Background: Safe Drinking Water Act Compliance Challenges

### *Public Drinking Water Systems in the United States*

Public water systems as defined by the EPA are drinking water systems which provide "water for human consumption through pipes or other constructed conveyances to at least 15 service connections or serves an average of at least 25 people for at least 60 days per year" (Environmental Protection Agency, n.d.). Approximately 152,700 privately and publicly owned drinking water systems across the United States meet this definition (Tiemann, 2017) .

Public water systems are categorized further based on the size and transience of population served. The three EPA categories are 1.) Community Water Systems (CWS) which supply the same population year-round, 2.) Non-Transient Non-Community (NTNC) Water Systems which regularly supply water "to at least 25 of the same people at least six months per year," and 3.) Transient Non-Community (TNC) Water Systems which provide water to a transient population (Environmental Protection Agency, n.d.).

There are approximately 51,350 CWS, and 82 percent of these systems serve a population of 3,300 persons or fewer (Tiemann, 2017). 55 percent of community water systems serve a population of 500 persons or fewer (Tiemann, 2017). Approximately 18,178 NTNC water systems, including entities such as businesses or schools, serve the same population for a period greater than six months but less than year-round (Tiemann, 2017). Nearly 100 percent of NTNC water systems serve populations of 3,300 persons or fewer (Tiemann, 2017). The third

category of systems, TNC, include entities such as gas stations which provide drinking water to transitory populations.

While U.S. citizens primarily receive drinking water from large systems like public utilities, approximately 21 percent of the population (69 million people) are served by small systems (U.S. Environmental Protection Agency, 2018).

*The Safe Drinking Water Act*

Congress passed the Safe Drinking Water Act (SDWA) in 1974 through the Public Health Service Act to protect public water supplies from harmful contaminants (Tiemann, 2017). SDWA allows the federal government to delegate the implementation and enforcement of SDWA to states (called "primacy"). Forty-nine states have primacy and maintain a Public Water Supply Supervision program to administer SDWA rules (Tiemann, 2017).

Under SDWA, the EPA has established regulations for more than ninety contaminants affecting drinking water (U.S. Environmental Protection Agency, 2018). The EPA uses three criteria to determine which contaminants to regulate. The criteria are listed as follows: 1.) "the contaminant may have an adverse effect on the health of persons," 2.) "the contaminant is known to occur or there is a high chance that the contaminant will occur in public water systems often enough and at levels of public health concern," and 3.) regulation of the contaminant presents a meaningful opportunity for health risk reductions for persons served by public water systems" (U.S. Environmental Protection Agency, 2018).

The EPA has established two categories of drinking water standards: the primary standard and the secondary standard. The national primary drinking water regulations are legally enforceable standards which apply to public water systems and they protect water quality by limiting the levels of regulated contaminants (U.S. Environmental Protection Agency, 2018). National secondary drinking water regulations are non-enforceable guidelines for contaminants that result in cosmetic or aesthetic effects in drinking water (U.S. Environmental Protection Agency, 2018).

*Small Drinking Water Systems and the Safe Drinking Water Act*

On a national scale, research shows that small drinking water systems have consistently struggled to achieve SDWA compliance. A report from the National Regulatory Research Institute found that in 2000, small systems represented 90 percent of all systems with a history of SDWA noncompliance (Stanford, 2008). A 2011 EPA report finds that "very small [community] water systems have the highest number of violations per 1,000 people of all system sizes….approximately 13,899 M&R violations for every 1 million people served, whereas large systems only have 42" (U.S. Environmental Protection Agency, 2011). A recent literature review on small drinking water states that, "studies have shown [small drinking water systems] have higher rates of noncompliance than larger systems" and "most violations are a result of failing to meet monitoring and reporting requirements rather than water quality standards" (McFarlane & Harris, 2018). The literature confirms that on the national level, population size is associated with SDWA compliance and that violations are often due to failures in monitoring and reporting and not typically due to contamination.

*National Need for Investment in Drinking Water Systems*

Drinking water systems are capital-intensive, and small drinking water systems have more difficulty accessing loans and grants due to their customer base size or due to their status as non-governmental entities (Kline, 2017). The EPA's most recent estimate on the national need for investment in drinking water systems is $74.4 billion for small systems and $472.6 billion for all systems (U.S. Environmental Protection Agency, 2018).

Small systems have a greater infrastructure investment need per connection than large systems because they have a much smaller customer base through which to pay for capital investments (U.S. Environmental Protection Agency, 2011). An EPA report using 2006 and 2007 survey data found that "systems serving 100 or fewer people have nearly 10 times the replacement need per residential connection than large systems" (U.S. Environmental Protection Agency, 2011). In addition, small systems have very limited access to federal funding assistance (delivered through states) because federal funding is often directed to projects requiring upgrades and new construction, while small systems often require capital for repairs and replacement (Kline, 2017)

## Background: North Carolina Drinking Water Rules

*SDWA Implementation in North Carolina*

North Carolina has primary enforcement responsibility for the Safe Drinking Water Act (SDWA). The state enforces the SDWA through the review and approval of system infrastructure plans, water quality standard enforcement, system site visits, system operator certification, and other activities to support local drinking water quality (North Carolina Department of Environmental Quality, 2018). Drinking water system operators submit data to the state on a regular basis which is checked against EPA contaminant rules. A monitoring violation is issued by the state to a drinking water system for each missed or incorrectly collected sample (North Carolina Department of Environmental Quality, 2018). A maximum contaminant level (MCL) violation is issued when a system has contaminants that exceed the MCL levels (North Carolina Department of Environmental Quality, 2018).

*Drinking Water System Operators*

North Carolina requires that public drinking water systems must have a certified operator to supervise the operation of water treatment facilities (N.C.G.S. § 90A). Different levels of certification require specific levels of experience and expertise. There are quantity and geographic constraints on which systems and how many systems an operator can legally operate. North Carolina code states that no single operator can be in charge of any more than,

> "(1) one surface water treatment facility, (2) five community public water systems with well water facilities, (3) ten non-community public water systems with well water facilities, (4) one distribution system serving over 3,300 service connections, (5) five distribution systems serving over 500 service connections and less than 3,300 service connections, (6) ten total distribution systems, (7) ten total cross-connection control systems, (8) or any facility located more than a 50-mile radius from where the operator resides" (NC Administrative Code T10.10E .0101 - .0105)."

The limits on operator responsibility imply that for mobile home parks and schools, the operator in charge will have a maximum responsibility of five (MHPs) or ten systems (schools).

*Sanitary Surveys*

North Carolina drinking water officials also interact with operators through site visits and inspections. Sanitary surveys, which are required by the EPA, are the most comprehensive staff visit to systems and include an assessment of the system's: source water, water treatment, distribution system, finished water storage, pumps, monitoring and reporting verification, management operations, and operator compliance (North Carolina Department of Environmental Quality, 2018). In 2017, DEQ staff made about 7,276 visits to drinking water systems, which included 2,612 sanitary surveys (North Carolina Department of Environmental Quality, 2018). The state performs sanitary surveys for community water systems at least once every three years, and at least once every five years for non-community water systems (North Carolina Department of Environmental Quality, 2018).

**Background: State and Federal Funding for Drinking Water in North Carolina**

*Infrastructure Challenges and Funding Eligibility*

In accordance with national infrastructure needs, North Carolina has cited the need for substantial investment (between $17 billion and $26 billion) in water and wastewater infrastructure over the next twenty years (Division of Water Infrastructure, NC DEQ, 2017). The cost estimates for drinking water systems alone is between $10 and $15 billion over the next twenty years (North Carolina Department of Environmental Quality, 2017).

The eligibility requirements of the state drinking water assistance programs show that non-governmental systems like mobile home parks are unable to access the same types of state funding opportunities as governmental systems. Public schools operating their own drinking water systems can access funding through their respective county; however, private schools with independent drinking water systems would not be eligible.

*State Funding Programs*

North Carolina provides state funding to public drinking water systems through its Drinking Water State Revolving Fund (DWSRF), through the Connect North Carolina Bond Act, through Community Development Block Grants, through the State Wastewater & Drinking Water Reserve Program, through the Merger/Regionalization Feasibility Grant Program, and through the Asset Inventory and Assessment Grant Program (North Carolina DEQ Division of

Water Infrastructure, n.d.). These funding programs primarily support local government and nonprofit water corporation entities.

The Community Development Block Grant program provides funding to local governments in HUD qualified low-to-moderate income communities, and the State Wastewater & Drinking Water Reserve program provides technical assistance and construction funding to local governments for wastewater and drinking water projects (North Carolina DEQ Division of Water Infrastructure, n.d.). Only local governments are eligible to apply for Community Development Block Grants and the State Wastewater & Drinking Water Reserve Program (North Carolina DEQ Division of Water Infrastructure, n.d.).

The USDA Rural Development program supports drinking water infrastructure through grants and loans to local governments (U.S. Department of Agriculture). Eligible applicants must be a type of public entity such as counties, towns, cities, water & sewer districts, water & sewer authorities, or sanitary districts (UNC Environmental Finance Center, 2015). This program is specifically targeted toward small and medium-sized systems; the project must serve a rural area and be located in a town or city with a population less than 10,000 people (UNC Environmental Finance Center, 2015). In addition, the grant or loan recipient must not be able to independently finance the project itself or by borrowing from a commercial source at a reasonable rate (UNC Environmental Finance Center, 2015).

The DWSRF funds water infrastructure projects to reduce public health risks and improve safety and compliance of drinking water systems (North Carolina Department of Environmental Quality, 2018). From 1998 through 2017, approximately $900 million DWSRF funds were allocated to drinking water systems through low-interest and principal-forgiveness loans (North Carolina Department of Environmental Quality, 2018). However, not all public water systems are eligible to apply for funding through the DWSRF. According to North Carolina General Statute 159G-31, only a

> "local government unit or nonprofit water corporation is eligible to apply for a loan or grant from the CWSRF, the DWSRF, the Wastewater Reserve, or the Drinking Water Reserve. An investor-owned drinking water corporation is also eligible to apply for a loan or grant from the DWSRF" (N.C.G.S. § 159G-31).

The Merger/Regionalization Feasibility Grants program provides grant funding to study the possibility of consolidating two or more systems and the physical interconnection of water or wastewater systems (North Carolina DEQ Division of Water Infrastructure, n.d.). Eligible applicants include local governments and nonprofit water corporations (North Carolina Division of Water Infrastructure, n.d.). Mobile home parks are ineligible for this grants program unless they are legally structured as a nonprofit water corporation.

Established in 2004, the Failing System Loan program provides principal-forgiveness loans to help drinking water systems incorporate a failing drinking water system (North Carolina Department of Environmental Quality, 2018). Failed systems are

those which have failed to comply with SDWA over a certain period of time or those which were illegally constructed. If a project is determined to be financially and operationally feasible by the partner drinking water system, North Carolina's Division of Water Infrastructure provides a loan and other technical assistance to help the systems consolidate.

To date, the Failing System Loan program has consolidated 26 systems representing 1,182 customers (North Carolina Department of Environmental Quality, 2018). In the past ten years, the program has led to the consolidation of at least 3 failing mobile home park drinking water systems, one high school, and one orphanage (community water system).[3] Partner drinking water systems which received loans to incorporate the systems were local governments and for one project, a public water and sewer authority. A conversation with a member of the Division of Water Infrastructure revealed that in terms of public health, the Failing System Loan program can have a significant return on investment because it eliminates a system that cannot provide safe drinking water.[4]

## Background: Water Resource Challenges

*Groundwater*

Across the United States, most small systems source raw water from ground water. In the 500 or fewer people category, 84 percent of systems primarily rely on ground water; in contrast, only 36 percent of systems serving 10,000 or more people primarily rely on ground water (U.S. Environmental Protection Agency, 2011).

*Groundwater in North Carolina*

More than 50 percent of North Carolina's population relies on groundwater as a primary source of drinking water (North Carolina Office of Environmental Education, n.d.). In addition, there are approximately 16,000 public supply groundwater wells throughout the state. (North Carolina Ground Water Association, 2019). Over 90 percent of mobile home parks and schools that operate as public water systems in North Carolina rely on groundwater.

There are a variety of pollutants and pathogens that can contaminate groundwater sources. Groundwater contaminants can be divided into two groups: geogenic (naturally occurring) and anthropogenic (manmade). Anthropogenic contaminants of groundwater in North Carolina are released into the environment mainly by agriculture, industry, and residential sources and ensuing related activities (Environmental Protection Agency, 2018).

Agricultural contamination of groundwater occurs through fertilizer storage and use, animal feedlots, manure stockpiles (including pits and lagoons), and pesticide runoff. The eastern lowlands of NC have one of the highest hog populations in the country, and past research has found contaminants linked to hog waste in both surface water and drinking water sources in this region (Rimler, 2015).

[3] Failing System Loan Program project information from the past ten years was provided by the North Carolina Division of Water Infrastructure.
[4] February 12 call with staff from NC Division of Water Infrastructure.

Industrial activity associated with groundwater contamination includes oil and gas production, chemical manufacture, mining, and coal-fired power plant production (Environmental Protection Agency, 2018). Many of the smaller systems in North Carolina struggle with residential contamination sources as well, including fuel oil storage tanks, septic tanks and leach fields, sewer lines, lawn fertilizer, and illegal dumping (Gibson & Pieper, Strategies to improve private-well water quality: a North Carolina perspective, 2017).

The main geogenic sources of contamination for groundwater are underground mineral deposits and rock and soil formations that release inorganic constituents like manganese and iron in water; radionuclides and heavy metals can also be released through rock and contaminate aquifers (Environmental Protection Agency, 2018; Griese, Mason, & Strickland, 1987). SDWIS data in North Carolina indicates most radionuclide violations are attributed to groundwater fed systems, and 81% of small systems in North Carolina, including schools and MHPs, list groundwater as their primary source of water supply (U.S. Environmental Protection Agency, n.d.). Even though radionuclide contamination can be naturally ocurring, nuclear power plant releases and hospital effluent can be sources of radioactivity in water (North Carolina Office of Environmental Education, n.d.). According to NC DEQ, schools, including those that rely on groundwater, are not required to test for radionuclides.

Radon and arsenic are two primary geogenic contaminants found in North Carolina aquifers (North Carolina Department of Environmental Quality, n.d.). Radon occurs through the decay of uranium-238,which is an element found in rocks in the Piedmont and Mountains region (Campbell, et al., 2011). Radon represents a significant public health risk and is the leading cause of lung cancer among non-smokers (Campbell, et al., 2011). The primary way humans are exposed to radon through water is through the inhalation of radon gas released during household use such as a shower (Campbell, et al., 2011). Nineteen counties have been identified within seven areas especially susceptible to radon exposure (Campbell, et al., 2011). These counties include: Mountains Region: Buncombe, Caldwell, Henderson, Jackson, McDowell, Mitchell, Rutherford, Transylvania, Watauga, Wilkes, Yancey, and the Piedmont Region: Catawba, Cleveland, Franklin, Gaston, Lincoln, Mecklenburg, Vance, and Wake (Campbell, et al., 2011).

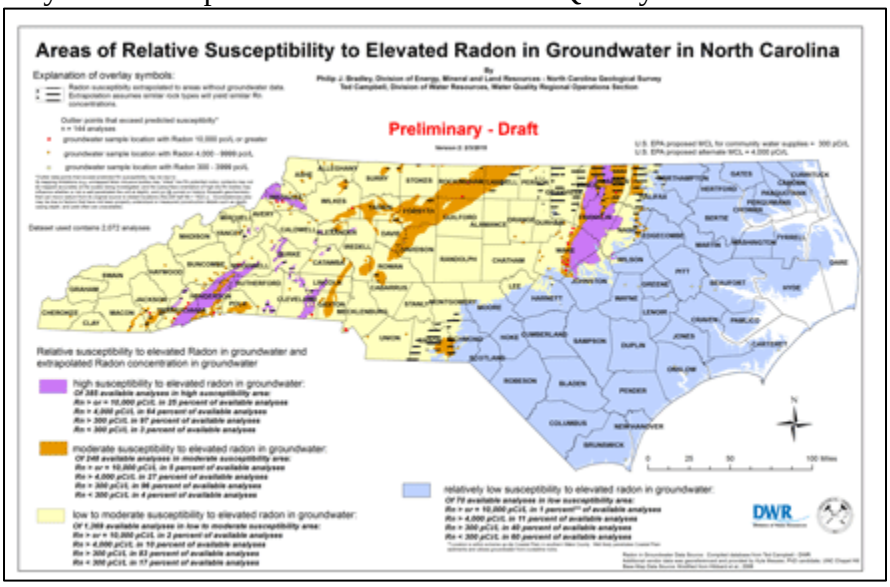
**Table 6:** Mobile home parks in our dataset

| County | Region | Number of Parks | Total Number of People |
|---|---|---|---|
| Wake | Piedmont | 48 | 5,962 |
| Gaston | Piedmont | 30 | 3,131 |
| Henderson | Mountains | 12 | 846 |
| Franklin | Piedmont | 11 | 740 |
| Buncombe | Mountains | 10 | 1,298 |
| Catawba | Piedmont | 8 | 936 |
| Mecklenburg | Piedmont | 4 | 1,139 |
| Lincoln | Piedmont | 3 | 415 |
| McDowell | Mountains | 3 | 247 |
| Watauga | Mountains | 3 | 462 |
| Vance | Piedmont | 2 | 350 |
| Jackson | Mountains | 1 | 127 |
| Transylvania | Mountains | 1 | 229 |
| Yancey | Mountains | 1 | 90 |

Wake County and Gaston County in the piedmont region feature the highest number of mobile home parks and the highest service population among all counties that include regions with high probability of radon (Table 6).

Although the EPA has recommended rules to require monitoring and to limit the amount of allowable radon, there is not enforceable rule at this time (Swistock, 2015). For this reason, we cannot determine which systems from our dataset are of the highest risk for radon contamination. However, the state of North Carolina has conducted research to identify geographic regions with the highest susceptibility to radon contamination in groundwater, as featured in Figure 7.

**Figure 7:** Map of "Areas of Relative Susceptibility to Elevated Radon in Groundwater in North Carolina" provided by the NC Department of Environmental Quality. [5]




Arsenic is a human carcinogen and is also present in aquifers throughout the state (North Carolina Department of Environmental Quality, n.d.). The central area of the Piedmont region in North Carolina has been identified as the area with the most groundwater wells having detectable and elevated arsenic (North Carolina Department of Environmental Quality, n.d.). Long-term exposure to even low levels of arsenic can be harmful, and the EPA MCL for arsenic in water is less than 10 parts per billion (North Carolina Department of Environmental Quality, n.d.). A 2012 study on arsenic in private drinking water wells across North Carolina identified over 1,400 wells with arsenic levels above the EPA standard (Sanders, et al., 2012). The top ten counties with arsenic in private drinking water wells are Stanly, Union, Anson, Montgomery, Dare, Randolph, Davidson, Alexander, Cleveland, and Currituck (Sanders, et al., 2012).

## Background: Mobile Home Parks and Schools

### Mobile Home Parks

*Mobile Home Parks across the United States*

Mobile homes represent a significant portion (about 6.4 percent) of the housing stock in the United States (Geoghegan, 2013). There are approximately 40,000 mobile home parks distributed across the United States, with South Carolina, New Mexico, West Virginia, Mississippi, Alabama, and North Carolina representing the six states with the highest number of mobile homes (Bear, 2018; Geoghegan, 2013). About twenty-two million people live in mobile homes throughout the United States, which is roughly 7 percent of the U.S. population (Dhesi, n.d.). About 12 million people live in mobile home parks (Rivlin, 2014).

[5] Map Source: NC Geological Survey and NC Division of Water Resources. First Presented at 2014 Southeastern Section of the Geological Society of America. https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/geologic-hazards/radon-arsenic

*Mobile Homes: Housing versus Property*

Mobile homes make up an important part of affordable housing in the United States. A comparison of housing prices shows that a new mobile home could cost as low as $45,000 while the median price of a single-family home costs over $300,000 (Dhesi, n.d.). Nationally, the median household income for families in mobile homes is $30,000 per year (Whoriskey, 2019). However, the designation of a mobile home unit as personal property or "chattel" instead of a home represents a significant financial barrier to mobile home owners. In a UCLA Law Review article, Soham Dhesi describes this barrier and writes, "In 2015, as many as 80 percent of new mobile homes were titled as personal property rather than real estate. Therefore, prospective mobile home owners use chattel loans instead of regular home loan mortgages. These loans are generally associated with high rates and shorter terms compared to traditional mortgages" (Dhesi, n.d.). Like automobiles and other vehicles, mobile homes treated as personal property depreciate in value over time (Cantrell, Nahmens, Peavey, Bryant, & Stair, 2012). A mobile home's designation as personal property greatly limits financing options for purchases or repairs (Dabson, 2018).

*Mobile Home Ownership*

Another important distinction between mobile homes and traditional single-family housing is that the ownership is divided between the mobile unit owner and the park. Typically, the resident owns the mobile unit or has a rent-to-own contract and rents the space and associated park infrastructure from the park owner (Becker & Rickert, 2018). There is also significant variation in the size and management characteristics of mobile home parks; the ownership of the park by a corporation or by a mom-and-pop business tends to be the differentiating factor (Becker & Rickert, 2018).

Research on this subject has revealed that mom-and-pop style ownership makes the owners, "more likely to be active, fair caretakers" (Kirk, 2017). Research and journal articles on mobile home park ownership have highlighted the tendency of corporate owners to increase the park rent (Kirk, 2017). A New York Times article covering a seminar on mobile home ownership states that seminar participants, "learned early in the course that one of the best things about investing in trailer parks is that ambitious landlords can raise the rent year after year without losing tenants" (Rivlin, 2014). However, the same article includes an example of investors improving park safety and facilities through investment (Rivlin, 2014). Restrictive zoning has led to a constraint on mobile home parks and in turn it constrains affordable housing; consequently, park owners are able to raise rents without losing residents (Whitford, 2018). A recent Washington Post article reveals that one company investing in mobile home parks has "produced tens of millions for investors…a return on investment of more than 30% between late 2016 and the end of 2017"; the article finds that such returns were at least partly due to increases in rental rates (Whoriskey, 2019).

