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Exploring the invisible water insecurity of water utility shutoffs in Detroit, Michigan

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Abstract A lack of regular access to clean and safe water and sanitation is a persistent problem in many parts of the world. Most water insecurity studies focus on the world's less-industrialized and lower-income countries, where sanitation and water delivery infrastructure may never have existed. However, many individuals in higher-income countries experience invisible water insecurity, wherein specific households or individuals lack access to sanitation and clean water despite the relative wealth of their country. In the United States, invisible water insecurity tends to manifest as a result of homelessness, a lack of plumbing facilities, and water utility shutoffs. Using a water shut-off dataset from the Detroit Water and Sewerage Department, we investigate the relationship between a suite of demographic variables and the water shut-off rates in different neighborhoods throughout Detroit, Michigan. We find that shut-offs are more common in areas with more Black households that are more impoverished. Our findings indicate that this relationship links to structural disadvantage resulting from a legacy of racism and segregation in the city.

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Introduction

In 2013, the Detroit Water and Sewerage Department (DWSD) started shutting off water to thousands of residents to start collecting on overdue water bills and increase their revenue. At the time, the DWSD was a deeply indebted utility whose debt accounted for one-third of the city's total outstanding debt associated with its 2013 bankruptcy (Hackman, 2014; Guy & Leigh, 2022). Since the initiation of efforts to crack down on past-due bills, thousands of Detroit residents have had water services terminated for nonpayment. As of 2020, estimates suggested that over 140,000 homes have had water services shut off since the campaign began. The sheer volume of residents with terminated services garnered international attention and condemnation from the United Nations (Gottesdiener, 2014). While shutdowns were suspended during the COVID-19 pandemic, the moratorium on shut-offs was lifted on January 1, 2023, leaving thousands of Detroit residents at risk of losing water services (James, 2022). Estimates suggest that twenty-seven percent, or 170,000 Detroit residents, are at risk for water shut-offs (Corrigan, 2023). Detroit is not the only city in the United States with a water shut-off problem (Lakhani, 2020; Swain et al., 2020). In fact, millions of Americans in cities across the United

States have had their water disconnected and are without water (Lakhani, 2020). This lack of access to water is an invisible form of water insecurity that is beginning to garner widespread attention (Swain et al., 2020).

Water access, insecurity, and water-related diseases are essential issues that have garnered significant research (Jepson et al., 2017; Rosinger & Young, 2020). Most of this research focuses on these issues in lower-income countries (Adams et al., 2020). Still, it is crucial to note that many in higher-income countries also suffer from water insecurity (Meehan et al., 2020). The primary causes of water insecurity in otherwise water-secure countries tend to be a lack of plumbing facilities (or older galvanized plumbing materials, which, as they corrode, introduce lead and cadmium to the water flowing through them), homelessness, poor water quality, and water shut-offs. Many of these issues are correlated and tend to stem from poverty (Deitz & Meehan, 2019).

In the United States, thousands of households, particularly racial and ethnic minorities (e.g., American Indian/Alaska Natives, Black people, Hispanics), lack access to plumbing facilities. Deitz and Meehan (2019) introduced the concept of plumbing poverty to investigate infrastructural and social inequality concerning water access. Their findings indicate that plumbing poverty is not randomly distributed in the United States, but is concentrated within certain ethnicities and areas, most commonly those that are historically disenfranchised. Alarmingly, other studies find that some regions in the country are seeing increasing rates of plumbing poverty over time (Brown, 2020). Meehan et al. (2021) examine plumbing poverty in detail in three U.S. cities and find that despite overall levels of increasing urban wealth and household affluence, a simultaneous increase in wealth inequality and housing unaffordability leads to rising rates of plumbing poverty.

Meanwhile, another factor contributing to water insecurity in more-industrialized and higher-income countries is poor water quality, even when plumbing facilities are present. In the United States, a household with poor water quality is typically unsafe for one of two reasons. First, bacterial contamination (typically a result of fecal contamination) is rare but causes waterborne diseases such as giardiasis and leptospirosis (Painter et al., 2015). Second is the presence of lead, which is nearly always the result of corroding plumbing materials, such as pipes, fixtures, and faucets (Edwards et al., 2009). There have been several high-profile lead contamination events in recent history, including in Washington, D.C., where investigators found elevated lead levels in children in the early twenty-first century, and Flint, Michigan, starting in 2014 (Pieper et al., 2017). In Flint, the drinking water source was changed from Lake Huron to the Flint River, a more corrosive water source. No additional corrosion inhibitors were introduced after the change, so the rate of lead leaching from the plumbing increased (Pieper et al., 2018). Hanna-Attisha et al. (2016) found elevated blood lead levels in children throughout Flint, mainly concentrated in areas of lower socioeconomic status (likely a result of aging infrastructure in those locations). Lead poisoning can negatively impact childhood neurological development and is associated with reduced intelligence and behavioral issues (Hou et al., 2013). Furthermore, these effects of lead poisoning are irreversible.

Related to plumbing poverty, homelessness is also a cause of water insecurity. In Phoenix, Arizona, for example, homeless people struggle with infrequent and inconsistent access to water sources, such as water fountains or trucks (DeMyers et al., 2017). For many of these individuals, bottled water is the primary or only source of water used for drinking and sanitation, with its expense perpetuating a cycle of homelessness and water insecurity. To alleviate these issues, many ad-hoc encampments exist along rivers and canals, which then serve as water sources. However, this type of untreated surface water is often unsafe for drinking, with Verbyla et al. (2021) finding that bacterial contamination increases as one moves downstream along the San Diego River. In addition, many purpose-built homeless encampments have inadequate or no sanitation infrastructure, contributing to the spread of disease within the tent cities. In Fresno, California, thousands of homeless individuals lived in an encampment with no sanitation infrastructure, although the city began providing sanitation services after numerous protests and petitions (Speer, 2016). Even amongst the homeless, racial disparities exist, with water insecurity more common among non-white homeless individuals than those who are white (Gasteyer et al., 2016).

Finally, the fourth source of water insecurity is water shut-offs. This aspect of insecurity is particularly pernicious because they are not captured in

traditional metrics of water and sanitation (Gleick, 2016). Furthermore, it is typically understudied, with most water insecurity research focusing on contaminants (Meehan et al., 2020). In the United States, water shut-offs are nearly always the result of a household failing to pay their water or sewage bill. This outcome frequently occurs in older, deindustrialized cities with a shrinking tax base (Swain et al., 2020). For example, Baltimore, Philadelphia, and Detroit experienced prolonged periods of decreasing tax revenue due to residents, particularly wealthier residents, moving elsewhere. In addition, many water utility costs are fixed, so their rates increased accordingly and were thus shouldered predominantly by poorer households that could not afford to leave (Butts & Gasteyer, 2011). Studies indicate that water insecurity is associated with psychological stress and that, irrespective of water supply status, financial stress is associated with paying for water services (Gaber et al., 2021).

This study contributes to research about water insecurity by investigating the insidious issue of water shut-offs which are not detectable using traditional measures of water security (e.g. access to plumbing). Using a unique geocoded database about water shut-offs and restorations for the City of Detroit in 2015, we analyze the geography of water shut-offs and factors that explain the incidence of shut-offs. These household-level shut-offs are associated with a suite of demographic data, and we construct several statistical models to determine the relationship between these characteristics and the rate of water shut-offs. Our findings indicate that water shut-offs are more common in poorer neighborhoods with higher percentages of minority populations.

The case of Detroit, Michigan

Detroit, Michigan, is a unique location to analyze the geography of water shut-offs. In 2014, the city made international news when it began to shut off water services due to nonpayment for thousands of residents across the city (U.N., 2014). These shut-offs represented an effort to recoup revenues for the Detroit Water and Sewerage Department in the wake of the city's historic 2013 bankruptcy filing. The bankruptcy filing represents the nexus of several historical trends related to globalization and

the decline of the manufacturing industry, reliance on debt financing, structural racism, and discriminatory housing practices against Black residents (Presbey, 2015). It also reflects the decline of federal funding for drinking water and wastewater systems in the United States, which places the burden of funding system builds and maintenance on state and local governments and consumers (Recchie et al., 2019).

At the close of the nineteenth century and the opening decades of the twentieth century, Detroit was a key hub of auto-manufacturing activity and home to several major automakers, including Packard Motors, Studebaker, and the famous big three automakers (Chrysler, General Motors, and Ford). It was also home to numerous supporting manufacturers specializing in tool and die, electronics, plastics, and metal forging (Sugrue, 2014). Many of the workers in these factories were Black and had migrated north to escape disruptions in the agricultural industry, Jim Crow, and racism in the South (Sugrue, 2014). At the height of its manufacturing dominance, Michigan contained 56% of all auto manufacturing jobs (Sugrue, 1995), and Detroit's population peaked in 1950 at 1,849,568 people (Tanner, 2017).