*Mobile Homes in North Carolina*

In North Carolina, mobile homes represent between 13 and 14 percent of housing units across the state (Owens, 2014; Dabson, 2018). According to data collected by Brian Dabson, a Research Fellow with the UNC School of Government, mobile homes represent 30% or greater of the total county housing stock in 13 of North Carolina's 100 counties.[6] In total, there are

[6] This data was provided by Brian Dabson, a Research Fellow with the UNC School of Government.

approximately 479,000 mobile units in North Carolina (Dabson, 2018). In a paper analyzing mobile home park rents in North Carolina, Charles Becker and Timothy Rickert state that about half of North Carolina mobile homes are located within parks (Becker & Rickert, 2018). According to this figure, the authors estimate that "roughly 800,000" North Carolina residents live in mobile home parks (Becker & Rickert, 2018). This estimate would imply that about 8 percent of the population in North Carolina reside in mobile home parks. Although there are scarce data on park ownership characteristics in the state, Becker and Rickert state that "in North Carolina one commonly encounters tiny parks with fewer than a dozen units" (Becker & Rickert, 2018).

In their analysis of mobile home park rents in North Carolina, Becker and Rickert posit that the low cost of living associated with mobile home parks in the state is due to the "limited access to credit by lower middle-class" residents "who have few assets" (Becker & Rickert, 2018). Becker and Rickert explain that the credit-constraint within this sector of the population means that housing demand decreases; therefore, park owners and mobile home manufacturers must lower rent and unit prices (Becker & Rickert, 2018). The authors state that, "the greatest proportionate losses may be to the many Americans who cannot raise capital to buy a used manufactured home, and hence who have to pay inflated rents" (Becker & Rickert, 2018).

**Schools**

Decision makers, researchers, and NGOs at the national, state, and local levels have been studying the issues around drinking water quality standards in schools for decades (Association American Public Health, 2017). Many consider this topic to be of utmost importance because of children's well known biological and behavioral vulnerabilities to environmental contaminants (Association American Public Health, 2017). When compared with adults, children breathe more air per pound of body weight, consume more food and water per pound, and have more time to develop chronic illnesses, such as cancer and neurodegenerative diseases (Association American Public Health, 2017). The environmental hazards students are most commonly exposed to in schools include copper, lead, volatile organic compounds, coliforms, and mold. According to experts, childhood diseases caused by environmental hazards at schools carry a heavy burden on society, costing approximately $76 billion (Association American Public Health, 2017).

Recent figures from across the country illustrate the substandard conditions that challenge schools across the country. The EPA predicts 45 percent of public schools lacked proper ventilation, and many others graded poorly in other environmental categories including sanitation, lighting, chemical management, and pesticide application (Association American Public Health, 2017). In a 2017 report on infrastructure, the American Society of Civil Engineers gave public schools a "D+" (American Society of Civil Engineers, 2017). The report highlights the underinvestment amidst increasing federal standards and regulations (American Society of Civil Engineers, 2017). The report states that, "state and local governments face a constant challenge to keep up with operations and maintenance and the need for new construction, in addition to accommodating improved health and safety standards, stronger accessibility requirements, and new technology infrastructure as they seek to fund, plan, construct, and maintain quality school facilities (American Society of Civil Engineers, 2017)." Overall surveillance and testing for environmental hazards at schools has deteriorated as well, as

inspection of drinking water outlets has decreased over time (American Society of Civil Engineers, 2017). This figure becomes more significant when given considering the fact most schools continue to operate without testing their water (Association American Public Health, 2017).

Our literature review found scarce research on the safety and capacity of North Carolina school drinking water systems. In addition, there is limited public school data available beyond the county level that would inform research about the finances, facilities, and general operations of North Carolina school drinking water systems. Therefore, it is difficult to infer the status of school drinking water systems beyond sanitary survey data and SDWA violations statistics.

Our research finds that most schools in North Carolina source their drinking water from governmental entities. Data collected from SDWIS indicates that approximately 6 percent of schools (about 160) in North Carolina operate, maintain, and own their public drinking water systems. We found 6 percent by dividing the number of schools in our dataset by the total number of schools in North Carolina according to 2017 state public figures. Even though systems that source water from governmental entities are still at risk of many of the environmental hazards discussed above, they do not carry the type of liability inherent in running operational, managerial, and financial decisions associated with operating a water system. Finally, SDWIS historical figures demonstrate smaller systems, such as schools, tend to be in noncompliance more often than larger systems (North Carolina Department of Environmental Quality, 2018).

The national narrative around drinking water in schools has focused on lead, and rightfully so. Lead, a neurotoxin that can impair cognitive development, is potentially affecting thousands of infants and children across the country (Hui, 2019). In relation to this topic, North Carolina was recently ranked among the worst states in the US by an advocacy group that claimed North Carolina's overall handling of lead in schools was inadequate (Hui, 2019). A study on lead exposures in North Carolina schools published in the North Carolina Medical Journal in 2018 highlighted the importance of paying special attention to smaller, less regulated school systems, "A more comprehensive study that also includes schools relying on unregulated water sources (such as private wells) and an expanded study area would better elucidate the water quality differences between public and unregulated water supplies" (Redmon, 2018). Even though schools categorized as public water systems are technically not unregulated (U.S. Environmental Protection Agency, n.d.), the independent water systems ran by schools discussed in our study share many similar characteristics to private unregulated systems.

## Methodology

### *Our Approach*

To improve understanding about small, non-governmental drinking water systems in North Carolina like mobile home parks and schools, we employed a variety of datasets that help to illuminate the technical, managerial, and financial (TMF) capacity of these systems. With assistance from NC Department of Environmental Quality officials, we collected sanitary survey records for all mobile home parks and schools. Sanitary surveys include data on the system age,

the system facilities, the number of connections, the service population, metering practices, and other technical aspects of the systems.

Using the U.S. EPA Safe Drinking Water Information System (SDWIS), we collected violations data on all North Carolina community and non-transient, non-community water systems with at least one health or reporting violation in the past five years. Violations data informs our understanding about the technical and managerial capacity of small drinking water systems in North Carolina.

We conducted spatial analysis using geographic coordinates of each mobile home park which we collected from sanitary surveys, and by collecting U.S. Census data on the block groups in which systems from our dataset are located. Because schools in our dataset are primarily public county schools and data would be limited to the county-level, we did not conduct a similar spatial analysis.

To inform our understanding about the population and community characteristics of schools, we collected data on economically disadvantaged students from the free and reduced meals applications provided by The NC Department of Public Instruction.

To learn about the financial and management capacity of mobile home parks, we conducted a survey of the owners of mobile home parks. Questions in the survey pertained to park characteristics, metering and billing, perspective on risks, perceived management challenges, and equipment and repair costs.

*Sanitary Survey Data Collection*

In North Carolina, sanitary surveys are completed by regional Public Water Supply staff through site visits to drinking water systems. Data is then uploaded into a central database. With assistance from North Carolina Public Water Supply staff, we queried this database to collect sanitary survey data using the "Service Area Code" to filter for mobile home parks and schools.[7] The Sanitary Survey dataset includes 528 systems, which includes 383 mobile home parks and 145 schools. The dataset contained over 30 different datapoints for each system and it contained individual rows for each facility within a system. We aggregated this data to capture all the datapoints in a single row for each system.

We did not include every mobile home park from the sanitary surveys in our primary dataset because it included systems that were directly connected to a local government and systems that are owned by water corporations like Aqua America. However, we did conduct preliminary analysis comparing our dataset with mobile home parks whose drinking water systems are owned by water corporations.

*Geospatial analysis*

Geospatial analysis was used to study the demographic characteristics of block groups containing mobile home parks from our dataset, and also to analyze the surrounding areas of mobile home parks and schools to determine if they were located in rural, suburban, or urban areas.

[7] Data collected by North Carolina Department of Environmental Quality Public Water Supply.

Locations of mobile home parks were collected through North Carolina Sanitary Survey data. 2010 TIGER/LINE Shapefiles were downloaded from the Census Bureau website to map out block groups and counties in North Carolina. Population density of communities containing these mobile home parks and schools and those communities without them were analyzed to learn community environmental features. Additionally, Land Use Land Cover (LULC), was collected from United States Geographical Survey (USGS) website to analyze the surrounding environment of mobile home parks and schools using those small water systems.

Demographic characteristics were analyzed on block group level. Block groups are next level above census blocks which are the smallest unit. Criteria for block groups in 2010 decennial survey are that population ranges from 600 to 3,000 and housing units counts range from 240 to 1,200. We used spatial imagery to confirm that block groups were the most appropriate scale to capture the most granular data possible; census tract-level data showed that many mobile home parks crossed tract boundaries. In addition, most socioeconomic information is only available at block group level as this is the most detailed study census level in American Community Survey (ACS). In this study, 2012-2016 demographic data was downloaded from Tiger/Line with Selected Demographic and Economic Data on the Census Bureau website to study race, age, and median household income. Demographic and Economic Data metadata was available on the website for reference. Demographic characteristics of target mobile home parks may resemble those of communities these parks are in.

Major Geographic Information System (GIS) software used was ArcGIS Pro and MS Excel was used for partial data processing and data analysis. Mobile home park locations, block group boundaries, and county borders were mapped out in ArcGIS Pro first. Counties were divided into three regions, Coastal Plains, Piedmont, and Mountains, based on topography. Next, block groups containing mobile home parks were selected. To study surrounding environment of mobile home parks, 10-mile buffer was created, percentage of each LULC cover was calculated, and outcome was summarized into 5 categories, open water, developed area, forest, agriculture, and other, in MS Excel. Similar method was used to approach surrounding environment of target schools, but 6-mile buffer was generated which is the average commuting distance from home to school. To study demographic characteristics, selected and pre-processed demographic information table was joined to the attribute table of block groups containing mobile home parks. Then, maps regarding different demographic characteristics were created and relevant data was analyzed in MS Excel. (U.S. Census Bureau, n.d.)

*SDWIS Drinking Water Violations Data Collection*

To gather information on drinking water quality in North Carolina, we constructed a dataset using data from the EPA Safe Drinking Water Information System (SDWIS) that included all water systems in violation (i.e., system failed to meet an EPA-mandated drinking water standard) dating back 5 years from the end of the third quarter of 2018. Our final list of systems excluded transient systems, such as gas stations or camp grounds, because these public drinking water systems do not provide water to the same population year-round and are considered a different entity type subject to other sets of regulations, issues, and constraints. Therefore, the final dataset consisted of community water systems (CWS) and non-transient non-

community water systems (NTNC) only. In total, we drew from a list of 1,158 water systems that combined for a total number of 11,360 violations over the period of study.

*School Community Characteristics*

The NC Department of Instruction provides school financial data at the county level, which is not sufficient to adequately assess the financial capacity of individual schools that have drinking water systems. Similarly, our use of U.S. census data to look at the communities in which schools are located would be limited to the county level, because schools have varying jurisdictions that could extend well beyond the block group geographic size. For these reasons, we chose to collect data on Free and Reduced Meals Applications for public schools in North Carolina.[8] This data is used by the state to assess the number of economically disadvantaged students (EDS) served by each school. This estimate is based on the number of applications and the number of students with free and reduced meals at each school. We believed that EDS could provide at least some level of granular insight about the student population and the community characteristics of schools in our dataset.

The dataset provides a 5% range estimate (for example, "Between 40% and 45%") for EDS. We took the lower bound estimate for each school and then separated out the public schools in our dataset. Because most public schools in our dataset are elementary schools, we compared the lower bound EDS statistic for all public elementary schools in our dataset against all public elementary schools in North Carolina.

*Mobile Home Park Owner Survey*

Over a three-week period in late January and early February, we conducted a phone and online-based survey to gather information from the owners of mobile home parks with drinking water systems. The purpose of the survey was to gather direct insight from mobile home park owners about their drinking water systems in order to learn about the operation and potential risks associated with these systems.

Of the 339 mobile home parks in our study, we contacted approximately 230 owners or administrators representing individual systems in the MHP owner survey. We used the North Carolina Public Water Supply Drinking Water Watch website to identify owners and collect contact information.[9] Approximately 86 systems were not listed on the NC Drinking Water Watch website or did not have phone numbers listed.

If a respondent represented more than one system, the respondent was asked to complete the survey and consider only one system they own or operate. The survey featured twenty questions concerning water rates, billing, equipment repairs and purchases, and owner perspective on drinking water risks. Of the 230 individual mobile home park owners or administrators included on our call list, we collected responses from 50 participants which represents a response rate around 22 percent.

[8] Dataset collected from the North Carolina Department of Public Instruction Financial and Business Services division, http://www.dpi.state.nc.us/fbs/resources/data/

[9] NC Public Water Supply Drinking Water Watch, https://www.pwss.enr.state.nc.us/NCDWW2/

The survey featured twenty questions and covered topics such as drinking water fees and billing, equipment and repair costs, financial practices, owner perception of system risks, and the future operation of the system. The questions are listed in Appendix Section D.

## Data Analysis

*Violations*

I. Implications of size

Even though large water systems (service population > 3,300 people) provide water for nearly 91% of the total service population of North Carolina (this figure does not consider private, unregulated sources and transient systems), small water systems represent 87 percent of the total amount of water systems in North Carolina. These 2,065 small systems serve an average population of 381 people (U.S. Environmental Protection Agency, n.d.). Research drawing from national studies on drinking water systems strongly suggests (U.S. Environmental Protection Agency, 2016) that small systems are more likely to violate SDWA regulations. Thus, we first focused on determining whether discrepancies between large and small water systems in North Carolina were observable through SDWIS violations data, and secondly, we compared how schools and MHPs performed, quantitatively, versus large and small water systems in terms of violation rates (i.e., violations/system, health-based violations frequency, etc.). We believed schools and MHPs provided an ideal research target because of their size (composed entirely of small systems), their reliance on groundwater, and a notion that some, or many of these systems may be currently in distress.

We identified approximately 498 systems – a subset composed of small systems entirely – that we believe represented the full amount of schools and MHPs with independent drinking water systems. To determine how this subgroup performed, we first calculated the number of systems within the subgroup that showed up in the SDWIS report (308 systems out of a possible 498) and then compared it against (1) the entire population of violating systems; and (2) all small water violating systems – large system comparisons (large system service population > 3,300 people) were also provided for reference purposes.

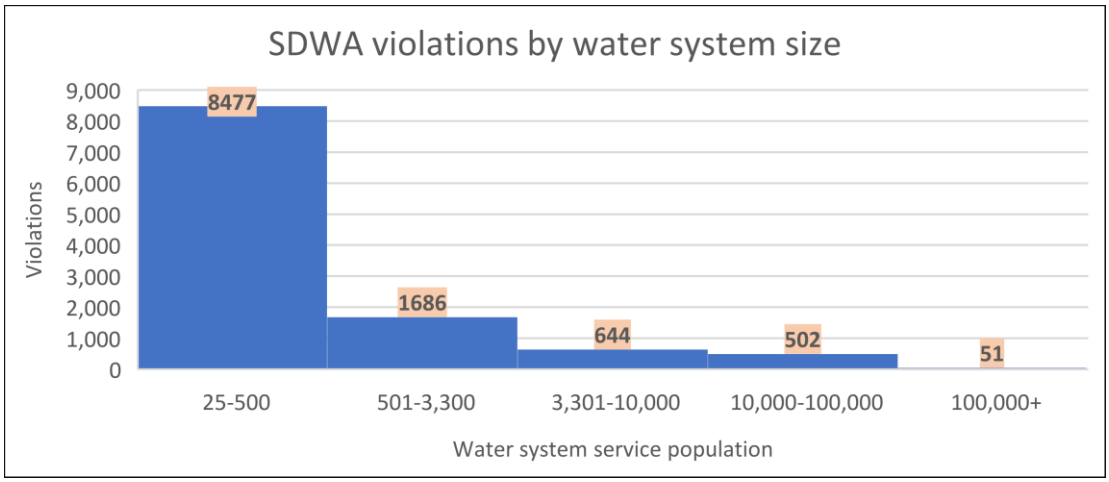
Our findings confirmed that population size is associated with SDWA compliance. In terms of sheer number of violations, small systems accounted for 8.5 times more violations than large systems. On average, small water systems had much higher noncompliance incidence rates, results showing a 62 percent higher average violation rate per system when compared to larger systems (Table 6). SDWIS violations data showed that nearly 90 percent of all violations are attributed to small systems (Figure 3 & Appendix I Table 1), with a heavy percentage of those violations originating from the smallest group of systems (service population ≤ 500 people). It is worth noting our analysis included systems with violations dating back five years, this limited our study to a total count of 1,153 systems (NC has a total of 2,347 active systems[10]).

[10] Our study includes community and non-transient noncommunity active water systems only. Transient systems are excluded because they are subject to different sets drinking water standards in North Carolina.

**Table 1:** Drinking water violations in North Carolina, with a comparison between systems in our dataset (schools and mobile home parks,"MHPs") and all small systems in the state. When looking at a count of violations per system, the number systems (308 out of our total 498) are limited to those that had at least one drinking water violation over the past five years (from 2013 – 2018). When we compare the number of systems with at least one violation over five years, we include the full 498 school and MHP drinking water systems.

| Drinking water violations in North Carolina | | | | |
|---|---|---|---|---|
| | **SMALL SYSTEMS (< 3,300 people served)** | **SUBGROUP (Schools +MHPs)** | **SCHOOLS** | **MHPs** |
| Percent of systems out of total DW system count | 41% | 13% | 7% | 14% |
| Total Violations Committed | 10,145 | 4,348 | 635 | 3713 |
| System Count | 967 | 308 | 82 | 226 |
| Violations/system | 10.49 | 14.12 | 7.74 | 16.43 |
| Total Population | 1,051,274 | 89,543 | 50,580 | 38,963 |
| Percent of systems on groundwater | 81% | 99% | 99% | 98% |
| Number of health violations out of total violations | 8% | 3% | 6% | 3% |
| Percent of systems with >1 violation over 5 years | 47% | -- | 55% | 57% |

**Figure 2:** Violations by system size.

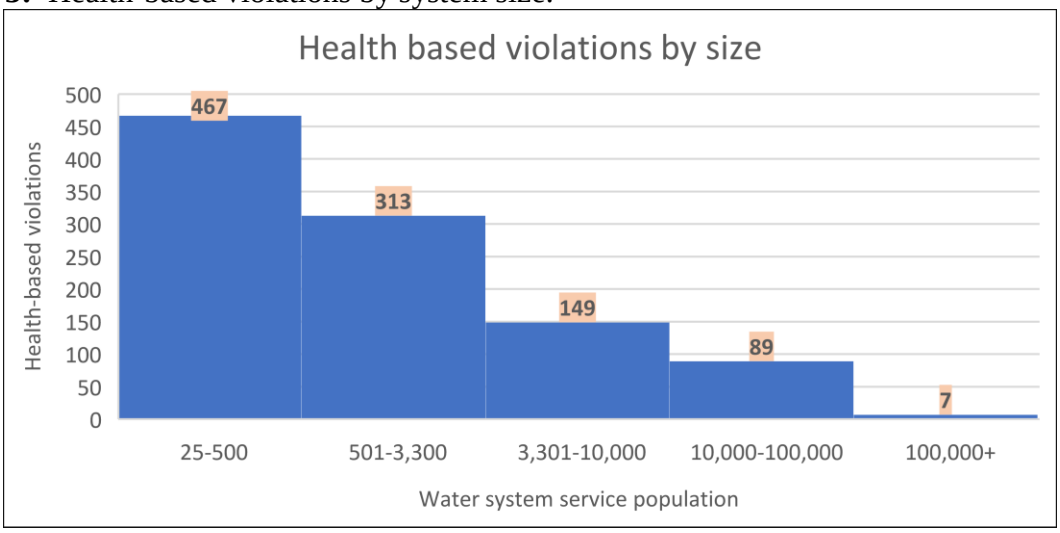



Finally, it is important to separate discussion of violations between health-based and non-health-based (monitoring and reporting) violations. Health-based violations occur due to a failure in operation or treatment by the water system that pose public health risks from contamination or hazardous treatment. SDWIS data demonstrated that small systems commit more health-based violations than large systems. Over the past 5 years, small systems in North Carolina committed 3.2 times more health-based violations than large systems (Figure 4). However, given the disproportionate amount of small water systems and their high violations count, we found system

violation percentages (violating systems/total amount of systems) to be a more appropriate metric to measure noncompliance (Appendix Section A).

With respect to health-based violations, two of the most prevalent health-based violations by contaminant rule were disinfection byproducts and radionuclides. Small systems accounted for 65 percent and 100 percent of these violations, respectively.

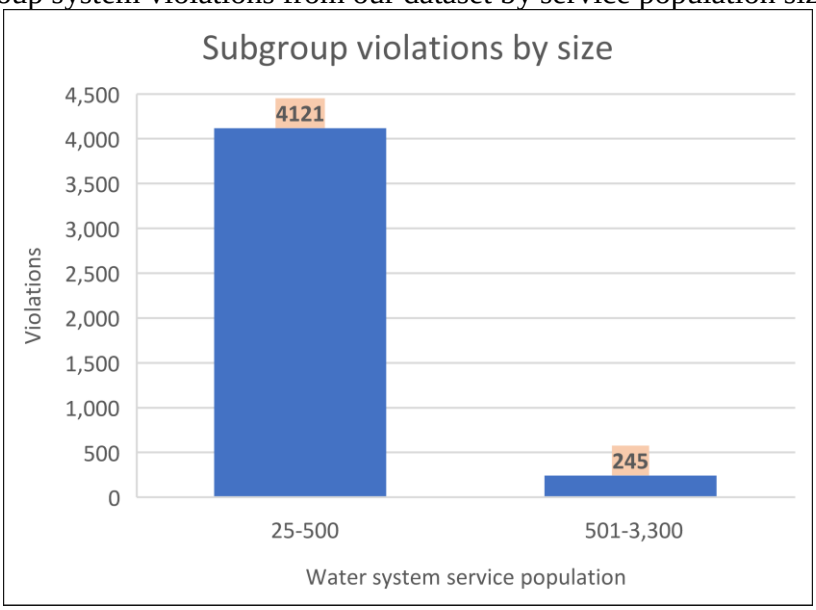
**Figure 3:** Health-based violations by system size.