In the 1950s, manufacturing jobs began to shrink as industry left the city—seeking lower cost labor markets in the South and the Caribbean (Sugrue, 2014). As a result, between 1950 and 1960, the city lost 20% of its population. In 1967, years of racial tension and discrimination culminated in the 1967 riot, which accelerated white flight to the suburbs, further reducing the city's population. The city's decline continued throughout the 1970s and 1980s due to factors including the energy crisis of the 1970s, the 1981–1982 recession, and competition from foreign automakers (Sablik, 2013; Padnani, 2013). An underlying feature of this economic decline is the history of discrimination that is inextricably linked with the story of Detroit. This connection is important because it underscores the city's history of discriminatory housing practices and the disproportionate impacts on the Black community of deindustrialization and disinvestment that continue to plague its residents (Sugrue, 1996; Moody et al., 2022). Currently, Detroit ranks as the most segregated city in America; the City of Detroit is 78% Black, while the suburbs are 68% White and 23% Black (Menendian et al., 2021).

The 2008 financial crisis was also crippling for Detroit, particularly amongst underrepresented groups who were more likely to have subprime mortgages (Presbey, 2015). In 2008, the big three automakers asked Congress for a bailout to deal with the effects of the Great Recession. Vacancy rates in the city soared, and around 2009, the average home price in Detroit was $7,500, and 29% of people were jobless (Harris, 2009). Poverty and vacancy rates also soared; 36% of people in the city had incomes below the poverty level, and vacancy rates in 2010 were around 27% (Padnani, 2013). In the wake of the crisis, homes were selling for as little as $1, leaving vast swathes of the city unoccupied and ripe for vandalism (McGreal, 2010; Schindler, 2016). Since 2005, one-third of the properties in the cities experienced foreclosure because of unpaid taxes or past due mortgages (Kurth & MacDonald, 2015. This nexus of population decline, elevated vacancy rates, and poverty posed problems for the provision of essential social services in the city (Padnani, 2013).

In short, continued population losses and a declining tax base placed Detroit in a vicious cycle of borrowing to cover revenue shortfalls (Schindler, 2016). As a result, the city filed for bankruptcy in the summer of 2013 (Reindl, 2019). The reasons for this bankruptcy are undoubtedly multi-faceted. Still, some core elements included pension and healthcare obligations to retirees, a declining tax base, and payments to service debt obligations, a large portion of which were related to the city's water and sewer services department (Kurtzleben, 2014). Efforts to reduce expenses and pay down debts resulted in privatizing basic public services and public property (Peck and Whiteside, 2016). For example, in 2014, trash collection services were awarded to two private companies, Rizzo Environmental Services, and Advanced Disposal, to save the city $6 million annually (Burns, 2014). The decline in the city's police force due to budget cuts meant that citizens hired private security companies to make up for gaps in service (Doucet and Smit, 2016). Additionally, there was pressure on pensioners to accept lower payouts to prevent the sale of pieces from the Detroit Institute of Art collection (Presbey, 2015). The sale of foreclosed properties at deep discounts also appears to have benefited speculators and other private interests more than families aspiring to homeownership (Presbey, 2015; Peck

and Whiteside, 2016; Schindler, 2016; Moody et al., 2022).

The history of the DWSD

The history of the DWSD also reflects the historical inequities between Detroit residents and those in the suburbs. Today, services are provided to 126 municipalities in seven Michigan counties (DWSD, 2022), a much larger service area than in 1955 when the city serviced only 44 suburban municipalities. As the utility's service area expanded, so too did conflicts about the means to pay for the system expansion (Kronberg, 2016). In the 1970s, Detroit proposed a series of rate hikes to finance the rising costs of providing service in an era of rising federal regulations and declining federal aid for water systems (Kornberg, 2016). White suburbanites opposed rate increases in favor of debt financing. This opposition to rate hikes meant that the debt obligations of DWSD ballooned: in 1970, about 30% of revenues were allocated to debt financing. This percentage grew to 80% by 2010. The 37 years of federal oversight of DWSD, which began in 1977, is also noted as a reason for the enormous debt load carried by the utility (We the People of Detroit, 2016). This reliance on debt service strained system revenues and was compounded by financing operations and maintenance for a system overbuilt due to faulty population projections. Specifically, projections from 1959 suggested that the population of Detroit would be 1.96 million people by 2000 when the actual population in 2000 was 950,000 (Kornberg, 2016).