II. Subgroup results & potential implications

The SDWIS dataset also revealed a high level of noncompliance originating from our subgroup of schools and MHPs. Our subgroup, comprised on 308 systems, committed a total of 4,348 violations – this figure includes regular and health-based violations (Table 1). Data showed that 38 percent of the total violations committed during the studied time frame originated from this specific subgroup. A histogram of water system size (Figure 4) illustrated the disparity that exists within the subgroup itself, where the smallest system category (25 – 500 service population size) was responsible for 92 percent of the violations (283 out of 308 possible systems). This translated into a violation per system average of nearly 14.5, the highest out of any water system category size in North Carolina.

**Figure 4:** Subgroup system violations from our dataset by service population size.




On average, our subgroup had higher violations and major violations (major violations are recorded by state inspectors but carry a high degree of subjectivity, therefore they are not considered as reliable a statistic as health-based violations) rates than small systems. Excluding monitoring and reporting violations, coliform, lead and copper, DBPs, and radionuclides were the most common rule type violations committed by schools and MHPs. Looking more closely at these rule type violations, we found our subgroup represented 49 percent and 60 percent of the total count of violations in North Carolina for coliform and radionuclides, respectively.

With respect to health-based infractions, our subgroup committed 14 percent of all health-based violations during the studied timeframe. Schools and MHPs had lower health-based violations/system and percentage health-based violations (health-based violations/total violations) than small systems, but this can be attributed to high amount of small systems in North Carolina (small systems represent 95 percent of all systems in NC). The most prevalent rule type violations were associated to coliform, lead and copper, DPBs, and radionuclides. Even though health-based violations within our subgroup did not appear to deviate substantially from small system averages, the types of contaminants and possible remediation strategies associated to these violations carry important considerations.

According to the North Carolina Division of Water Resources, the highest amount of maximum contaminant level (MCL) violations (MCL violations represent 90 percent of all health-based violations in NC, highest percentage of any type of health-based violation) issued in 2017 were attributed to the disinfection byproduct rule and radionuclide exceedances (North Carolina Department of Environmental Quality, 2018). These two health-based violations rule types are prevalent within our subset of systems.

In order to eliminate health-threatening microbial pathogens, disinfection products, such as chlorine, are added to drinking water. Chlorination is a necessary component of the overall water treatment process. However, in the chemical process of chlorination, disinfection products

often mix with compounds in the water to form harmful disinfection byproducts (DBPs) (Environmental Protection Agency, 2018). Haloacetic acids (HAA5) and Total Trihalomethanes (TTHMs) – two of the most common DBP contaminants in water – are linked to increased risk of cancer and to liver, kidney and central nervous system failures (Environmental Protection Agency, 2018). DBP related violations represented almost a third of health-based violations in our subgroup.

Radionuclides, such as uranium and radium, are anthropogenic and geogenic occurring elements that can be found in groundwater (Environmental Protection Agency, 2018). Unlike DBPs, trace amounts of radionuclides in drinking water are directly linked to cancer and other chronic illnesses (Environmental Protection Agency, 2018). EPA's rule on radionuclides states the purpose of regulating these radioactive elements is to, "reduce the risk of cancer" (Environmental Protection Agency, 2018). EPA requires all community water systems, regardless of size, to test for these toxic elements. (North Carolina Department of Environmental Quality, 2018). However, non-transient non-community systems, such as schools, are not subject to radionuclide testing. Therefore, we consider that the statistic for total radionuclide exceedances in our subgroup is heavily understated given the number of school systems that form part of our study. The dataset revealed that 60 percent of all radionuclide violations originated from our subgroup, but none from NTNC systems.

*Sanitary Survey*

Data from the sanitary survey dataset provides further insight on the TMF capacity of mobile home parks and schools. Our sanitary survey dataset is limited to mobile home parks and schools in North Carolina; for this reason, we are unable to compare across other drinking water systems in the state.

Approximately 39,000 people are served by all mobile home parks in our system (Table 1). On average, mobile home parks serve 116 people per park; however, the service population data are highly skewed across parks in our dataset (Figure 2). The median service population for mobile home parks in our dataset is 86 people (Table 1).

**Table 1:** Population characteristics of MHPs from our dataset.

| Population served | |
|---|---|
| Total number of people served | 38,963 |
| Mean population served per MHP | 115.6 |
| Median population served per MHP | 86 |
| Max population served per MHP | 688 |
| Min population served per MHP | 9 |
| Standard deviation | 105.04 |
| | |
| Blank | 2 |
| Total | 337 |

**Figure 2:** Distribution of service population across MHPs.

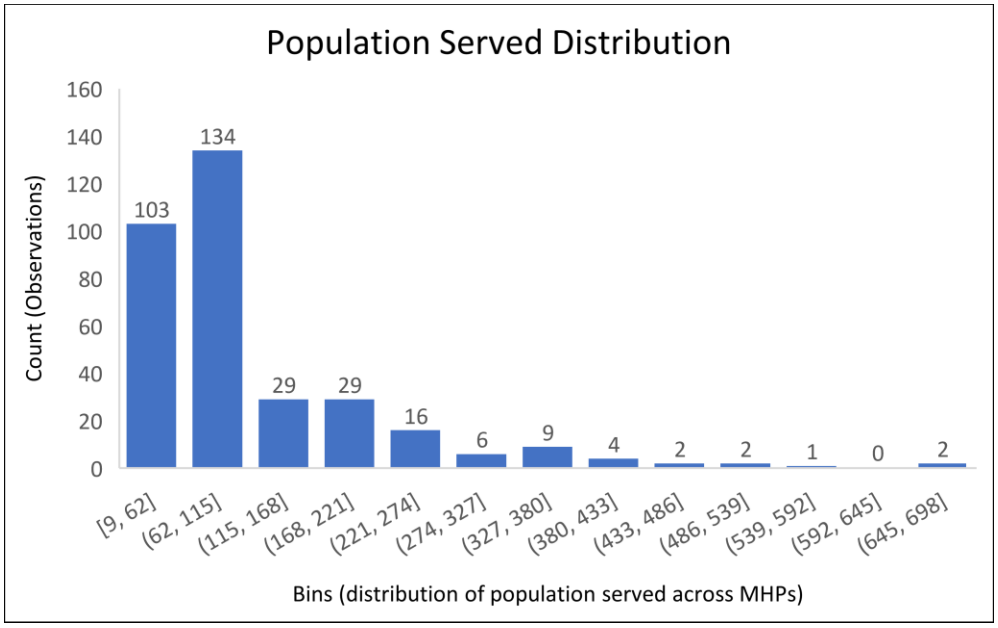



**Figure 3**: A box and whisker chart of the service populations in MHPs shows a number of outliers that exceed the upper bound of the range.

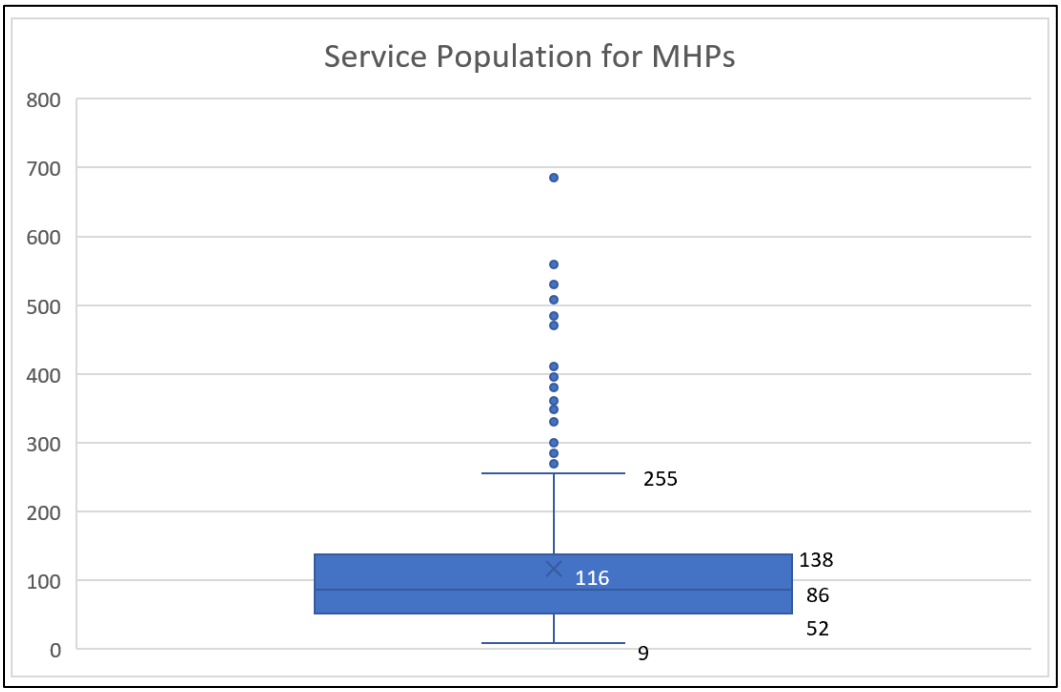
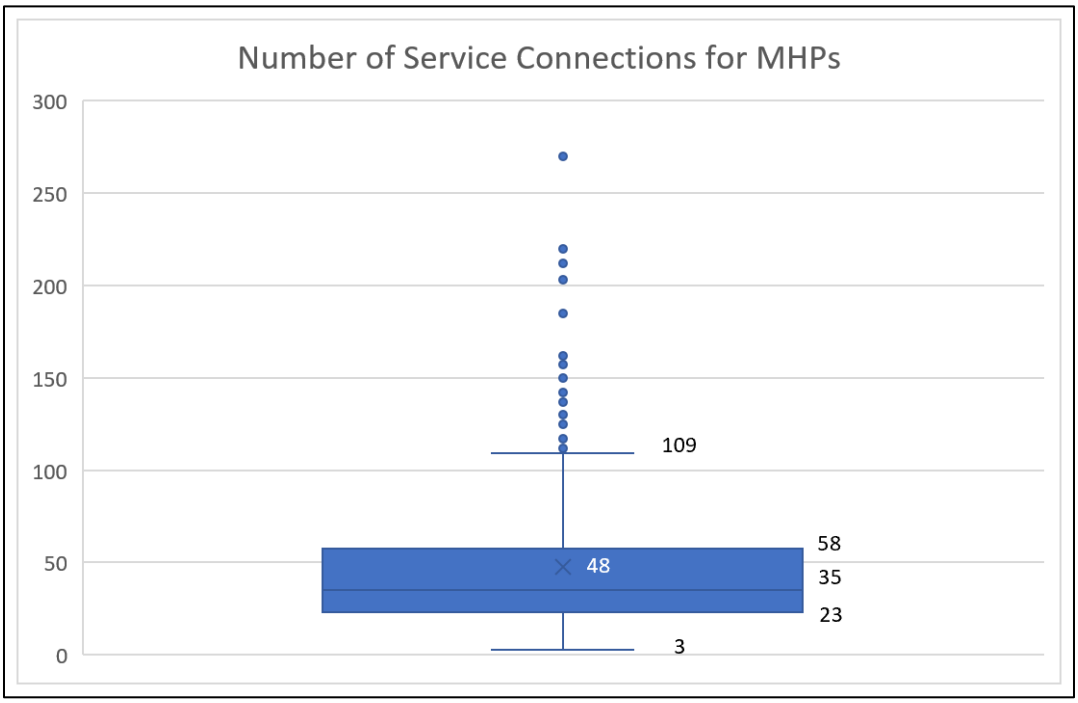


**Figure 4**: A box and whisker chart of the numbers of service connections in MHPs shows a number of outliers that exceed the upper bound of the range.




The sanitary survey dataset includes facility activity status dates for each facility within a drinking water system. We found the number of service connections are positively skewed with an average of 48 (Figure 4). The minimum number of connections is 3, and the interquartile range is between 23 and 58. We also determined the age of a facility based on this status date, and then took the average age of facilities for each system. On average, facilities in mobile home parks are 34 years old (Table 5). The interquartile range is from 29 years and 41 years (Figure 6). The highest average age of facilities in the dataset is 53 years (Table 5).

**Table 5:** Summary statistics on mobile home park facilities

| MHP Drinking Water System Summary Statistics | |
|---|---|
| Mean average age of facilities | 33.88 |
| Median average age of facilities | 35.33 |
| Max average age of facilities | 53 |
| Min average age of facilities | 1 |
| Standard deviation | 9.3 |
| | |
| Blank | 14 |
| Total | 325 |

The sanitary survey includes permitting status information for each drinking water system. Of 368 MHPs with this status, 54 percent are approved systems and 39 percent are not approved (Table 7). If a system has not been approved at the time of permitting, it may be grandfathered. Of 339 systems with a "grandfathered" status, 26 percent are grandfathered (Table 7). This portion may represent some systems that were not approved.

**Figure 6**: A box and whisker chart of average facility age for each MHP. Two outliers are shown below the lower bound.

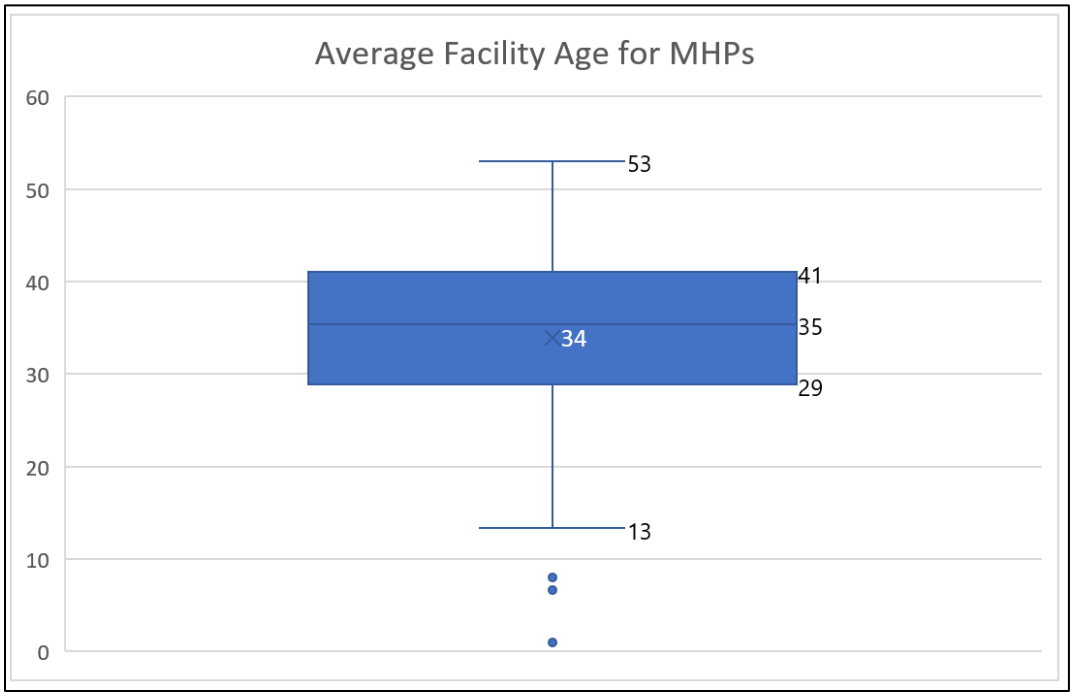



**Table 7:** Approved and Grandfathered system counts. An approved system has submitted the necessary engineering plans, design specifications, and reports, which were approved, according to the rules in effect at the time. A grandfathered system is a system that was established prior to the rules requiring approval of engineering plans, specifications, and reports before construction.

| Approved and Grandfathered MHP Systems | | |
|---|---|---|
| *Approved System?* | | |
| Approved | 183 | 54% of 339 |
| Not Approved | 133 | |
| | | |
| Blank | 23 | |
| Total Count (minus blank) | 368 | 93% of 339 |
| | | |
| *Grandfathered System?* | | |
| Grandfathered | 89 | 26% of 339 |
| Not Grandfathered | 151 | 45% of 339 |
| | | |
| Blank | 99 | 29% of 339 |
| Total Count (minus blank) | 240 | 71% of 339 |

**Table 8:** Population characteristics of schools from our dataset.

| Population served | |
|---|---|
| Total number of people served | 50,579 |
| Mean population served per School | 395.5 |
| Median population served per School | 318 |
| Max population served per School | 2,427 |
| Min population served per School | 34 |
| Standard deviation | 364.5 |
| | |
| Blank | 27 |
| Total | 132 |

Our school water systems serve the population of approximate 50,579 in total. The mean service population per school is 395.5 in average, but the highly positively skewed distribution could overestimate the population due to some outliers (Figure 9). Excluding the outliers, the service population per school is ranged from 34 to 905 with a median service population of 318.

**Figure 9**: Distribution of service population across school water systems.

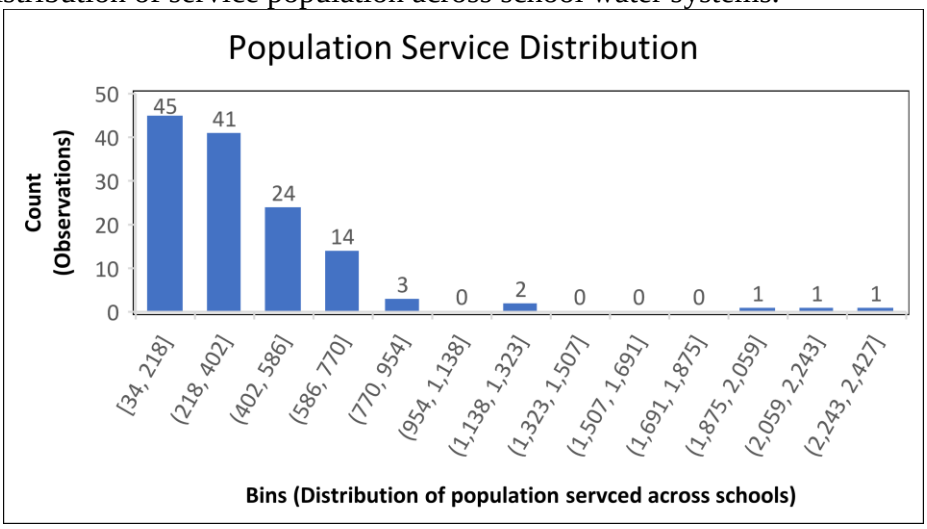
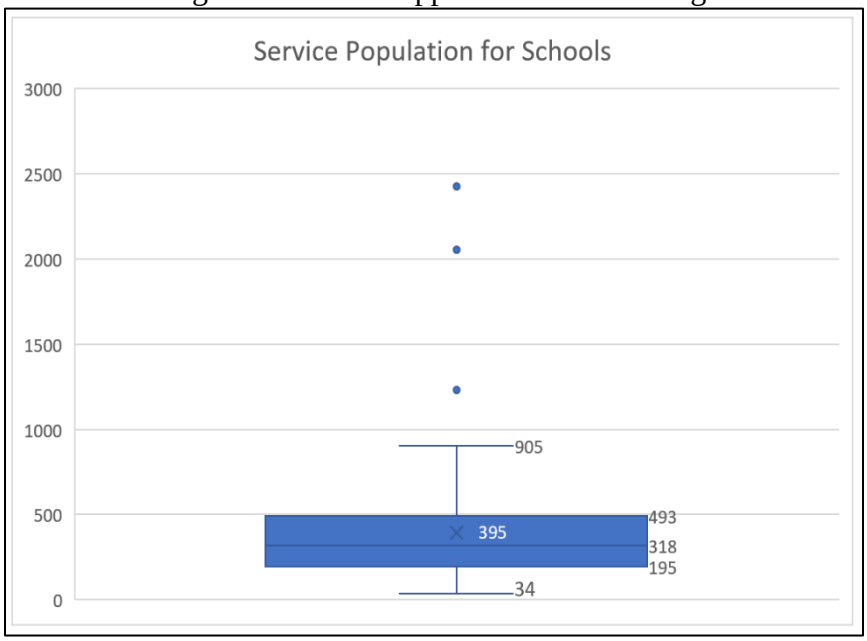


**Figure 10:** A box and whisker chart of the service populations for school water systems. There are three outliers that are greater than the upper bound of the range.




Regarding the facility status, the average age of all facilities in each school water system is 28.4 years with a standard deviation of 12 years. The range of the average age is from 1 to nearly 50 years with a median average age of 31 (Figure 12). The interquartile range of the average age is from 18 to 41 years (Figure 12). No outliers are found in the average age data.

**Table 11:** Summary statistics on school facilities.

| School Drinking Water System Summary Statistics | |
|---|---|
| Mean average age of facilities | 28.4 |
| Median average age of facilities | 31 |
| Max average age of facilities | 49.7 |
| Min average age of facilities | 1 |
| Standard deviation | 11.9 |
| | |
| Blank | 17 |
| Total | 142 |

**Figure 12:** A box and whisker chart of the average facility age for each school water system.

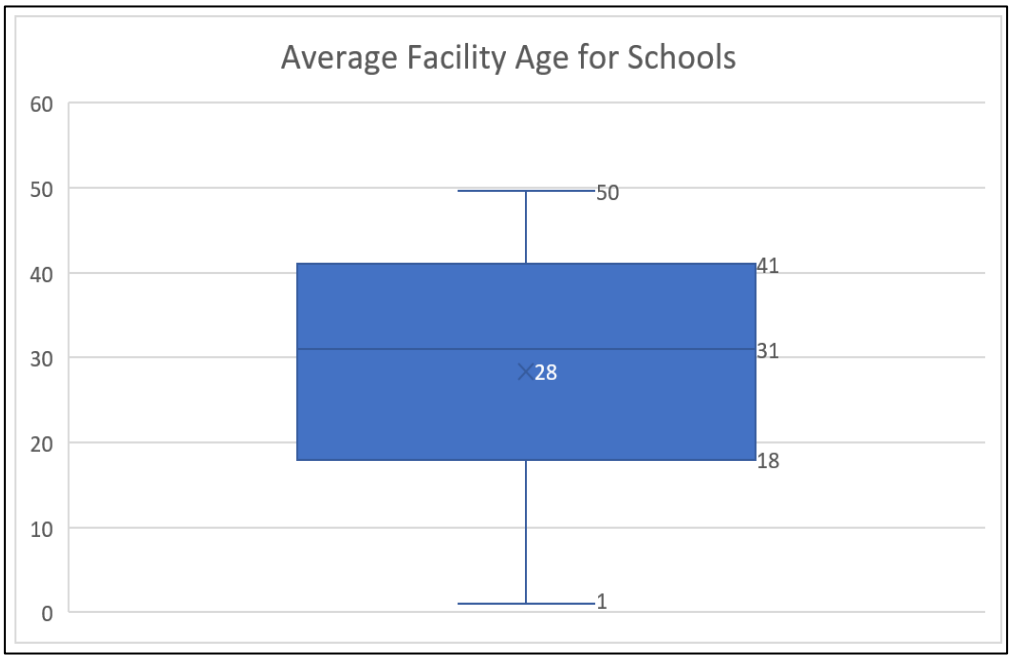



**Table 13:** Approved and Grandfathered system counts. Among 159 school water systems, 78 systems (49%) are approved, and 43 systems (27%) are not approved. There are 37 systems (23%) labeled as "grandfathered" and 57 systems (36%) labeled as "not grandfathered".

| Approved and Grandfathered School Systems | | |
|---|---|---|
| *Approved System?* | | |
| Approved | 78 | 49% of 159 |
| Not Approved | 43 | 27% of 159 |
| | | |
| Blank | 38 | 24% of 159 |
| Total Count (minus blank) | 121 | 76% of 159 |
| | | |
| *Grandfathered System?* | | |
| Grandfathered | 37 | 23% of 159 |
| Not Grandfathered | 57 | 36% of 159 |
| | | |
| Blank | 65 | 41% of 159 |
| Total Count (minus blank) | 94 | 59% of 159 |

*School Community Characteristics*

Our EDS dataset includes 86 of the 1270 public elementary schools in North Carolina. We found a mean EDS of 62.09 percent for elementary schools in our dataset, and a mean EDS of 62.57 percent for all NC Public elementary schools (Table 14). The distribution of EDS across schools is strongly negatively skewed (Appendix Section C Figure 1). A more robust comparison using the median shows that the median EDS for our dataset is 60 percent and the median EDS for all NC public elementary schools is 65 percent (Table 11). Because the sample and population are very skewed, we cannot infer using a means test comparison. Comparing the median EDS statistic between our dataset and all NC public elementary schools provides some evidence that schools in our dataset have a smaller portion of economically disadvantaged students in the school student body.

**Table 14:** Comparison of economically disadvantaged students (EDS) statistics between all NC public elementary schools and public elementary schools with their own drinking water system.

| **North Carolina Public Elementary Schools** | | **Elementary Schools in our dataset** | |
|---|---|---|---|
| | | | |
| Number of Schools | 1270 | Number of Schools | 86 |
| Mean EDS (lower bound) | 62.57% EDS | Mean EDS (lower bound) | 62.09% |
| Median EDS (lower bound) | 65% EDS | Median EDS (lower bound) | 60% |
| | | | |
| One Sample Means Test, Two-Tailed* | | | |
| Standard Error | | 0.0284 | |
| Z Stat | | -0.16774 | |
| P value | | 0.5675 | |

**The distributions of the population and sample do not meet the required assumption for normal distribution*.

Though EDS can be used to estimate the poverty level of the affected student bodies, it does not directly indicate the financial capacity of the schools in our dataset. For example, national data collected in 2012 shows that about half of public-school children were eligible for free or reduced lunches but the poverty rate of public-school students was 22 percent (Snyder & Musu-Gillette, 2015). This finding shows that the free and reduced lunch statistic is not necessarily a good estimate of poverty and therefore may not be a good estimate for community financial capacity. Nevertheless, the EDS dataset provides evidence that public elementary schools in our dataset (86 schools out of 159 total schools) are not significantly-different from other public elementary schools in the state when it comes to free and reduced meals, which implies the affected students and their families are not necessarily more economically disadvantaged than other public schools.

*MHP Survey*

The survey of Mobile Home Park owners underscored the fact that compared to large systems and utilities, small drinking water systems face inherent challenges in achieving SDWA compliance. While many of the drinking water systems appear to be well run and appear to have enough funding and resources to achieve compliance, owners perceive that the relative cost of achieving compliance is much greater for their systems than it is for larger systems. Owners

expressed that they were mostly able to cover equipment and repair costs through savings or through operational revenue, but some aging facilities might represent a significant cost in the future.

**Q1** How many units (number of mobile homes) do you have in the park? Please write as a number (for example, "25"). If you own multiple parks, please select one and provide your answers according that that park.

| Count | Mean | Median | Max | Min | Standard Deviation |
|---|---|---|---|---|---|
| 25 responses | 59.52 | 36 | 275 | 10 | 57.3 |
| | | | | | |
| 329 | 47.61 | 35 | 271 | 3 | 40.93 |

Question 1 some provides evidence that our sample is representative of mobile home parks with public drinking water systems in North Carolina. We added this question after the survey had already begun; for that reason, our sample size for this question is 25. Figures 19 and 20 show the distribution of Question 1 responses and data from the Sanitary Survey dataset. Both the sample and the population are strongly positively skewed. For this reason, the median is a more robust measure of the number of units within mobile home parks. The median number of units in mobile home parks from our survey is 36, and as a point of comparison, the median number of units in mobile home parks from the Sanitary Survey dataset is 37.

**Figure 19**

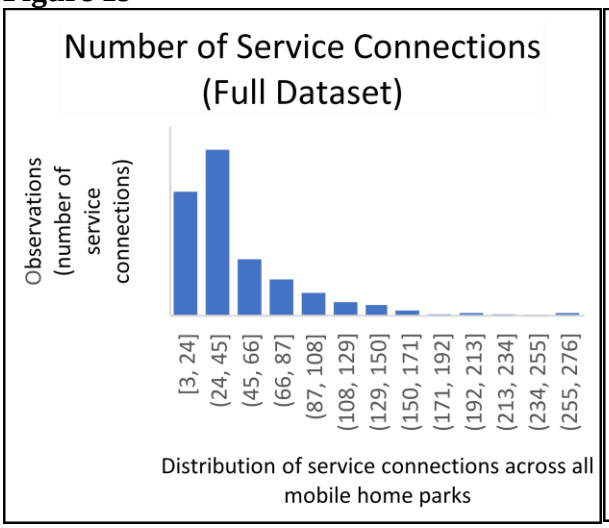
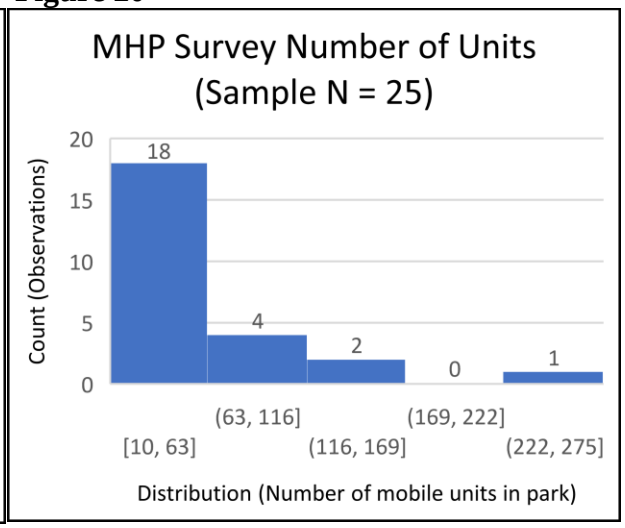



**Figure 20**



**Q2** "Are the units in your park owned or rented by residents?"

| Count | Owned | % | Rented | % | Both | % |
|---|---|---|---|---|---|---|
| 50 | 19 | 38% | 7 | 14% | 24 | 48% |

Question 2 shows that 48 percent of respondents owned parks in which mobile units were owned or a mix of owned and rented by residents. 19 respondents said that units in their park were all owned by residents. Only 14 percent of respondents said that units in their park were solely rented by residents. This question does not inform us about the proportion of owned/rented units in parks that feature both owned and rented units.

**Q3** "Do you monitor water usage for each mobile unit in your park?"

| Count | Yes | % | No | % | I don't know | % | Blank |
|---|---|---|---|---|---|---|---|
| 50 | 6 | 12% | 41 | 82% | 0 | 0% | 3 |

Data from the Sanitary Surveys indicate that approximately 77 percent of mobile home parks are either unmetered or metering information is unknown for these parks. Survey respondents indicated on Question 3 that 41 respondents do not monitor water usage for each mobile unit in the park. Extending from this, 46 respondents stated that they did not directly charge each mobile unit in the park for water. Only four respondents indicated that they billed directly for water, and of these respondents two billed using a flat fee and two billed using a volumetric fee. The fees for these respondents are provided in Appendix Section D Table 1.

**Q10** "Do you keep financial records about your park's drinking water system separate from other park financial records?"

| Count | Yes | % | No | % | I don't know | % | Blank | % |
|---|---|---|---|---|---|---|---|---|
| 50 | 29 | 58% | 21 | 42% | 0 | 0% | 0 | 0% |

Questions concerning the financial capacity of systems provided some evidence that mobile home park owners are not necessarily financially burdened by the drinking water system, at least with respect to general operations and equipment and repairs. Question 10 revealed that 29 respondents indicated that they keep financial records about the park drinking water system separate from other financial records.

**Q11** "Do you have an emergency 'rainy day' fund that can be used toward your park drinking water system in case of an emergency?"

| Count | Yes | % | No | % | I don't know | % | Blank | % |
|---|---|---|---|---|---|---|---|---|
| 50 | 31 | 62% | 18 | 36% | 1 | 2% | 0 | 0% |

**Q12** "If the park drinking water system has ever required significant repairs, how did you cover the cost of repairs?"

| Count | Savings | % | Debt | % | Both | % | Blank | % |
|---|---|---|---|---|---|---|---|---|
| 50 | 36 | 72% | 1 | 2% | 0 | 0% | 13 | 26% |

Question 11 revealed that 31 respondents claimed to have an emergency "rainy day" fund available for drinking water systems, while 18 claimed they did not have such a fund available. On Question 12, 36 respondents stated that if they ever had to pay for repairs for the drinking water system, they used savings[11] to cover their costs.

**Q13:** In the past five years, have you had to purchase or repair the equipment related to the park's drinking water system?

| Count | Yes | % | No | % | I don't know | % | Blank | % |
|---|---|---|---|---|---|---|---|---|
| 50 | 40 | 80% | 10 | 20% | 0 | 0% | 0 | 0% |

**Q14:** Please estimate the total cost of all purchases and repairs for the drinking water system in the last 5 years (in $ dollars).

| Count | Mean | Median | Max | Min | Standard Deviation |
|---|---|---|---|---|---|
| 37 responses | $17,836 | $10,000 | $50,000 | $300 | $17,097 |

Questions 13 and 14 provided some insight on the capital costs associated with mobile home park drinking water systems in North Carolina. On Question 13, 40 respondents stated that they had to make a purchase or make a repair to the park drinking water system in the past 5 years. On Question 14, respondents provide a "ballpark" estimate on the total cost of all purchases and repairs related to the drinking water system in the past five years. There was one outlier response of $200,000 which represented the cost of replacing the entire system according to the respondent. This outlier was removed since it represented a capital investment that would be outside the definition of "repair."

37 participants responded to this question and stated that the average cost over five years was about $18,000. The median response was $10,000, and the standard deviation was about $17,100. Even when removing the outlier, the distribution of costs is strongly positively skewed. Further research on this topic, when combined with other data points such as the number of mobile units and the age of the system, would inform understanding about equipment and repair costs. Discussion with owners on the phone revealed that owners often expect and are prepared for equipment repair and replacement costs. However, many owners emphasized that the cost of regular monitoring and testing represented a significant and unreasonable operational cost.

Most park owners told us that they used "savings" to cover the cost of equipment replacement and repairs. We did not explicitly ask if owners passed those costs directly onto residents. Our survey would have benefited from querying owners about how they incorporate unexpected costs, because if they do charge residents, that would be a signal for how they price the water system.

[11] We verbally communicated to respondents that savings could include operational revenue, a checking account, or other cash immediately available for drinking water system expenses.

**Q15:** Which risks do you associate with your park's drinking water system?

| Count | No Risk Associated | % | Equipment Failure | % | Contaminants | % |
|---|---|---|---|---|---|---|
| 50 responses | 27 | 54% | 8 | 16% | 4 | 8% |

| Funding & Equipment Failure | % | Water Shortage & Equipment Failure | % | Contamination & Equipment Failure | % | Maintenance | % |
|---|---|---|---|---|---|---|---|
| 4 | 8% | 2 | 4% | 1 | 2% | 1 | 2% |

Question 15 prompted owners to consider risks that they would associate with their park drinking water system. Risks included equipment failure, contaminants, water shortage, and funding. Respondents had the option to select multiple risks or provide another risk that was not stated in the survey. 27 respondents stated that they did not associate any risk with their park drinking water system. 8 percent cited that equipment failure is a risk with respect to their system. 4 respondents selected contaminants as a risk, and another 4 selected both funding and equipment failure as a risk. If we count the respondents who selected both funding and equipment failure with those who just selected equipment failure, 12 respondents cited equipment failure as a risk.

**Q16:** In the past 5 years, have you had to shut down the park's drinking water system for longer than 24 hours?

| Count | Yes | % | No | % | I don't know | % | Blank | % |
|---|---|---|---|---|---|---|---|---|
| 49 | 10 | 20% | 39 | 78% | 0 | 0% | 1 | 2% |

| Count | Regulation & associated costs | % | Old Equipment & associated costs | % | Available staff / owner with expertise | % | Storms, disruptions, water quality | % |
|---|---|---|---|---|---|---|---|---|
| 50 | 9 | 18% | 10 | 20% | 3 | 6% | 7 | 14% |

On question 16, 10 respondents said that within the past five years they were forced to shut off the water system at least once longer than 24 hours. Only 2 respondents stated that they were forced to shut off the water system three times or more during a five-year period. The primary reasons for shut off were water main breaks, frozen pipes, or lost power.

**Q19:** Which potential problems do you foresee in the future operation of your drinking water system? Please describe.

| Funding (alone) | % | No Problems Foreseen | % |
|---|---|---|---|
| 2 | 4% | 19 | 38% |

Question 19 prompts respondents to consider the potential for future problems with their system and discuss what might concern them. This question is structured as a free form response. We categorized responses based on our perception of the main themes communicated by respondents. The categories we identified are "regulation and associated costs," "old equipment and associated costs," "available staff or owner with expertise," "storms, disruptions, water quality," "funding (by itself)," and "no foreseen problems." 19 respondents stated that they did not foresee any future problems related to the operation of their system. 10 cited old equipment and future costs associated with repairing and replacing the equipment. 9 respondents cited regulation and the costs associated with testing and compliance as a potential future problem. 3 cited the potential for a lack of owner expertise to maintain the system in the future. These perceived future problems echo many of the challenges cited by the literature on small drinking water systems.

**Q20:** "Would you be interested in merging or transferring ownership of the park drinking water system with another entity (for example, a private company, a nearby mobile home park, or local government)?"

| Count | Yes | No | I don't know | Blank |
|---|---|---|---|---|
| 50 | 25 | 20 | 0 | 5 |

The final question prompts respondents to state whether they would be interested in merging or transferring the ownership of the drinking water system to another entity. Respondents were relatively divided on this issue, and we had to clarify that the question assumes that it would be feasible for systems to merge. 25 respondents said they would consider, and 20 said that they would not consider. 10 percent did not answer the question. Some respondents stated that they had consulted with a local government about the possibility of merging but that the cost was too high. One respondent offered that the county would have charged the park $75,000 to connect to the county system located a half-mile away. Another respondent offered that about once a week their park receives mail from solicitors seeking to purchase the park outright.

Our survey of mobile home park owners reveals that most parks do not charge directly for water or monitor individual unit water usage. Most owners expressed confidence in the park's financial capacity to pay for maintenance and repairs, and most did not associate any water quality, water quantity, financial, or operational risks with their system. Some owners pointed out that the cost of SDWA compliance, through monitoring and testing, represents a greater financial burden than system maintenance and repairs. In general, we learned that the park owners surveyed were typically able to pay for maintenance and repairs through park

operations. One of most notable results from our survey is that at least half of the respondents indicated that they would consider transferring ownership of the drinking water system if it was feasible. The response indicates that at least a portion of owners we spoke with would prefer to transfer responsibility of providing drinking water to another entity.

There are several limits to this survey which inhibit our ability to infer across all mobile home parks with drinking water systems in North Carolina. Out of 339 mobile home parks that own and operate drinking water systems, we were able to contact about 230 owners and from this group our survey had a total of 50 individual respondents. Surveying such a small group of systems is a challenge, and our small sample population limits our ability to make conclusive inferences beyond the sample population.

Our survey provides some insight to financial capacity, but responses may not accurately reflect the true financial state of mobile home parks with drinking water systems. Regarding financial capacity, we did not ask respondents if they were part of a larger corporate entity or if they were independent owners. Our background research suggests that investor-backed, corporate-owned parks have greater financial resources as compared to independently-owned parks. Further research into these parks could reveal the dominant ownership-types for parks with drinking water systems.

*Spatial Analysis*

We mapped the drinking water systems in our study and conducted spatial and demographics analysis to better understand the land and population features where our systems are located. We separated systems based on the statewide topography (Coastal Plains, Piedmont, and Mountains region). Our demographics analysis explores race, age, median household income, and poverty characteristics of the block groups containing at least one mobile home park from our study.

*Location*

**Figure 1. Locations of North Carolina mobile home parks with independent drinking water systems.**

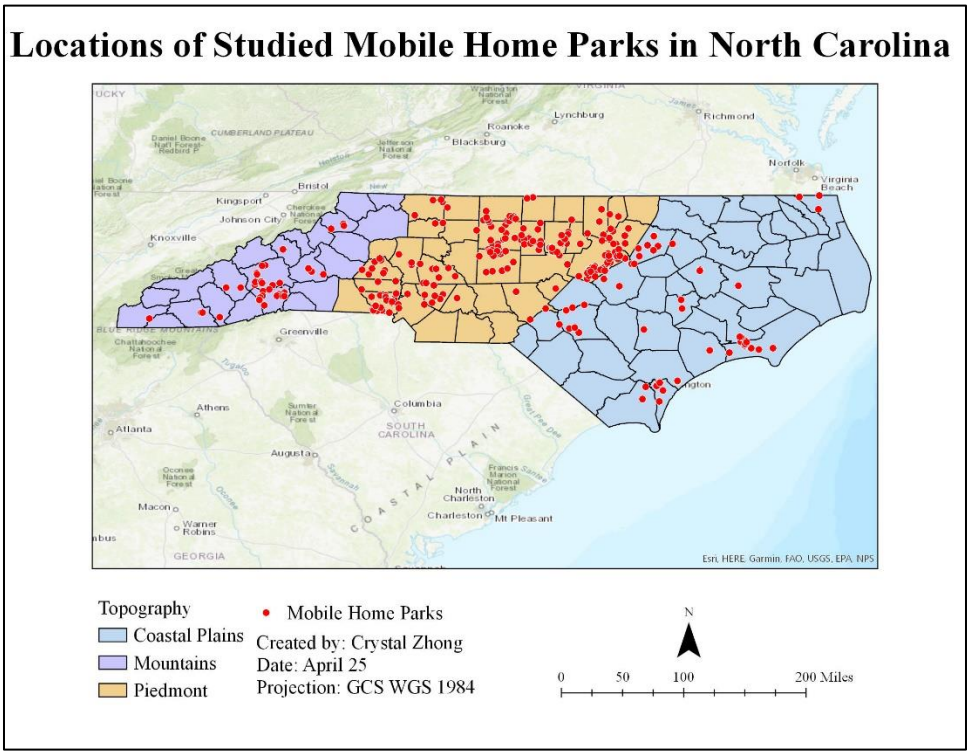



Figure 1 shows the locations of mobile home parks in North Carolina. There are 339 mobile home parks water systems located in 250 block groups across North Carolina. The Coastal Plains, Piedmont, and Mountains regions have 44, 172, and 34 mobile home parks, respectively. On the county level, mobile home parks in our dataset are mainly clustered in Carteret County, Wake County, Orange County, Durham County, Guilford County, Surry County, and Gaston County.