Detroit filed for bankruptcy in July 2013 (Lafferty, 2018). At the time of the filing, DWSD accounted for one-third ($6.4 billion) of the $18 billion of debt of the City of Detroit (Peck and Whiteside, 2016; We the People of Detroit, 2016). Privatization of the water system was a consideration prior to bankruptcy. Concerns grew when Veolia Water reviewed DWSD and recommended how DWSD could reduce costs (Presbey, 2015). The alternative to privatization was a regionalization of the system under one authority (Recchie et al., 2019), a solution adopted in 2014 with the creation of the Great Lakes Regional Water Authority (GLWA). Today, the GLWA is responsible for the management and operations of the DWSD across the City of Detroit and Wayne, Oakland, and Macomb counties (GLWA, 2021).

Studies note several inequities associated with the GLWA leasing agreement (We the People of Detroit, 2016; Recchie et al. 2019; Moody et al., 2022). Under the restructuring agreement between DWSD and GLWA, suburban users of the water system are charged wholesale rates by GLWA, and city dwellers pay retail rates (Mesmer et al., 2020). This outcome means that the water charges to city residents are higher than those for suburban residents. GLWA's lease agreement also upholds the 1999 Rate Settlement Agreement, which apportions costs related to the systems' combined sewer system into an 83/17 split—meaning Detroiters are responsible for 83% of sewer system costs even if the system serves consumers outside of Detroit, leaving suburban residents responsibly for the remaining 17% (Recchie et al., 2019). Furthermore, the current system is problematic because it frequently becomes overwhelmed during storm events which can cause sewage to leak and contaminate water bodies, posing public health risks (Recchie et al., 2019).

Another visible consequence of the bankruptcy for DWSD customers was the decision to pursue water shut-offs to recover about $90 million in past due amounts from an estimated 90,000 delinquent customers to pay down debt (Wisely, 2014; Swaine, 2014). The volume of shut-offs drew international attention from UN Special Rapporteurs about this violation of the human right to water and sanitation (UN News, 2014). The focus on residential accounts is also controversial. Many scholars and activists note that deciding to collect on residential rather than commercial accounts was unjust because commercial accounts accounted for a larger proportion of past-due amounts (Presbey, 2015). This approach is different from other cities grappling with delinquent accounts. In Baltimore, Maryland, for example, the city chose to focus collection efforts on corporate accounts and customers with the largest past-due balances (Recchie et al., 2019). This effort mitigated the impacts of shut-offs on the most impoverished households in Baltimore.

Methods

Data sources

We obtained information about water shut-offs and restorations in 2015 from Food and Water Watch (FWW), which received these data from the City of Detroit Water and Sewerage Department (DWSD). Although efforts were made to obtain data directly from DWSD via a Freedom of Information Act (FOIA) request, this request was ignored. There were 23,298 shut-offs and 12,894 restorations in 2015. The attributes associated with these shut-offs and restorations made it possible to determine the water service shut-offs because of nonpayment. In the 2015 file, 15,083 of these shut-offs fell within Detroit's municipal boundary.

We draw the demographic data used in this study from the American Community Survey (ACS) 5-year estimate from 2013 to 2017. Specifically, we use ACS tables containing data on educational attainment, median household income, and racial and ethnic populations from the U.S. Census Bureau at the tract level within Wayne County, Michigan (U.S. Census Bureau, 2017). In addition, we obtained the entire Detroit parcel shapefile from Detroit's GIS Services office within the Department of Innovation and Technology (Detroit 2021).

Data about income, race, and age are incorporated in the statistical analysis, given news coverage that water shut-offs disproportionately affect the poor, the elderly, and racial/ethnic minorities. In addition, we include the percentage of vacant homes, given the high incidence of empty homes in the city (CRC, 2022). The age of homes is also important, given that older homes are expensive to upgrade and maintain and may have outdated plumbing. All analysis takes place using U.S. Census tracts as the unit of analysis. In the following section, we detail the calculation process for tabulating water shut-off and restoration events at the tract level. Table 1 describes all of these variables used in the analysis that follows.

Geocoding

The Detroit Water and Sewage Department's two datasets were masked to preserve household-level anonymity. The water shut-off dataset's addresses were anonymized such that the last two digits of each street number were missing—so '1350 Madison St.' becomes '13XX Madison St.' Meanwhile, the water restoration dataset was anonymized similarly, but with the first two digits of each street address masked. In this dataset, '1350 Madison St.' would be listed as 'XX50 Madison St.' This type of masking presents

Table 1 List of the datasets used to develop the models in this paper

Dataset	Type	Source
Water shut-off data	Data on all water shut-offs in Detroit during 2015	DWSD
Population	Population count and age distribution	ACS
Ethnicity/race	Percentage of population that is Black, white, Hispanic, Asian, Native American, or all others combined	ACS
Educational attainment	Percentage of the population that has a high school diploma or equivalent, the percentage with a Bachelor's degree, and the percentage with a post-graduate degree	ACS
Household income	Median household income	ACS
Renter/owner status	Rates of household home ownership (rather than rent)	ACS
Resident disability rate	Rate of population disability	ACS
Housing unit count	Count of housing units	ACS
Housing age	Age of housing units	ACS
Vacancy rate	Rate of vacant homes	ACS

some geocoding difficulties. Still, the fact that two datasets were available mitigates this difficulty to some degree.

The first step in geocoding these observations was to de-anonymize the data entries where possible. For example, each water shut-off and restoration observation contained a customer ID number. When a particular customer had their water turned off and restored in 2015, an entry was present in both datasets representing these outcomes. Because the masking techniques between the datasets differed, it became possible to completely de-anonymize these entries, as long as the street number of the address had at least four digits. For example, if a given shut-off had an address listed as '13XX Madison St.,' and that same customer (as indicated by the customer ID number) had their water restored that same year, the restoration address would be listed as 'XX50 Madison St.' Since we were able to determine that both entries corresponded to the same household, it was possible to completely un-mask these data, meaning that the actual address of '1350 Madison St.' was known. This outcome was possible in 15% of the data—the remaining 85% did not have a corresponding entry in the opposite dataset, so the actual address could not be determined.

For these observations, we leveraged a medoid geocoding technique, as described in Helderop et al. (2023). First, all possible matching addresses were determined using the Detroit parcel shapefile for each masked address. For example, '13XX Madison St.' would produce a list of potential candidate addresses

containing '1300 Madison St.,' '1310 Madison St.,' '1320 Madison St.,' etc. Depending on the length of the street, some candidate lists had only a single address, meaning that, once again, the exact address of the data observation could be determined. For lists with two candidates, one was randomly chosen and assigned as the 'true' address for geocoding purposes. For lists with more than two candidate addresses, the medoid address was determined (the centermost address of the candidates). As outlined in Helderop et al. (2023), this method minimizes the spatial error associated with geocoding masked data. Based on the resulting geocode matches, we assigned each observation to the Census tract in which it fell. We implemented this process using a custom Python script.

Model construction

Several statistical models were constructed with varying suites of independent variables (demographic and health) to determine which particular arrangement best explained the variance in shut-off rates across Census tracts in Detroit. In one set of models, the dependent variable was the shut-off rate itself, treated as a continuous variable. This set of models are ordinary least squares (OLS) models with the following specification:

$$y = \alpha + \beta X + \varepsilon \qquad (1)$$

In these models, y is the shut-off rate in terms of the number of shut-offs per 1,000 people. X is

a matrix of covariates, β is a vector of coefficients on our covariates, α is a constant, and ε is an error term. To understand the relative risk of residing in Census tracts with a higher level of shut-offs, we estimate logit models of the following form:

$$\Pr(y = 1 | x) = \frac{e^{x'\beta}}{(1 + e^{x'\beta})} \qquad (2)$$

In these models, we assign Census tracts a binary variable that denotes whether they are high or low for shut-offs. We threshold this value at the median rate of shut-offs across our study area. Tracts with a shut-off rate equal to or exceeding the median rate are designated high-shutoff tracts, while those with a shut-off rate lower than the median value are designated low-shutoff tracts. In these models, x is a matrix of covariates, and β is a set of odds ratio estimates for each covariate. An odds ratio greater than one indicates that a given variable increases the probability of residing in a Census tract with a high incidence of shut-offs. Odds ratios less than one indicate a decreased probability of living in a Census tract with an increased incidence of shut-offs. We implemented all of these models in R.