**Figure 2. Locations of schools using independent drinking water system in North Carolina**

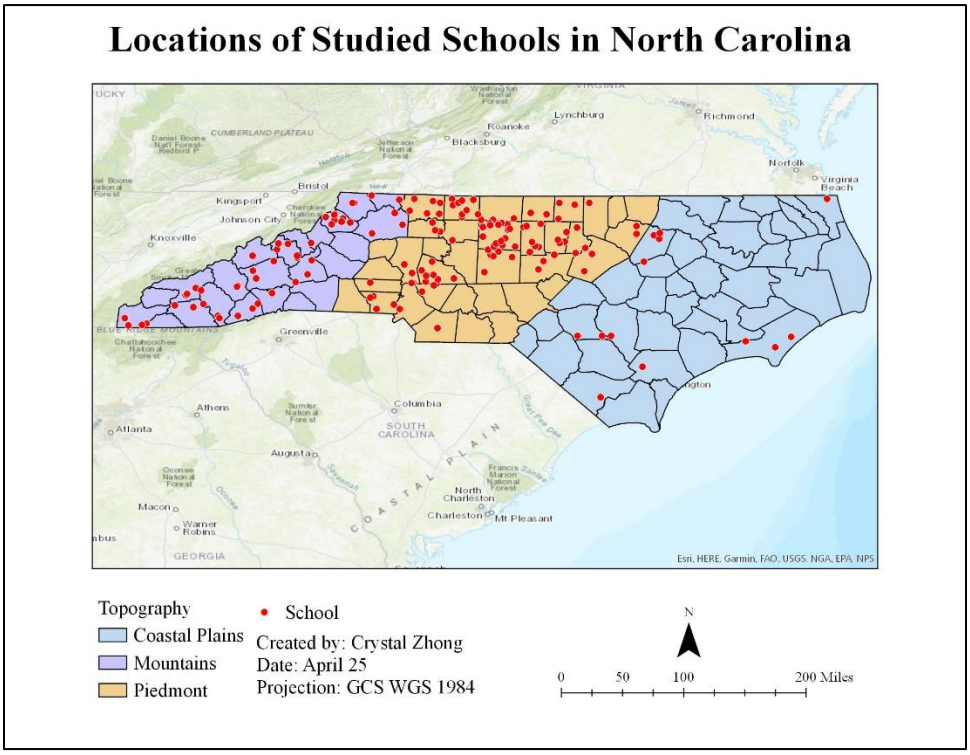



Figure 2 shows the locations of 159 schools using independent drinking water systems in North Carolina. 15 schools are in Coastal Plains, 99 schools are in Piedmont region, and 45 schools are in Mountains.

*Community and surrounding environment*

**Table 3. Population density of block groups containing mobile home parks[12]**

| Population Density | Block groups with mobile home parks | Block groups without mobile home parks |
|---|---|---|
| Mean | 427 | 1,351 |
| Median | 252 | 664 |
| Min | 15 | 0 |
| Max | 3,154 | 20,680[11] |

**Table 4. Population density of block groups containing schools**

| Population Density | Block groups with mobile home parks | Block Groups without mobile home parks |
|---|---|---|
| Mean | 230 | 1,339 |
| Median | 110 | 646 |
| Min | 6 | 0 |
| Max | 2,646 | 20,860 |

Tables 3 and 4 show the population density of block groups with target mobile home parks and schools as compared to block groups without them, respectively. The mean population density of block groups with mobile home parks is much lower than that of block groups without target mobile home parks. This pattern holds true for block groups containing target schools. This proves that schools and mobile home parks are in rural block groups.

*Race*

Previous evidence has indicated that minorities face more environmental injustice, including lack of access to safe, community drinking water services (Gibson & Leker, 2018). In a study on access to community water systems in North Carolina, Jacqueline Gibson and Hannah Leker found that census blocks with 100% black residents have lowest odds of having access to community water services while census block without any black resident have highest odds of having at least one community water service. Thus, this section examines the race distribution in block groups containing at least one mobile home park throughout North Carolina.

We looked at the average number of non-Hispanic white populations in each block group and compared across block groups containing mobile home parks from our dataset and those that do not contain mobile home parks from our dataset.

[12] Data in this table is estimated data, if the population in one block group is over 6,000, this block group will be split into more than 1 block group in next National Census Survey.

**Figure 3:** Mean percentage of non-Hispanic white population in block groups with MHP and in block groups without MHP

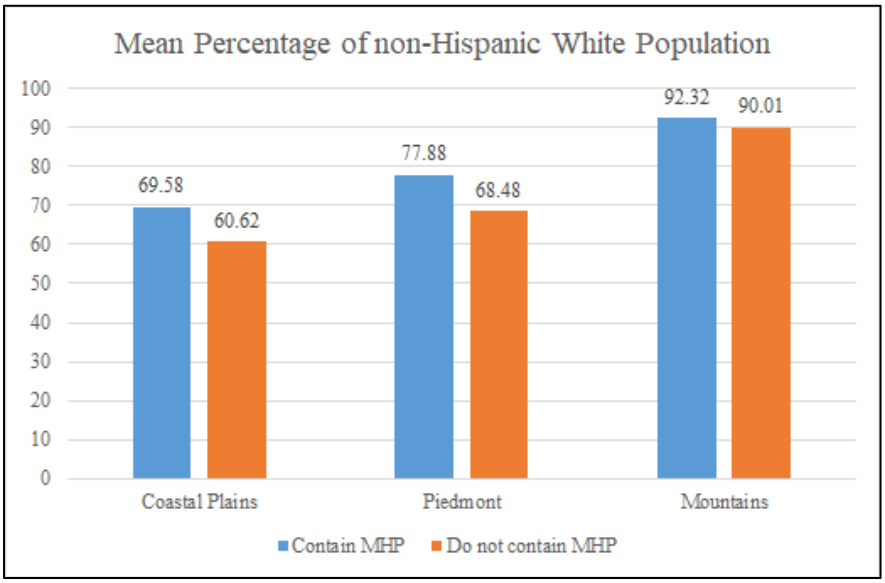



Figure 3 showed that block groups containing mobile home parks have racial demographics with a higher average percent white population compared to block groups without mobile home parks in all three topographic regions. This percentage also increased significantly from Coastal Plains to Mountains. Thus, it is possible that there are more non-Hispanic white residents living in those mobile home parks than that living in other communities.

*Age*

Children and senior citizens are more physiologically vulnerable than young adults and adults leading to higher risks of getting sick, even death ( Rafieian-Kopaei et al. , 2014). We examine the percentage of population under 19 years old in block groups and the percentage of population over 65 years old in block groups. Mean percentage were compared between block groups containing mobile home parks and block groups without parks from our dataset, and we compared across the three topological regions.

**Figure 4:** Mean percentage of population aged under 20 years old in block groups with MHP and in block groups without MHP

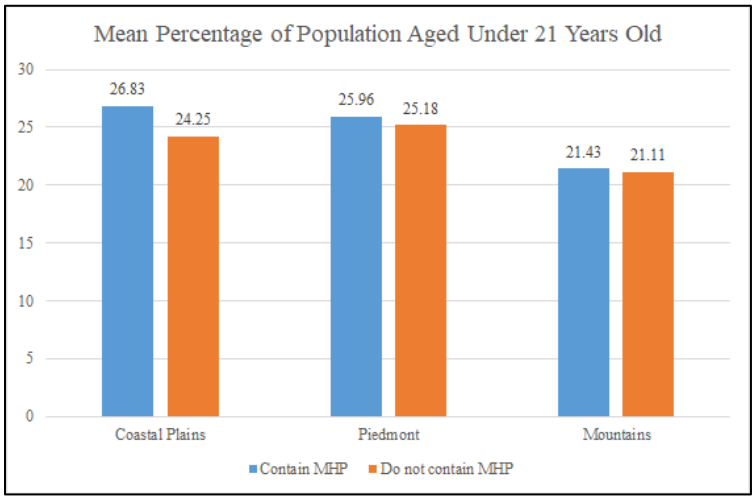



**Figure 5:** Mean percentage of population aged above 64 years old in block groups with MHP and in block groups without MHP

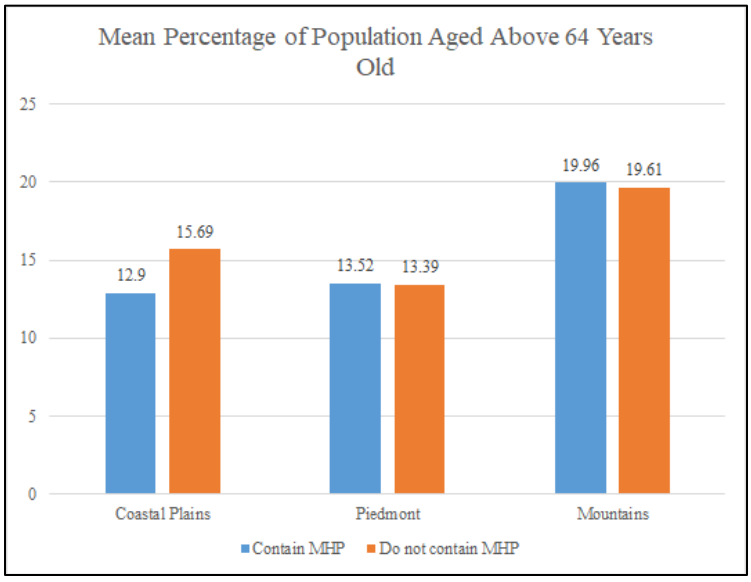



Figure 4 shows that the average percentage of population under 20 years old in block groups containing mobile home parks is slightly higher than in the block groups without mobile home parks. Figure 5 shows that the mean percentage of senior population of block groups with mobile home parks is similar to that of block groups without mobile home parks in all three regions. The biggest difference occurs in Coastal Plains, 2.79%. From Mountains to Coastal Plains, the mean percentage increases, but the percentage is lower than young population. The populations of block groups containing parks from our dataset tend to be younger in age as compared to those in other block groups.

*Median household income and poverty rate*

Previous studies revealed that less advantaged residents tend to have a lower median household income and a higher poverty rate (Lovett, 2015). Since residents living in target mobile home parks are more vulnerable, an initial hypothesis was stated that selected block groups have a relatively low median household income and poverty rate. Based on the community survey data, it is estimated that household size in selected block groups is 2.54. Therefore, the poverty line at set at $20,420 dollars which is the federal poverty line for a household of 3. Another threshold was set at $28,280 dollars which is the minimum requirement, 138% poverty line, to have access to Medicaid.

**Figure 6:** Percentage of communities with a median household income below the poverty line

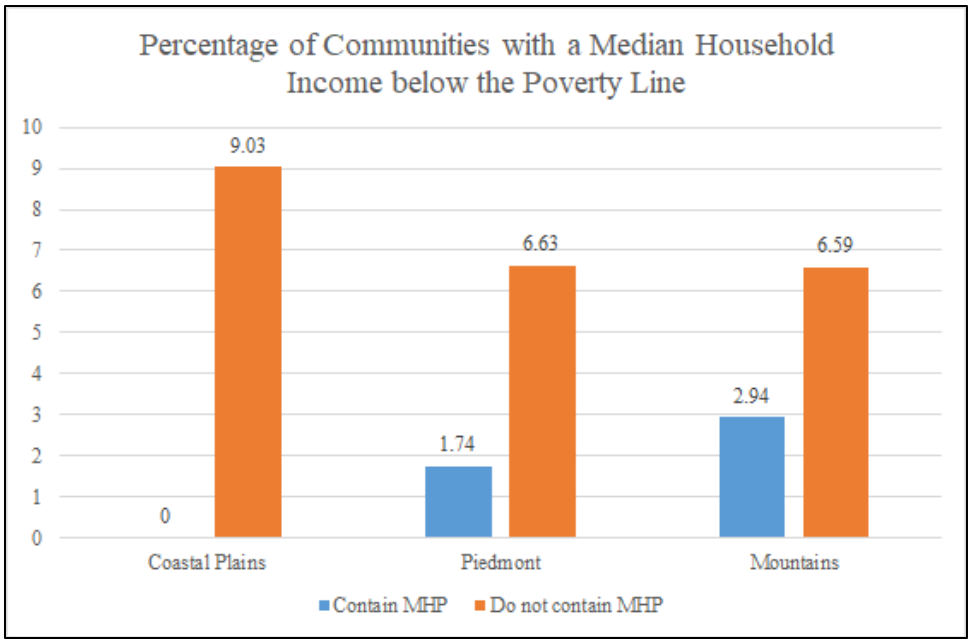



Figure 6 showed the percentage of block groups with a median household income below the poverty line in block groups contain mobile home parks and in block groups that do not contain mobile home parks. Surprisingly, block groups with mobile home parks have lower poverty rates than block groups without mobile home parks, especially in Coastal Plains. Mobile home park residents make up a small percentage of the total population in block groups, so we cannot infer based on the socioeconomic data that residents of mobile homes also have a higher income. Mobile home parks in our dataset are mainly clustered in Carteret County, Wake County, Orange County, Durham County, Guilford County, Surry County, and Gaston County which are wealthiest counties in North Carolina except Surry County. Thus, real socioeconomic information might hide behind huge gap between the rich and the poor.

In summary, this section analyzed the population density, race, age, and household income to explore the demographics in communities with mobile home parks and compare that with communities without mobile home parks. Population density revealed that the locations of our subgroup of mobile home parks was consistent with our initial hypothesis. Our spatial analysis revealed MHPs were located in areas associated with rural land use characteristics. Differences in mean percentage of white population spread across regions revealed

associations/patterns that carry implications on racial diversity, but nothing conclusive. The higher percentage of younger populations in MHPs also denotes a greater risk to threats of water quality. Our results from the median household income analysis proved our initial hypothesis wrong, our subgroup of MHPs did not show any economic disadvantage when looking purely at statistics.

**Comparing Datasets for Further Insight**

Drawing from sanitary survey, SDWA violations, and data from NC free and reduced meals data, we conducted comparative analysis to identify potential relationships between a water system's financial capacity and their compliance performance. We used different approaches using data from the sources outlined above to establish these relationships.

We used the number of service connections as a characteristic representing a system's financial capacity. Drinking water systems with a greater number of service connections can have lower overall costs because they have a greater customer base that allows them to spread their fixed costs of operation. To assess the state of a water system's infrastructure, we found the average age of facilities that comprise the drinking water system. The average age of facilities was calculated using the average age of all active and installed facilities.

Based on our evaluation of most pressing water quality issues for our subgroup of systems, we determined the following types of violations to be of special concern, and thus included in our analysis: (1) regular monitoring rule, (2) volatile organic chemicals rule, (3) total coliform & revised total coliform rule, (4) disinfection byproducts rule (DBPRs), (5) lead and copper rule, and (6) radionuclide rule. We included regular monitoring rules because, although they are not health-based violations, compliance with these set of rules can be an onerous task (based on direct feedback from owners) for these small water systems. All other violations are included due to high violations count, their negative health-based potentiality, and special recommendations provided by trusted sources of literature (i.e., NC DEQ studies have identified arsenic as a prevalent contaminant in NC groundwater sources).

We analyzed both types of violations: (1) health-based and (2) regular violations. The former type occurs when systems exceed maximum contaminant levels established by the EPA, while the latter are due to systems failing to complete sampling, testing, monitoring, and reporting related to drinking water regulations. We enhanced the analysis by separating health-based violations out to examine whether the systems with health-based violation history have different average numbers of connections and average ages.

When comparing the average number of connections and the average age of system facilities between the entire subgroup and the systems with any violations, we found that MHPs with more connections and older facilities are more likely to have all of the selected violation types (Appendix E). Comparing the numbers of connections among the school water systems does not reveal any consistent pattern, but comparing their average facility ages shows these water systems with newer facilities are more prone to have violations.

When comparing the average number of connections and the average age of system facilities between the subgroup and the systems with health-based violations, we did not identify any consistent pattern of the average connection number and the average facility age among MHPs (Appendix E). Three are only three health-based violation types for which school water systems have violation records, including total coliform rule & revised total coliform rule, lead and copper rule, and disinfection byproduct rule. Throughout all three violation types, we found school water systems with health-based violations have newer facilities than the entire subgroup of school water systems, but there is no consistent pattern for the number of connections in these systems.

The statistic test was only conducted when comparing a minimum of 20 water systems as the difference is not statistically valid when comparing less than 20 samples. As a result, there are only four differences rendered as statistically significant. First, with a p-value of 0.01, water systems in MHPs with any regular monitoring violations have older facilities than the entire subgroup of MHPs. Second, with a p value of 0.01, MHPs with any total coliform rule violations have older facilities. Third, with a p value of 0.01, MHPs with health-based total coliform rule violations have few numbers of connections. Lastly, the test implies MHPs with any disinfection byproduct rule violations have older facilities with a p value of 0.08. These low p values suggest that the difference between the violating water systems and their respective subgroup does not exist by chance. However, given the plethora of variations that are not captured in our analysis, any inference beyond these associations is unjustified.

*Comparing against MHP drinking water systems operated by water corporations*

We learned through our MHP owner survey that at least 44 MHPs in the sanitary survey dataset provided by DEQ are systems owned by Aqua America or another water corporation. We excluded these from our primary analysis, but we did compare difference between this group and the systems in our main dataset. We hypothesize that there are differences in characteristics between MHPs that have drinking water systems owned or operated by corporations and MHPs do not have this distinction. We will refer to MHPs that maintain ownership and operation of their drinking water systems as MHPs in ‘our study dataset.’ We will refer to the other group as ‘Water Corporation MHPs.’ We hypothesize that characteristics such as the service population (customer base) would make some MHP drinking water systems more eligible candidates for acquisition by a water corporation. There are also system characteristics such as metering, system approval, and average age of facility that might reveal differences between the two groups.

Of a total 383 MHPs listed collectively in SDWIS or in the NC Sanitary Survey database, we identified 44 MHPs that are owned by water corporations like Aqua America (Table 21). This group represents parks that have a drinking water system operated by a separate entity; this is different from parks (and their drinking water systems) owned by a separate entity.

**Table 21:** Population and connections comparison between our dataset and organization-owned MHPs.

| | Water Corporation MHPs | MHPs that maintain ownership & operation of drinking water system (Our study dataset) |
|---|---|---|
| **Population** | | |
| Number of systems | 44 | 339 |
| Average population served | 170 | 116 |
| Median population served | 124 | 86 |
| Total population served | 7,317 | 38,963 |
| **Mobile Units (Connections)** | | |
| Average number of mobile units per MHP (connections) | 65 | 48 |
| Median number of mobile units (connections) | 46 | 35 |
| # of systems over capacity (more connections than permitted) | 1 | 15 |

On average, MHPs in our study dataset serve 116 people compared with corporate-owned MHPs which serve an average of 170 people (Table 21). The median population of an MHP in our dataset is 86, and the median population of a corporate-owned MHP is 124. The sanitary survey dataset indicates, according to connections and the number of approved connections, that 16 systems of 383 are over capacity (Table 21). Approximately 39,000 people live in the MHPs from our dataset, while about 7,300 people live in the MHPs with corporate-owned drinking water systems (Table 21)

The differences in population served could support the theory that the best candidates for acquisition by water corporations have a higher than average service population (customer base). In addition, the data shows that MHPs from our dataset have a median of 35 mobile units, while the MHPs have a median of 46 units (Table 21). Although it only represents a small portion of the MHP dataset, we found that fifteen of the MHPs from our dataset are over-capacity compared with one water corporation MHP that is over-capacity (Table 21).

**Table 22:** MHP drinking water system permitting status comparison between our dataset and organization-owned MHPs.

| | Water Corporation MHPs | | | MHPs that maintain ownership & operation of drinking water system (Our study dataset) | | |
|---|---|---|---|---|---|---|
| **Permitting Status** | | | | | | |
| *Status* | *Yes* | *No* | *Blank* | *Yes* | *No* | *Blank* |
| **Approved System?** | 39 | 5 | 0 | 183 | 133 | 23 |
| Percent of Total | 89% | 11% | 0% | 54% | 39% | 7% |
| | | | | | | |
| **Grandfathered System?** | 6 | 27 | 11 | 89 | 151 | 99 |
| Percent of Total | 14% | 61% | 25% | 26% | 45% | 29% |

In terms of differences among system characteristics, we found that 54 percent of the MHP drinking water systems in our dataset were approved and 39 percent were grandfathered, whereas 75 percent of water corporation MHPs were approved and only 20 percent were grandfathered (Table ).[13]

**Table 23:** facilities and metering comparison between our dataset and organization-owned MHPs.

| | Water Corporation MHPs | | | | | MHPs that maintain ownership & operation of drinking water system (Our study dataset) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Facilities** | | | | | | | | | | |
| Mean average age of facilities in a MHP | 40 | | | | | 33.88 | | | | |
| Median average age of facilities in a MHP | 41 | | | | | 35.33 | | | | |
| **Metering** | | | | | | | | | | |
| **ME = Metered, UM = unmetered, MU = both, UN = unknown, blank = no data** | | | | | | | | | | |
| Status | ME | UM | MU | UN | Blank | ME | UM | MU | UN | Blank |
| Number of systems | 43 | 5 | 0 | 7 | 0 | 33 | 146 | 7 | 145 | 8 |
| Percent of Total | 78% | 9% | 0% | 13% | 0% | 10% | 43% | 2% | 43% | 2% |

[13] An approved system has submitted the necessary engineering plans, design specifications, and reports, which were approved, according to the rules in effect at the time. A grandfathered system is a system that was established prior to the rules requiring approval of engineering plans, specifications, and reports before construction. This description was provided by officials from the Public Water Supply division of the NC Department of Environmental Quality.

The sanitary survey data also shows that the average age of MHP facilities in our dataset is 34 years, while the average age of water corporation MHPs is 33 years (Table 23). There was a distinct difference in metering between the two groups. Just 10 percent of the MHPs in our dataset are metered, while 78 percent of the organization-owned MHPs are metered (Table 23).

## Limitations

We recognize that our underlying data may not accurately depict the characteristics of the systems in our research. To illustrate, we used only two key variables, number of connections and average age, to represent the technical and managerial capacity of systems. However, given that the available data are limited due to insufficient process and infrastructure that facilitates data collection, we believe these data can still help us gain a better understanding of these small water systems.

Additionally, systems that lack the variables were removed from the analysis. The purpose is to ensure that we analyzed the same group of systems consistently. There are some limitations to this approach. Firstly, it raises the question of representativeness. It is possible that the removed systems have some common characteristics that relate to our research interests. Secondly, removing these systems makes some of the analysis statistically insignificant since some of the sample sizes are already small.

When testing for statistical significance, our samples often failed to meet the necessary criteria needed for such analysis. For example, the independent t-test used in the comparative analysis assumes the two compared groups are unrelated. However, since we included all examined systems as one group in each comparison, this violated the assumption of independence.

There are limitations in predicting demographic characteristics of MHPs. Service population in these mobile home parks are usually less than 100 people while the minimum population threshold of a block group is around 600 people. Therefore, our study created a bias by looking at block group demographic statistics to describe that of MHPs. The American Community Survey is conducted annually among a small percentage of households in a block group. Despite the fact that we used 5-year estimates, non-response or false response bias cannot be avoided. When a respondent completes the survey, the possibility of misreporting demographic information related to household income and education, is a limiting factor.

## Discussion

### *Confirming our initial expectations*

In accordance with national level research on small drinking water systems and non-compliance, we found that MHPs have a higher rate of noncompliance than other drinking water systems, even other small systems. MHPs demonstrated a higher percentage of violating systems (number of violating systems/total number of systems) and a higher violation rate (number of total violations/total number of systems) when compared to small water systems in North Carolina. Schools also displayed similar characteristics. The higher rate of schools and mobile home parks with at least one violation over five years indicates that these systems struggle to

comply with the Safe Drinking Water Act. The fact that most violations are due to monitoring and reporting, and not due to contamination, provides evidence that these systems struggle to achieve compliance but the populations they serve may not be at a higher risk for contamination.

Sanitary survey data show that these are simple systems in terms of the facilities that comprise them. The average age of drinking water facilities at mobile home parks and schools, 35 and 31 respectively, appear to be well within the lifespan of materials used in drinking water systems (American Water Works Association, 2012). Our conversations with mobile home park owners revealed that while drinking water facilities do require replacements or repair from time to time, these costs are not exorbitant and may not represent the biggest cost in relation to the system. Our survey also confirmed that mobile home parks typically do not charge directly for water and instead pay for the water system using resident rent payments.

Our attempt to connect system characteristics with violations data revealed few correlations between datasets. Furthermore, we did not find any discernible associations between violations and the characteristics for violations that small water systems are most likely to violate. However, there is a pattern that MHPs with violations have older facilities. This could suggest that if a system has older facilities, it may be an indication that the park has less financial capacity and is more likely to struggle with SDWA compliance.

*What surprised us*

Although MHPs have higher incidence of violations when compared to larger and smaller water systems, we saw a similar rate of health-based violations as other systems across the state. We are only able to speculate the differences in proportions of reporting and health-based violations for this group. It could be the case that, in terms of drinking water treatment and contamination prevention, these water systems perform as well as larger systems and that the difference in reporting violations can be attributed to having fewer or less experienced staff. Our conversations with mobile home park owner did not reveal “red flags” that would indicate serious challenges with the current and future operation of these systems from an infrastructure or managerial perspective. However, it is also possible that violations committed by these systems are underreported. Even though MHPs have a higher percentage of systems with at least one violation and more overall violations, they are not found to have a proportionally elevated number of health-based violations – this finding was similarly observed in schools.

One possible explanation is regulators have exercised greater flexibility with small drinking water systems to help them achieve compliance. North Carolina’s most recent Capacity Development report for public drinking water systems states that, “if during the review it is determined that a water system is not on the path to compliance, that system will be issued a ‘last chance letter,’ indicating that an action plan must be provided to the Section within a specified deadline to avoid further legal action.” (North Carolina Department of Environmental Quality, 2018).

In addition, it is possible our survey with owners did not reveal the true status of these systems. Most surprising to us was that most park owners with whom we spoke expressed to us that the drinking water system was not financially burdensome to their overall park operation. We had expected more respondents to tell us they had to use credit cards or loans from time to

time to pay for the system; however, only one respondent said they used a form of debt to pay for the system.

One conversation we had with a mobile home park owner raised the relative importance of septic systems as an aspect of overall park risk. The park owner revealed to us that, if septic systems are not maintained and fail, the lot attached to the septic system can no longer be used. Because mobile home parks are constrained by space, the loss of a few lots due to septic system failure could affect the park's ability to operate. This conversation revealed other infrastructure risks for entities that own and operate drinking water systems.

Regarding our spatial and demographic analysis, we found that it was challenging to target the populations served by our systems using available U.S. census data. For example, it was surprising to see mobile home parks located within block groups with higher income and lower poverty rates, especially given the fact that block groups containing our subgroup of mobile home parks had higher percentage of white residents. This was surprising because our research and talks with mobile home park owners led us to believe these populations would show a greater level of diversity and higher number of minority residents.

*Concluding Thoughts*

North Carolina has achieved a high rate of compliance across drinking water systems and the number of systems with at least one SDWA violation and the absolute number of violations committed has decreased substantially over time (North Carolina Department of Environmental Quality, 2018). Our study shows that the small systems we examined do not have higher rates of health-based violations and the populations they serve are not-necessarily at greater risk for contamination. However, the fact that these small systems still struggle to achieve SDWA compliance through monitoring and reporting indicates that there is room for capacity development. Conversations with mobile home park owners revealed that small system owners feel the burden of compliance, and some are interested in transferring ownership of their drinking water system to another owner. As North Carolina continues to work diligently to increase SDWA compliance and to invest in drinking water infrastructure, we hope our research helps to highlight often overlooked drinking water systems and will help to incorporate these groups in the state's planning efforts related to compliance and infrastructure investments for public drinking water systems.

# Appendix

## Appendix Section A: Violations

**Table 1:** Breakdown of water system size by service population; bars highlighted in yellow indicate small water systems. All 308 systems in the school and MHP subgroup fall within the small water system category. Figures were taken from SDWIS database.

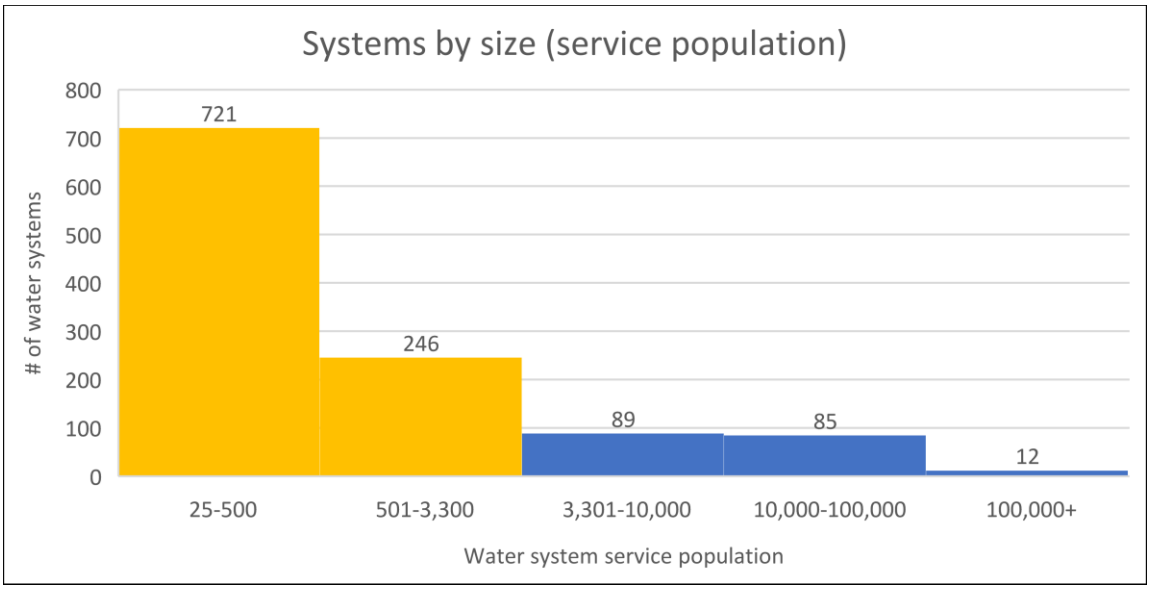



**Figure 2:** Comparing the number of systems with violations over five year (2013 – 2018). Figure includes all NC Community and Non-Transient, Non-Community Water systems, Small Systems (<3,500 served), and Mobile Home Parks (MHPs).

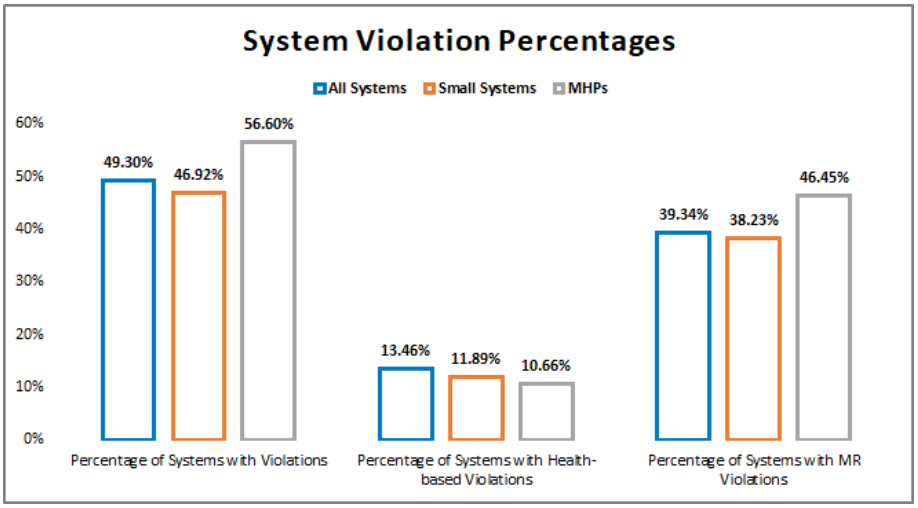


**Figure 3:** Comparing the number of systems with violations over five year (2013 – 2018). Figure includes all NC Community and Non-Transient, Non-Community Water systems, Small Systems (<3,500 served), and Schools (MHPs).

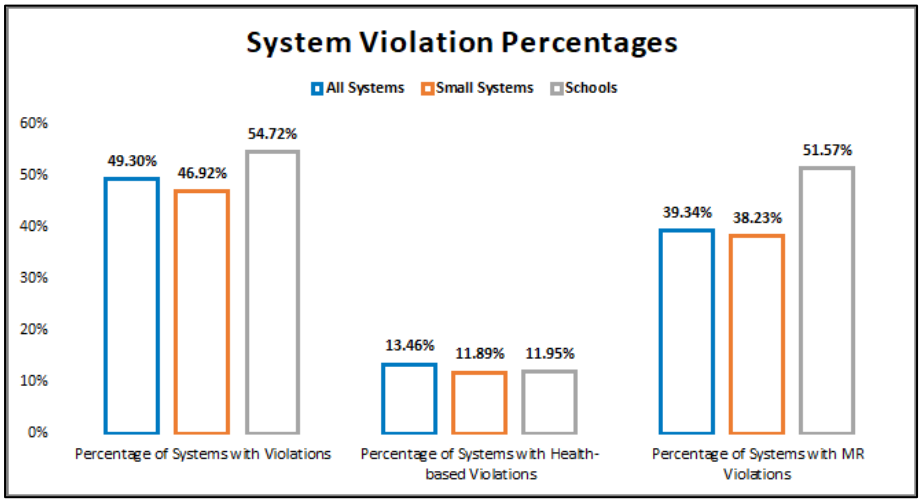



**Table 4:** Data from NC Capacity Development Report Table on "The Number of Public Water Systems with Maximum Contaminant Level (MCL) and Monitoring (MR) Violations." (North Carolina Department of Environmental Quality, 2018)

| Calendar Year | Population | Community | | | | | Non-Transient, Non-Community | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Systems | MCL | % | MR | % | Systems | MCL | % | MR | % |
| 1999 (Baseline) | <500 | 1700 | 44 | 3% | 483 | 28% | 541 | 23 | 4% | 3322 | 55% |
| | 500 – 9,999 | 555 | 9 | 2% | 154 | 28% | 132 | 1 | 1% | 34 | 39% |
| | 10K – 49.9K | 92 | 4 | 4% | 15 | 16% | | | | | |
| | ≥50K | 24 | 1 | 4% | 2 | 8% | | | | | |
| | Totals | 2371 | 58 | 2% | 654 | 28% | | 24 | 4% | 3356 | 55% |
| 2014 | <500 | 1411 | 32 | 2% | 114 | 8% | 317 | 7 | 2% | 486 | 15% |
| | 500 – 9,999 | 476 | 30 | 6% | 62 | 13% | 56 | 0 | 5% | 5 | 9% |
| | 10K – 49.9K | 105 | 5 | 5% | 10 | 10% | | | | | |
| | ≥50K | 28 | 2 | 7% | 4 | 14% | | | | | |
| | Totals | 2020 | 69 | 3% | 190 | 9% | 373 | 10 | 3% | 491 | 15% |
| 2015 | <500 | 1401 | 28 | 2% | 98 | 7% | 308 | 7 | 2% | 388 | 12% |
| | 500 – 9,999 | 475 | 26 | 5% | 54 | 11% | 55 | 0 | 0% | 4 | 7% |
| | 10K – 49.9K | 106 | 7 | 7% | 11 | 10% | | | | | |
| | ≥50K | 29 | 0 | 0% | 4 | 14% | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Totals | 2011 | 61 | 3% | 167 | 8% | 363 | 7 | 2% | 392 | 12% |
| 2016 | <500 | 1389 | 16 | 1% | 86 | 6% | 299 | 2 | 1% | 467 | 15% |
| | 500 – 9,999 | 477 | 24 | 5% | 37 | 8% | 56 | 0 | 0% | 6 | 12% |
| | 10K – 49.9K | 108 | 5 | 5% | 10 | 9% | | | | | |
| | ≥50K | 29 | 1 | 3% | 3 | 10% | | | | | |
| | Totals | 2003 | 46 | 2% | 136 | 7% | 355 | 2 | 1% | 473 | 15% |
| 2017 | <500 | 1369 | 14 | 1% | 78 | 6% | 297 | 3 | 1% | 353 | 11% |
| | 500 – 9,999 | 482 | 29 | 6% | 38 | 8% | 58 | 0 | 0% | 6 | 12% |
| | 10K – 49.9K | 109 | 4 | 4% | 8 | 7% | | | | | |
| | ≥50K | 31 | 2 | 6% | 2 | 6% | | | | | |
| | Totals | 1991 | 49 | 6% | 126 | 6% | 355 | 3 | 1% | 359 | 11% |

**Table 5:** Top contaminants by count associated with SDWA violations across North Carolina and across mobile home parks and schools over a five-year period.

| **All Top 10 contaminants by type** | | | **MHPs and Schools Top 10 contaminants (sorted by % of total contaminant count)** | | |
|---|---|---|---|---|---|
| *Contaminant* | *Count* | *% of total violations* | *Contaminant* | *Count* | *% of total contaminant count* |
| Public Notice | 1497 | 13.2% | Radium -226 | 50 | 80% |
| Lead and Copper Rule | 982 | 8.64% | Radium -228 | 49 | 80% |
| Lead and Copper Rule | 982 | 8.6% | Nitrate | 138 | 66% |
| TTHM | 923 | 8.1% | Antimony, Total | 30 | 61% |
| Total Haloacetic Acids (HAAS) | 748 | 6.6% | Gross Alpha, excluding Radon and U | 65 | 55% |
| Coliform (TCR) | 607 | 5.3% | Beryllium, Total | 22 | 54% |
| Consumer Confidence Rule | 519 | 4.6% | Chromium | 18 | 51% |
| Chlorine | 422 | 3.7% | Nickel | 18 | 49% |

| | | | | | |
|---|---|---|---|---|---|
| Revised Total Coliform Rule | 314 | 2.8% | Selenium | 18 | 49% |
| Nitrate | 206 | 1.8% | Arsenic | 18 | 45% |
| Combined Radium (-226 and -228) | 152 | 1.3% | Lead and Copper Rule | 342 | 35% |
| Arsenic | 39 | 0.3% | | | |

**Table 6:**

| Violation Category | Health-based Violations (% and unit number) | All Violations |
|---|---|---|
| Regular Monitoring | 40% | N/A |
| Consumer Confidence and Public Notice Rules | 44% | N/A |
| Disinfection Byproduct Rule | 33% | 53% |
| (Revised) Total Coliform Rules | 0% | 59% |
| Lead and Copper Rule | 44% | 38% |

## Appendix Section B: Sanitary Survey

**Table 1:** Sanitary Survey analysis

| | |
|---|---|
| **Number of Mobile Home Parks in Sample** | 339 |

**Table 1.1:** Summary statistics for Mobile Home Park Drinking Water System

| Mobile Home Park Drinking Water System Summary Statistics | |
|---|---|
| Mean average age of facilities | 33.88 |
| Median average age of facilities | 35.33 |
| Max average age of facilities | 53 |
| Min average age of facilities | 1 |
| Standard deviation | 9.3 |
| | |
| Blank | 14 |
| Total | 325 |

**Figure 1.2:** Distribution of the average ages of facilities across MHPs.

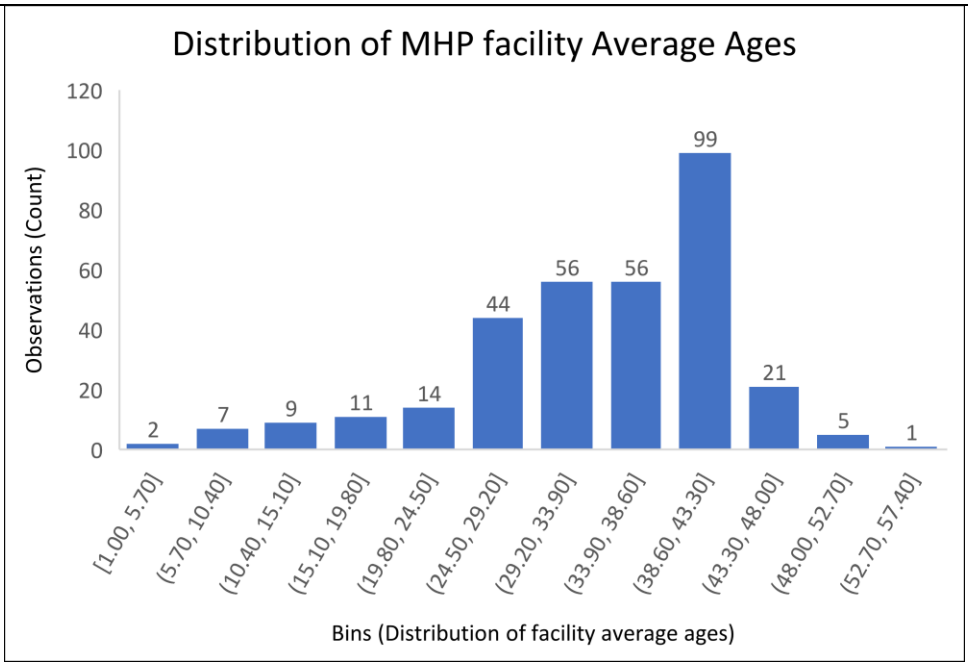



**Table 1.3:** Summary statistics of population served by MHPs.

| Population served | |
|---|---|
| Total number of people served | 38,963 |
| Mean population served per MHP | 115.6 |
| Median population served per MHP | 86 |
| Max population served per MHP | 688 |
| Min population served per MHP | 9 |
| Standard deviation | 105.04 |
| | |
| Blank | 2 |
| Total | 337 |

**Figure 1.4:** Distribution of MHP service populations across all MHPs.

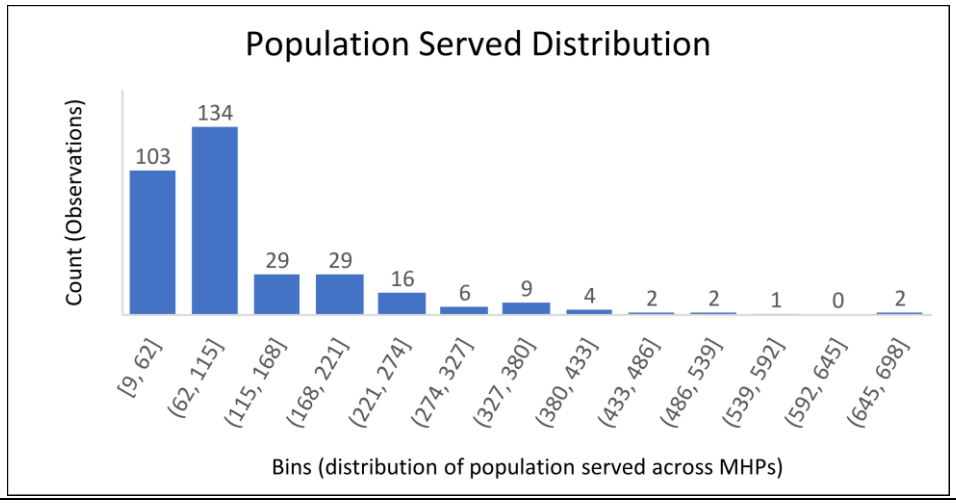


**Table 1.5:** Approved and Grandfathered system counts. An approved system has submitted the necessary engineering plans, design specifications, and reports, which were approved, according to the rules in effect at the time. A grandfathered system is a system that was established prior to the rules requiring approval of engineering plans, specifications, and reports before construction.

| Approved and Grandfathered Systems | | |
|---|---|---|
| *Approved System?* | | |
| Approved | 183 | 54% of 339 |
| Not Approved | 133 | 39% of 368 |
| | | |
| Blank | 23 | 7% of 394 |
| Total Count (minus blank) | 368 | 93% of 339 |
| | | |
| *Grandfathered System?* | | |
| Grandfathered | 89 | 26% of 339 |
| Not Grandfathered | 151 | 45% of 339 |
| | | |
| Blank | 99 | 29% of 339 |
| Total Count (minus blank) | 240 | 71% of 339 |

**Table 1.6:** Treatment facilities

| Treatment facilities | | |
|---|---|---|
| Count with treatment facility | 259 | 76% of 339 |
| Count without treatment facility | 68 | 20% of 339 |
| | | |
| Blank | 12 | 4% of 339 |
| Total | 327 | 96% of 339 |

**Table 1.7:** Metering

| Metering | | |
|---|---|---|
| Metered | 33 | 10% of 339 |
| Unmetered | 146 | 43% of 339 |
| Unknown | 145 | 43% of 339 |
| Metered and Unmetered | 7 | 2% of 339 |
| | | |
| Blank | 8 | 2% of 339 |
| Total | 331 | 98% of 339 |

**Table 2:** Number of schools in sample.

| **Number of Schools in Sample** | 159 |
|---|---|

**Table 2.1:** Summary statistics for School Drinking Water System

| School Drinking Water System Summary Statistics | |
|---|---|
| Mean average age of facilities | 27.52 |
| Median average age of facilities | 27.5 |
| Max average age of facilities | 49.67 |
| Min average age of facilities | 1 |
| Standard deviation | 12.18 |
| | |
| Blank | 17 |
| Total | 142 |

**Figure 2.2:** Distribution of the average ages of facilities across MHPs.

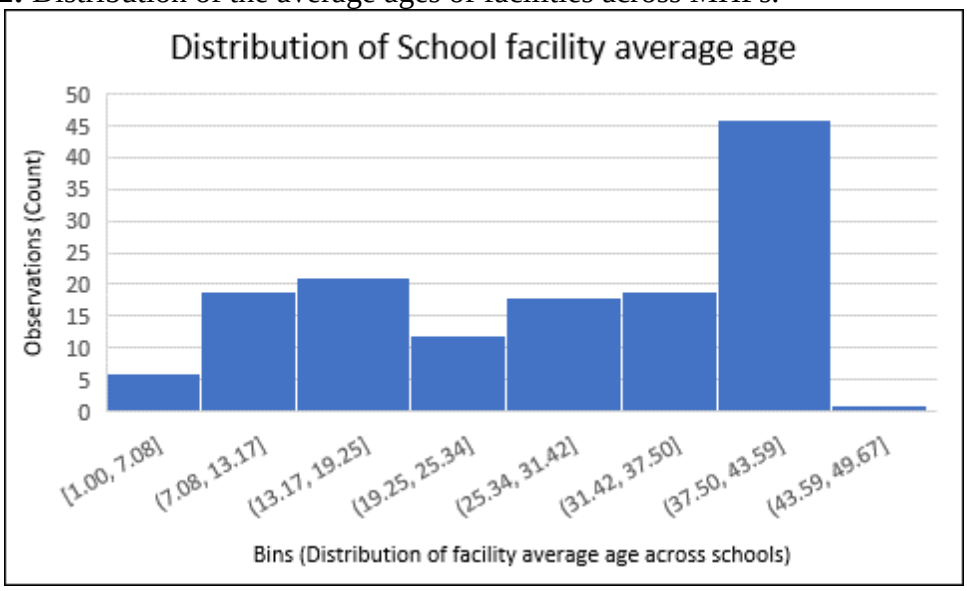



**Table 2.3:** Summary statistics of population served by MHPs.

| Population served | |
|---|---|
| Total number of people served | 50,579 |
| Mean population served per school | 383.17 |
| Median population served per school | 302.5 |
| Max population served per school | 2427 |
| Min population served per school | 34 |
| Standard deviation | 361.3 |
| | |
| Blank | 27 |
| Total | 152 |

**Figure 2.4:** Distribution of school service populations across all schools.

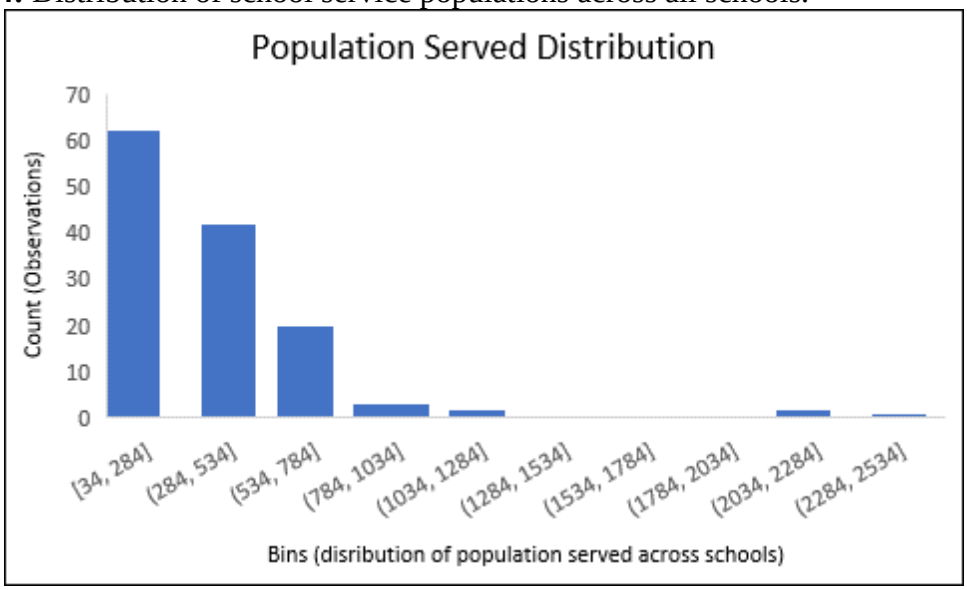



**Table 2.5:** Approved and Grandfathered system counts. An approved system has submitted the necessary engineering plans, design specifications, and reports, which were approved, according to the rules in effect at the time. A grandfathered system is a system that was established prior to the rules requiring approval of engineering plans, specifications, and reports before construction.

| Approved and Grandfathered Systems | | |
|---|---|---|
| *Approved System?* | | |
| Approved | 37 | 39% of 94 |
| Not Approved | 57 | 61% of 94 |
| Blank | 65 | |
| Total Count (minus blank) | 94 | 59% of 159 |
| | | |
| *Grandfathered System?* | | |
| Grandfathered | 78 | 64% of 121 |
| Not Grandfathered | 43 | 36% of 121 |
| Blank | 38 | |
| Total Count (minus blank) | 121 | 76% of 159 |

**Table 2.6:** Treatment facilities

| Treatment facilities | | |
|---|---|---|
| Count with treatment facility | 134 | 95% |
| Count without treatment facility | 7 | 5% |
| Blank | 18 | |
| Total | 141 | 89% of 159 |

**Table 2.7:** Metering for schools.

| Metering | | |
|---|---|---|
| Metered | 47 | 30% |
| Unmetered | 41 | 26% |
| Unknown | 70 | 44% |
| Metered and Unmetered | 1 | 1% |
| Total | 159 | 100% of 159 |

**Table 3. Corporate-owned MHPs versus MHPs in our dataset**

**Table 3.1:** Number of systems and summary statistics for system facilities age.

| MHPs in our dataset | | Corporate-owned MHP DW systems | |
|---|---|---|---|
| Number of MHPs | 339 | Number of MHPs | 44 |
| | | | |
| *Facility stats* | | *Facility stats* | |
| Mean average age | 33.88 | *Mean average age* | *35.06* |
| Median | 35.33 | *Median* | *35.94* |
| Max average age per MHP | 53.00 | *Max average age per MHP* | *43.00* |
| Min average age per MHP | 1.00 | *Min average age per MHP* | *17.5* |
| Standard Deviation | 9.30 | *Standard Deviation* | *6.66* |
| | | | |
| Blank | 14 | Blank | 0 |
| Sample N | 325 | Sample N | 44 |

**Table 3.2:** Age of oldest facility.

| MHPs in our dataset | | Corporate-owned MHP DW systems | |
|---|---|---|---|
| *Age of oldest facility* | | *Age of oldest facility* | |
| Median | 41.00 | Median | 41.00 |
| Mean | 38.38 | Mean | 39.91 |
| Max | 57.00 | Max | 44.00 |
| Min | 1 | Min | 18 |
| Standard deviation | 8.88 | Standard deviation | 4.22 |
| | | | |
| Blank | 19 | Blank | 1 |
| Sample N | 320 | Sample N | 43 |

**Table 3.3:** Summary statistics for active wells.

| MHPs in our dataset | | Corporate-owned MHP DW systems | |
|---|---|---|---|
| *Number of Active Wells* | | *Number of Active Wells* | |
| Mean | 1.0 | Mean | 1.53 |
| Median | 1 | Median | 1 |
| Max | 3 | Max | 5 |
| Min | 0 | Min | 1 |
| Standard Deviation | 0.63 | Standard Deviation | 0.83 |
| | | | |
| Blank | 12 | Blank | 1 |
| Sample N | 327 | Sample N | 43 |

**Table 3.4:** Summary statistics on number of mobile units across systems.

| MHPs in our dataset | | Corporate-owned MHP DW systems | |
|---|---|---|---|
| *Number of Connections (units)* | | *Number of Connections (units)* | |
| Mean | 47.61 | Mean | 65.44 |
| Median | 35 | Median | 46 |
| Max | 271 | Max | 251 |
| Min | 3 | Min | 10 |
| Standard Deviation | 40.93 | Standard Deviation | 50.74 |
| | | | |
| Blank | 10 | Blank | 1 |
| Sample N | 329 | Sample N | 43 |

**Table 3.5:** Summary statistics on population served.

| MHPs in our dataset | | Corporate-owned MHP DW systems | |
|---|---|---|---|
| *Population* | | *Population* | |
| # systems over capacity | 15 | # systems over capacity | 1 |
| Total # of People Served | 38963 | Total # of People Served | 7,317 |
| Median size | 86 | Median size | 124 |
| Mean | 115.62 | Mean | 170.16 |
| Max | 688 | Max | 638 |
| Min | 9 | Min | 26 |
| Standard Deviation | 144.8 | Standard Deviation | 128.39 |
| | | | |
| Blank | 2 | Blank | 1 |
| Sample N | 337 | Sample N | 43 |

**Table 3.6:** Summary statistics for treated wells.

| MHPs in our dataset | | | Corporate-owned MHP DW systems | | |
|---|---|---|---|---|---|
| *treatment* | *Count* | *Percent of Total* | *treatment* | *Count* | *Percent of Total* |
| # without treatment | 68 | 20% | # without treatment | 0 | 0% |
| # with | 259 | 76% | # with | 43 | 98% |
| # blank | 12 | 4% | # blank | 11 | 2% |
| total | 339 | | total | 44 | |
| | | | | | |
| total minus blank | 327 | | total minus blank | 43 | |

**Table 3.7:** Approved versus not-approved system.

| MHPs in our dataset | | | Corporate-owned MHP DW systems | | |
|---|---|---|---|---|---|
| *Approved System?* | *Count* | *Percent of Total* | *Approved System?* | *Count* | *Percent of Total* |
| Yes | 183 | 54% | Yes | 39 | 89% |
| No | 133 | 39% | No | 5 | 11% |
| (Blank) | 23 | 7% | (Blank) | 0 | 0% |
| total | 339 | | total | 44 | |
| | | | | | |
| total minus blank | 316 | | total minus blank | 44 | |

**Table 3.8:** Grandfathered versus not-grandfathered systems.

| MHPs in our dataset | | | Corporate-owned MHP DW systems | | |
|---|---|---|---|---|---|
| *Grandfathered System?* | *Count* | *Percent of Total* | *Grandfathered System?* | *Count* | *Percent of Total* |
| Yes | 89 | 26% | Yes | 6 | 14% |
| No | 151 | 45% | No | 27 | 61% |
| (Blank) | 99 | 29% | (Blank) | 11 | 25% |
| total | 339 | | total | 44 | |
| | | | | | |
| total minus blank | 240 | | total minus blank | 33 | |

**Table 3.9:** Metering across systems.

| MHPs in our dataset | | | Corporate-owned MHP DW systems | | |
|---|---|---|---|---|---|
| *Meter Type* | *Count* | *Percent of Total* | *Meter Type* | *Count* | *Percent of Total* |
| # metered (ME) | 33 | 10% | # metered | 34 | 77% |
| # unmetered (UM) | 146 | 43% | # unmetered | 5 | 11% |
| # unknown (UN) | 145 | 43% | # unknown | 5 | 11% |
| # metered and unmetered (MU) | 7 | 2% | # metered and unmetered | 0 | 0% |
| # blank | 8 | 2% | # blank | 0 | 0% |
| Total | 339 | | Total | 44 | |

## Appendix Section C: School Free and Reduced Meals Applications (Economically-Disadvantaged Students)

**Figure 1:** Distribution of EDS representation across NC public elementary schools.

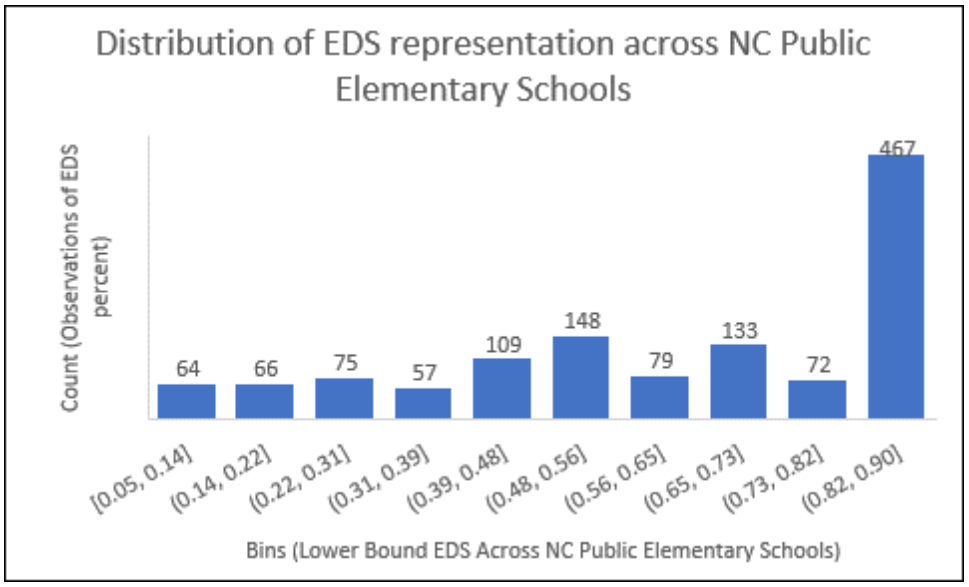
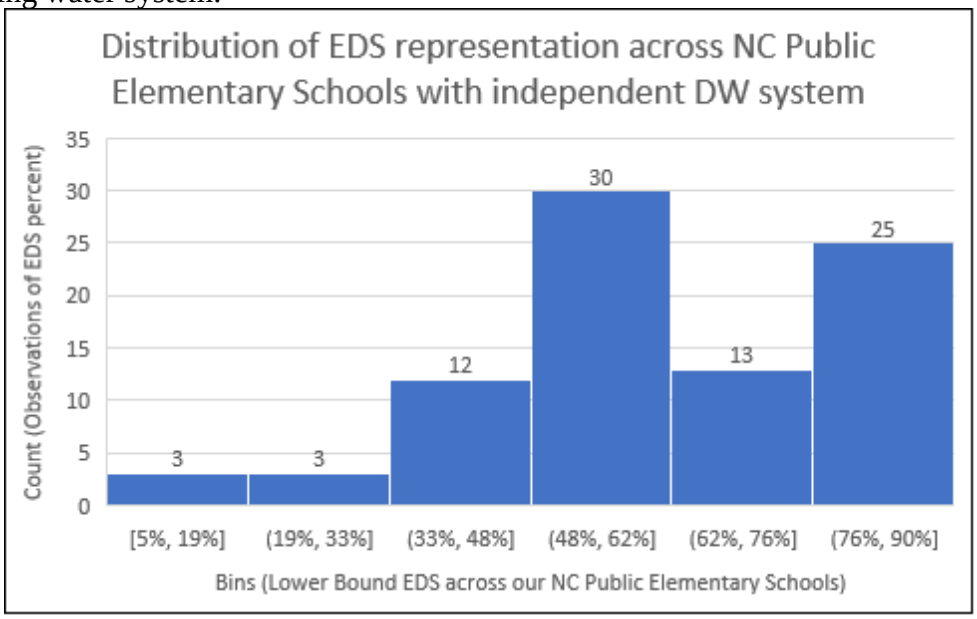


**Figure 2:** Distribution of EDS representation across NC public elementary schools with their own drinking water system.




## Appendix Section D: MHP Owner Survey

**Table 1:** MHP Owner Survey Responses (50 participants[14])

**Q1:** How many units (number of mobile homes) do you have in the park? Please write as a number (for example, "25"). If you own multiple parks, please select one and provide your answers according that that park.

*Manual Entry*
Number of Units

| Count | Mean | Median | Max | Min | Standard Deviation |
|---|---|---|---|---|---|
| 25 responses | 59.52 | 36 | 275 | 10 | 57.3 |

**Q2:** Are the units in your park owned or rented by residents?

*Multiple Choice*
- Owned
- Rented
- Both

| Count | Owned | % | Rented | % | Both | % |
|---|---|---|---|---|---|---|
| 50 | 19 | 38% | 7 | 14% | 24 | 48% |

[14] Question 1 was added after the survey had begun and 50% of the participants were asked this question.

**Q3:** Do you monitor water usage for each mobile unit in your park?

*Multiple Choice*
- Yes
- No
- I don't know

| Count | Yes | % | No | % | I don't know | % | Blank |
|---|---|---|---|---|---|---|---|
| 50 | 6 | 12% | 41 | 82% | 0 | 0% | 3 |

**Q4:** Do you charge each mobile unit in your park for water?

*Multiple Choice*
- Yes
- No
- I don't know

| Count | Yes | % | No | % | I don't know | % | Blank |
|---|---|---|---|---|---|---|---|
| 50 | 4 | 8% | 46 | 92% | 0 | 0% | 0 |

**Q5:** How do you charge each mobile unit for their water usage?

*Multiple Choice*
- Flat Fee
- Volumetric Fee (based on amount of water used)
- No Fee (Park does not charge units for water)

| Count | Flat Fee | Volumetric |
|---|---|---|
| 4 | 2 | 2 |

**Q6:** If you charge each mobile unit for water usage using a flat fee, how much do you charge? Enter a number in dollars per mobile unit. For example, $10.00 per mobile unit.

*Manual Entry*

| Respondent 1 | Respondent 2 |
|---|---|
| 41.2 | 12.5 |

**Q7:** How frequently do you charge the flat fee?

*Multiple Choice*
- Once per month
- Twice per month
- Annually

*Manual Entry*
Other

| Respondent 1 | Respondent 2 |
|---|---|
| Monthly | Monthly |

**Q8:** If you charge mobile units for water usage using a volumetric fee, how much is the fee? Enter a dollar number per unit of water. For example, $10.00 per 100 gallons.

*Manual Entry*

| Respondent 1 | Respondent 2 |
|---|---|
| $27 average | blank |

**Q9:** How frequently do you charge the volumetric fee?

*Multiple Choice*
- Once per month
- Twice per month
- Annually

*Manual Entry*
Other

| Respondent 1 | Respondent 2 |
|---|---|
| Monthly | Monthly |

**Q10:** Do you keep financial records about your park's drinking water system separate from other park financial records?

*Multiple Choice*
- Yes
- No
- I don’t know

| Count | Yes | % | No | % | I don’t know | % | Blank | % |
|---|---|---|---|---|---|---|---|---|
| 50 | 29 | 58% | 21 | 42% | 0 | 0% | 0 | 0% |

**Q11:** Do you have an emergency "rainy day" fund that can be used toward your park drinking water system in case of an emergency?

*Multiple Choice*

- Yes
- No
- I don't know

| Count | Yes | % | No | % | I don't know | % | Blank | % |
|---|---|---|---|---|---|---|---|---|
| 50 | 31 | 62% | 18 | 36% | 1 | 2% | 0 | 0% |

**Q12:** If the park drinking water system has ever required significant repairs, how did you cover the cost of repairs?

*Multiple Choice*

- I had to use savings to cover expenses
- I had to use debt to cover expenses
- I had to use both savings and debt to cover expenses
- I don't know

| Count | Savings | % | Debt | % | I don't know | % | Blank | % |
|---|---|---|---|---|---|---|---|---|
| 50 | 36 | 72% | 1 | 2% | 0 | 0% | 13 | 26% |

**Q13:** In the past five years, have you had to purchase or repair the equipment related to the park's drinking water system?

*Multiple Choice*

- Yes
- No
- I don't know

| Count | Yes | % | No | % | I don't know | % | Blank | % |
|---|---|---|---|---|---|---|---|---|
| 50 | 40 | 80% | 10 | 20% | 0 | 0% | 0 | 0% |

**Q14:** Please estimate the total cost of all purchases and repairs for the drinking water system in the last 5 years (in $ dollars).

*Manual Entry*

| Count | Mean | Median | Max | Min | Standard Deviation |
|---|---|---|---|---|---|
| 38 responses | $22,630 | $10,000 | $200,000 | $300 | $34,024 |

**Q15:** Which risks do you associate with your park's drinking water system?

*Multiple Choice, can select multiple options*

- Contaminants in water
- Water shortage
- Funding
- Equipment failure
- I do not see any risk associated with the park's drinking water system

*Manual Entry*
Other

| Count | No Risk Associated | % | Equipment Failure | % | Contaminants | % |
|---|---|---|---|---|---|---|
| 50 responses | 27 | 54% | 8 | 16% | 4 | 8% |

| Funding & Equipment Failure | % | Water Shortage & Equipment Failure | % | Contamination & Equipment Failure | % | Maintenance | % |
|---|---|---|---|---|---|---|---|
| 4 | 8% | 2 | 4% | 1 | 2% | 1 | 2% |

**Q16:** In the past 5 years, have you had to shut down the park's drinking water system for longer than 24 hours?

*Multiple Choice*

- Yes
- No
- I don't know

| Count | Yes | % | No | % | I don't know | % | Blank | % |
|---|---|---|---|---|---|---|---|---|
| 49 | 10 | 20% | 39 | 78% | 0 | 0% | 1 | 2% |

**Q17:** If you answered yes to Question 16, how many times have you had to shut down the park's drinking water system for longer than 24 hours?

*Multiple Choice*

- Once
- Twice
- Three times or more

| Once | Twice | Three times or more |
|---|---|---|
| 5 | 3 | 2 |

**Q18:** For which of the following reasons were you forced to shut down your park's drinking water system?

*Multiple Choice*
- Water main break or other system failure
- Insufficient funds
- Flooding
- Contamination

*Manual Entry*
Other (Please describe)

| Water Main Break | Insufficient Funding | Flooding | Contamination | Other |
|---|---|---|---|---|
| 5 | 0 | 1 | 0 | 2 due to frozen pipes, 2 due to lost power with no backup available |

**Q19:** Which potential problems do you foresee in the future operation of your drinking water system? Please describe.

*Manual entry*

| Count | Regulation & associated costs | % | Old Equipment & associated costs | % | Available staff / owner with expertise | % | Storms, disruptions, water quality | % |
|---|---|---|---|---|---|---|---|---|
| 50 | 9 | 18% | 10 | 20% | 3 | 6% | 7 | 14% |

| Funding (alone) | % | No Problems Foreseen | % |
|---|---|---|---|
| 2 | 4% | 19 | 38% |

**Q20:** Would you be interested in merging or transferring ownership of the park drinking water system with another entity (for example, a private company, a nearby mobile home park, or local government)?

*Multiple Choice*

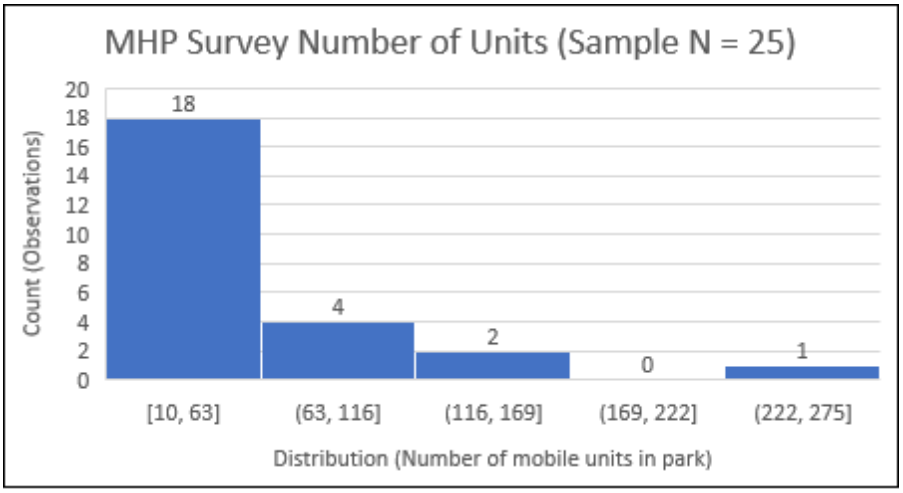
- Yes
- No
- I don't know

| Count | Yes | No | I don't know | Blank |
|---|---|---|---|---|
| 50 | 25 | 20 | 0 | 5 |

**Table 2:** Comparison between survey participants and full dataset (number of units).

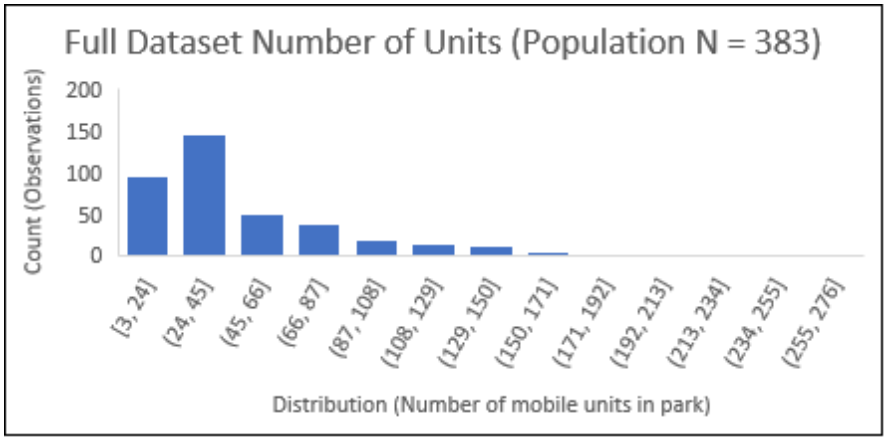
| | Nongovernmental Dataset | MHP Survey | Absolute Difference | Z stat | P value[15] |
|---|---|---|---|---|---|
| Mean # units | 51.19 | 59.52 | 8.33 | 0.94 | 0.1736 |
| Median # units | 37 | 36 | 1 | | |
| Max # units | 272 | 275 | 3 | | |
| Min # units | 3 | 10 | 7 | | |
| Std Deviation | 44.35 | 57.3 | 12.95 | | |
| Sample Size | 383 | 25 | | | |

**Figure 3:** Distribution of number of mobile units per park, collected through MHP Owner Survey.




[15] The skewness of the data limits our ability to use this value for inference.

**Figure 4:** Distribution of number of mobile units per park, collected through Sanitary Survey dataset.




## Appendix Section E: Comparative analysis

**Table 1:** Comparative analysis of the number of connections and facility age between subgroups and violating systems.

**Mean Comparison (Systems failing to Pass Regular Monitoring Requirement)**

| | | Number of Connections | Average Age | Number of Systems |
|---|---|---|---|---|
| **Schools** | **Violating Groups** | 5.24 | 25.57 | 71 |
| | **Subtotal Groups** | 4.37 | 27.52 | 76 |
| **MHPS** | **Violating Groups** | 52.30 | 35.64 | 168 |
| | **Subtotal Groups** | 47.62 | 33.88 | 325 |

**Mean Comparison (Systems Violating (Revised) Total Coliform Rules)**

| | | Number of Connections | Average Age | Number of Systems |
|---|---|---|---|---|
| **Schools** | **Health-based Violating Groups** | 2.33 | 17.89 | 3 |
| | **Violating Groups** | 4.50 | 24.01 | 22 |
| | **Subtotal Groups** | 4.37 | 27.52 | 76 |
| **MHPs** | **Health-based Violating Groups** | 34.85 | 34.58 | 20 |
| | **Violating Groups** | 48.05 | 36.51 | 86 |
| | **Subtotal Groups** | 47.62 | 33.88 | 325 |

**Mean Comparison (Systems Violating Lead and Copper Rule)**

| | | Number of Connections | Average Age | Number of Systems |
|---|---|---|---|---|
| Schools | Health-based Violating Groups | 5.33 | 26.75 | 12 |
| | Violating Groups | 4.27 | 24.30 | 44 |
| | Subtotal Groups | 4.37 | 27.52 | 76 |
| MHPs | Health-based Violating Groups | 51.30 | 39.16 | 10 |
| | Violating Groups | 53.60 | 35.01 | 113 |
| | Subtotal Groups | 47.62 | 33.88 | 325 |

**Mean Comparison (Systems Violating Radionuclides Rule)**

| | | Number of Connections | Average Age | Number of Systems |
|---|---|---|---|---|
| Schools | Health-based Violating Groups | | | 0 |
| | Violating Groups | | | 0 |
| | Subtotal Groups | 4.37 | 27.52 | 76 |
| MHPs | Health-based Violating Groups | 64.40 | 35.82 | 5 |
| | Violating Groups | 57.25 | 36.67 | 16 |
| | Subtotal Groups | 47.62 | 33.88 | 325 |

**Mean Comparison (Systems Violating Disinfection Byproduct Rules)**

| | | Number of Connections | Average Age | Number of Systems |
|---|---|---|---|---|
| Schools | Health-based Violating Groups | 1.50 | 20.08 | 4 |
| | Violating Groups | 6.24 | 26.07 | 38 |
| | Subtotal Groups | 4.37 | 27.52 | 76 |
| MHPs | Health-based Violating Groups | 40.00 | 41.00 | 1 |
| | Violating Groups | 53.32 | 35.56 | 82 |
| | Subtotal Groups | 47.62 | 33.88 | 325 |

**Mean Comparison (Systems Violating Volatile Organic Chemical Rules)**

| | | Number of Connections | Average Age | Number of Systems |
|---|---|---|---|---|
| **Schools** | **Health-based Violating Groups** | | | 0 |
| | **Violating Groups** | 3.29 | 24.10 | 24 |
| | **Subtotal Groups** | 4.37 | 27.52 | 76 |
| **MHPs** | **Health-based Violating Groups** | 41.50 | 27.67 | 2 |
| | **Violating Groups** | 51.54 | 35.64 | 7 |
| | **Subtotal Groups** | 47.62 | 33.88 | 325 |

# Works Cited

Rafieian-Kopaei et al. . (2014). Comparative Immune Response in Children and Adults with H. pylori Infection. *Journal of immunology research*, 315957.

Allaire, M., Wu, H., & Lall, U. (2018, January 9). National trends in drinking water quality violations. *Proceedings of the National Academy of Sciences of the United States of America*, pp. 2078-2083.

American Society of Civil Engineers. (2017). Infrastructure Report Card ASCE, Schools.

American Water Works Association. (2012). *Buried No Longer: Confronting America's Water Infrastructure Challenge.* Denver: American Water Works Association.

Aqua America, Inc. (2019). *Aqua North Carolina Service Territory*. Retrieved from Aqua America Water Utility Service: https://www.aquaamerica.com/our-states/north-carolina.aspx

Association American Public Health. (2017). Establishing Environmental Public Health Systems for Children at Risk or with Environmental Exposures in Schools. *American Public Health Association*.

Bear, C. (2018, April 23). *The Case for Preserving Mobile Homes*. Retrieved from City Lab: https://www.citylab.com/design/2018/04/the-case-for-preserving-mobile-homes/558563/

Becker, C., & Rickert, T. (2018). *Zoned Out? North Carolina Manufactured Housing Rents.* Durham: Duke University.

Blanchard, C. S., & Eberle, W. D. (2013). Technical, managerial, and financial capacity among small water systems. *American Water Works Association*, E229-E235.

Campbell, T., Mort, S., Fong, F., Crawford-Brown, D., Vengosh, A., Cornell, E., & Field, R. W. (2011). *North Carolina Radon-in-Water Advisory Committee Report.*

Cantrell, R. A., Nahmens, I., Peavey, J., Bryant, K., & Stair, M. (2012). *Pre-Disaster Planning for Permanent Housing Recovery.* Upper Marlboro: U.S. Department of Housing and Urban Development.

Dabson, B. (2018, January 16). *Hidden In Plain Sight*. Retrieved from UNC School of Government Environmental Finance Center Blog: http://efc.web.unc.edu/2018/01/16/hidden-in-plain-sight/

Dhesi, S. (n.d.). *Protecting Mobile Homes as Affordable Housing*. Retrieved from UCLA Law Review: https://www.uclalawreview.org/protecting-mobile-homes-as-affordable-housing/

Division of Water Infrastructure, NC DEQ. (2017). *Report on the Water Infrastructure Fund and State Water Infrastructure Authority.* Raleigh: North Carolina Department of Environmental Quality.

Durso, F., Solomon, J., & Colson, K. (2019). North Carolina's Bold Water and Wastewater Infrastructure Plan. *American Water Works Association*.

Environmental Protection Agency. (2018). *National Primary Drinking Water Regulations.* Washington DC: Environmental Protection Agency.

Environmental Protection Agency. (2018). *Potential Well Water Contaminants and Their Impacts.* Washington, DC.

Environmental Protection Agency. (n.d.). *Information about Public Water Systems*. Retrieved from Drinking Water Requirements for States and Public Water Systems: https://www.epa.gov/dwreginfo/information-about-public-water-systems

Eskaf, S., & Whisnant, R. (2013, November 13). *An Overview of NC Water Service Providers.* Retrieved from UNC Environmental Finance Center: www.sog.unc.edu

Geoghegan, T. (2013, September 24). *Why do so many Americans live in mobile homes?* Retrieved from BBC News: https://www.bbc.com/news/magazine-24135022

Gibson, J. M., & Leker, H. G. (2018). Relationship between race and community water and sewer service in North Carolina, USA. *PLoS ONE*.

Gibson, J. M., & Pieper, K. J. (2017). Strategies to improve private-well water quality: a North Carolina perspective. *Environmental Health Perspectives*.

Gibson, Leker & Gordon. (2017). Relationship between race and community water and sewer service in North Carolina, USA. *PloS One*, e0193225.

Griese, G., Mason, R. R., & Strickland, A. (1987). *North Carolina Ground-Water Quality.* Raleigh.

Hui, T. K. (2019, March 21). NC gets an 'F' grade for keeping lead out of school drinking water, new report finds. Raleigh, North Carolina, United States of America.

Kirk, M. (2017, October 25). *How Mobile Homes Hinder the American Dream*. Retrieved from City Lab: https://www.citylab.com/equity/2017/10/why-mobile-homes-hamper-the-american-dream/543906/

Kline, K. J. (2017). *Small Water Systems: Surveying State Utility Commission Best Practices.* Silver Spring: National Regulatory Research Institute.

Leker, H. G., & Gibson, J. M. (2018). Relationship between race and community water and sewer service in North Carolina, USA. *PLoS ONE*.

Lovett, J. A. (2015). Tragedy or Triumph in Post-Katrina New Orleans? Reflections on Possession, Dispossession, Demographic Change, and Affordable Housing. *Journal of Affordable Housing & Community Development Law*, 289–305.

McFarlane, K., & Harris, L. M. (2018). Small systems, big challenges: review of small drinking water system governance. *NRC Research Press*, 378-395.

N.C.G.S. § 159G-31, North Carolina General Assembly.

N.C.G.S. § 90A (North Carolina General Assembly).

NC Administrative Code T10.10E .0101 - .0105. (n.d.). *DW Operator Certification: Rules.* Retrieved from North Carolina Department of Environmental Quality: https://files.nc.gov/ncdeq/Water+Quality/Operator_Certification_Files/DW_Files/18D_2018.pdf

North Carolina Department of Environmental Quality. (1990). Subchapter 18D - Water Treatment Facility Operators.

North Carolina Department of Environmental Quality. (2017). *North Carolina's Statewide Water and Wastewater Infrastructure Master Plan.* Raleigh: North Carolina Department of Environmental Quality.

North Carolina Department of Environmental Quality. (2018). *North Carolina Capacity Development Report for Public Water Systems.* Raleigh: N.C. Department of Environmental Quality.

North Carolina Department of Environmental Quality. (n.d.). *Radon and Arsenic*. Retrieved from North Carolina Department of Environmental Quality: https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/geologic-hazards/radon-arsenic

North Carolina DEQ Division of Water Infrastructure. (2017). *2017 Master Plan*. Retrieved from North Carolina DEQ Division of Water Infrastructure: http://portal.ncdenr.org/web/wi/master-plan

North Carolina DEQ Division of Water Infrastructure. (n.d.). *Funding Programs and Application Information*. Retrieved February 11, 2019, from North Carolina Department of Environmental Quality Division of Water Infrastructure: http://portal.ncdenr.org/web/wi/application-information

North Carolina Division of Water Infrastructure. (n.d.). *Merger/Regionalization Feasibility Grants*. Retrieved from North Carolina Department of Environmental Quality: https://deq.nc.gov/about/divisions/water-infrastructure-draft/i-need-funding/mergerregionalization-feasibility-grants

North Carolina Ground Water Association. (2019). *North Carolina Ground Water Association*. Retrieved from North Carolina Ground Water Association: https://ncgwa.org/

North Carolina Office of Environmental Education. (n.d.). *Groundwater*. Retrieved from North Carolina Office of Environmental Education: https://www.eenorthcarolina.org/resources/educational-materials/your-ecological-address/groundwater

North Carolina Office of State Budget & Management. (n.d.). *County/State Population Projections.* Retrieved from North Carolina Office of State Budget & Management: https://www.osbm.nc.gov/demog/county-projections

North Carolina Office of State Budget & Management. (n.d.). *State Demographer.* Retrieved from North Carolina Office of State Budget & Management: https://files.nc.gov/ncosbm/documents/files/Rec2018-19_PopulationDynamics.pdf

Owens, D. W. (2014, May). *Manufactured Housing, Modular Housing, and Zoning*. Retrieved from UNC School of Government: https://www.sog.unc.edu/resources/legal-summaries/manufactured-housing-modular-housing-and-zoning

Ramseur, J. L., & Tiemann, M. (2018). Water Infrastructure Financing: History of EPA Appropriations. *Congressional Research Service*, 1-41.

Redmon, J. H. (2018). Safeguarding children's health: Time to enact a health-based standard and comprehensive testing, mitigation, and communication protocol for lead in drinking water. *North Carolina Medical Journal*.

Rimler, R. (2015, August 30). Study finds hog farm waste in NC waters, but significance is disputed. *The News & Observer*.

Rivlin, G. (2014, March 13). The Cold, Hard Lessons of Mobile Home U. *The New York Times*, pp. https://www.nytimes.com/2014/03/16/magazine/the-cold-hard-lessons-of-mobile-home-u.html.

Sanders, A. P., Messier, K. P., Shehee, M., Rudo, K., Serre, M. L., & Fry, R. C. (2012). Arsenic in North Carolina: Public Health Implications. *Environment International*, 10-16.

Snyder, T., & Musu-Gillette, L. (2015, April 16). *Free or reduced price lunch: A proxy for poverty?* Retrieved from National Center for Education Studies: https://nces.ed.gov/blogs/nces/post/free-or-reduced-price-lunch-a-proxy-for-poverty

Stanford, M. J. (2008). *Small Water Systems: Challenges and Recommendations.* Washington, D.C.: National Regulatory Research Institute.

Sunderman, G. L., & Croninger, R. (2018). *High Suspending Schools in Maryland.* Department of Teaching and Learning, Policy and Leadership.

Swistock, B. (2015, May 28). *Reducing Radon in Drinking Water*. Retrieved from Penn State Extension: https://extension.psu.edu/reducing-radon-in-drinking-water

Switzer & Teodor. (2018). Class, Race, Ethnicity, and Justice in Safe Drinking Water Compliance. *Social Science Quaterly*, 524-535.

Tiemann, M. (2017). *Safe Drinking Water Act (SDWA): A Summary of the Act and Its Major Requirements.* Washington, D.C.: Congressional Research Service.

U.S. Census Bureau. (n.d.). *American Community Survey (ACS)*. Retrieved from U.S. Census Bureau: https://www.census.gov/programs-surveys/acs/about.html

U.S. Census Bureau. (n.d.). *Boundary and Annexation Survey*. Retrieved from U.S. Census Bureau: https://www.census.gov/programs-surveys/bas.html

U.S. Census Bureau. (n.d.). *Decennial Census of Population and Housing*. Retrieved from U.S. Census Bureau: https://www.census.gov/programs-surveys/decennial-census/about/psap.html

U.S. Department of Agriculture. (n.d.). *Water & Waste Disposal Loan & Grant Program Fact Sheet.* Retrieved from U.S. Department of Agriculture Rural Development: https://www.rd.usda.gov/files/fact-sheet/RD-FactSheet-RUS-WEPDirect.pdf

U.S. Environmental Protection Agency. (2011). *National Characteristics of Drinking Water Systems Serving 10,000 or Fewer People.* Washington, D.C.: U.S. EPA.

U.S. Environmental Protection Agency. (2016, September 30). *Learn about Small Drinking Water Systems*. Retrieved from Building the Capacity of Drinking Water Systems: https://www.epa.gov/dwcapacity/learn-about-small-drinking-water-systems

U.S. Environmental Protection Agency. (2016, December 5). *Small Drinking Water System Variances*. Retrieved from U.S. Environmental Protection Agency: https://www.epa.gov/dwregdev/small-drinking-water-system-variances

U.S. Environmental Protection Agency. (2017, June). *Drinking Water State Revolving Fund Eligibility Handbook.* Retrieved from United States Environmental Protection Agency: https://www.epa.gov/sites/production/files/2017-06/documents/dwsrf_eligibility_handbook_june_13_2017_updated_508_version.pdf

U.S. Environmental Protection Agency. (2018). *Drinking Water Infrastructure Needs Survey and Assessment.* Washington, D.C.: U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency. (2018, June 6). *How EPA Regulates Drinking Water Contaminants*. Retrieved from U.S. Environmental Protection Agency: https://www.epa.gov/dwregdev/how-epa-regulates-drinking-water-contaminants

U.S. Environmental Protection Agency. (2018, March 22). *National Primary Drinking Water Regulations*. Retrieved from Ground Water and Drinking Water: https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations

U.S. Environmental Protection Agency. (2018, July 23). *Small Drinking Water Systems Research*. Retrieved from U.S. Environmental Protection Agency: https://www.epa.gov/water-research/small-drinking-water-systems-research

U.S. Environmental Protection Agency. (n.d.). *SDWIS*. Retrieved from Safe Drinking Water Information System: https://ofmpub.epa.gov/enviro/sdw_query_v3.get_list?wsys_name=&fac_search=fac_beginning&fac_county=&fac_city=&pop_serv=500&pop_serv=3300&pop_serv=10000&pop_serv=100000&pop_serv=100001&sys_status=active&pop_serv=&wsys_id=&fac_state=NC&last_fac_name=&page=1

UNC Environmental Finance Center. (2015, February). *U.S. Department of Agriculture Rural Development, Rural Utilities Service Water and Environmental Programs.* Retrieved from University of North Carolina Environmental Finance Center: https://efc.sog.unc.edu/sites/default/files/2016/08%20USDA%20Delong.pdf

University of Massachusetts Amherst. (n.d.). *Small Systems Information*. Retrieved from Water Innovation Network for Sustainable Small Systems: https://www.umass.edu/winsss/resources/learn-small-systems

Van Dam, A. (2017, December 29). Why trailer parks are all over rural America, but not Iowa. *The Washington Post*.

Whitford, E. (2018, November 30). Affordable Housing is Disappearing. These Mobile Home Residents are Fighting to Protect Theirs. *Time*.

Whoriskey, P. (2019, February 14). A billion-dollar empire made of mobile homes. *The Washington Post*.