Results

Figure 1 shows shut-off rates by Census tract within the city boundary of Detroit. Several neighborhoods are notable for their high shut-off rates—Brightmoor neighborhood in northwestern Detroit is a predominantly Black neighborhood that suffered from extreme depopulation beginning in 1970 (Cornelissen, 2022) and has experienced consistently high crime until recently. In northern Detroit, Nolan, a lower-income neighborhood with a low cost of living, also exhibits high rates of shut-offs. Unfortunately, the neighborhood has poor public schools and relatively few local jobs. Most residents have a high school diploma or some college education. The Fox Creek neighborhood is located on the east side of Detroit (Perna, 2020), and, despite its proximity to one of the wealthiest neighborhoods in the region (Grosse Pointe), Fox Creek also experienced high rates of household water shut-offs in 2015 (Detroit Urbex, n.d.). This neighborhood, and several others in the area, were once the center of the auto industry in the 1940s and 1950s and have since suffered substantial job losses and depopulation (Detroit Urbex, n.d.). Barton-McFarland was similarly hollowed out during the 1950s and has had trouble recovering due to

Fig. 1 Water shut-off rates in Detroit census tracts
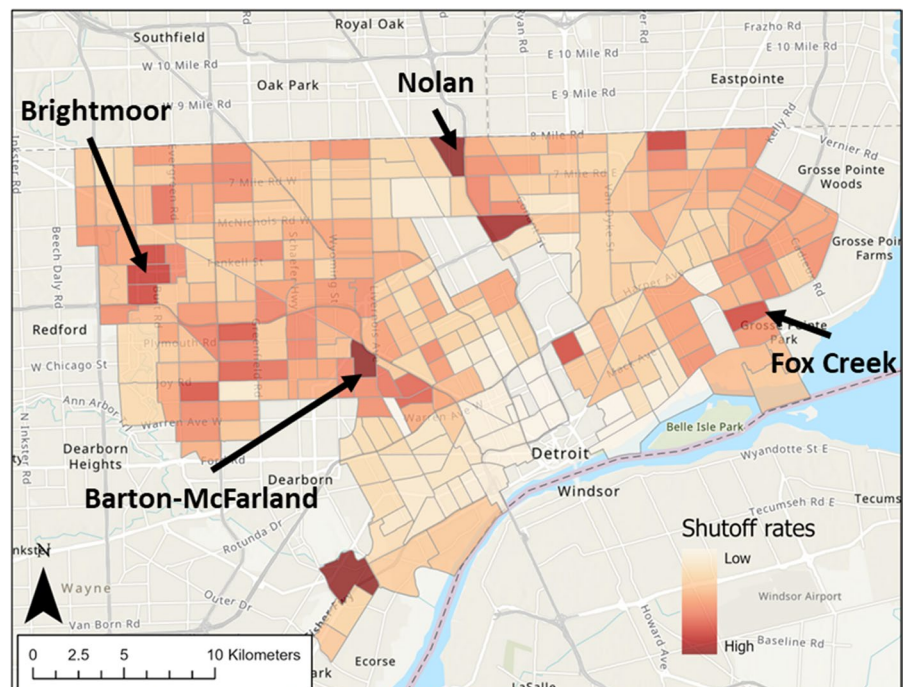
consistent public disinvestment and the proximity of nearby freeways that have depressed residential property value. The gaps in coverage in Fig. 1 are primarily the cities of Hamtramck and Highland Park. While Detroit surrounds them, they are technically separate cities, and we could not obtain shut-off and restoration data for those areas.

In our study area of Detroit, there are 283 unique Census tracts, forming the sample size of the modeling framework. Table 2 displays a select group of characteristics of these 283 Census tracts by quartile of shut-off rates. A comparison of these quartiles indicates that Census tracts in the top quartile of shut-offs have majority Black populations, high vacancy rates, low household incomes, and low levels of educational attainment. They also have the largest percentage of homes built between 1940 and 1960. Interestingly, the percentage of homes built before 1939 is not an indicator of a high incidence of shut-offs. Instead, tracts with a large portion of older homes appear in the first quartile of shut-offs—alongside the largest percentage of the newest homes, built in the last several decades. This trend, along with the corresponding information about household income and educational attainment, suggests that these Census tracts contain residents with the knowledge and resources to upgrade old homes. They may have even sought out these homes for purchase and renovation (although it is essential to note that Black households face significantly more difficulty obtaining competitive home mortgages than white households; Quillian

et al., 2020). The lower shut-off tracts are also home to more recent builds.

Given these trends, Table 3 displays the ordinary least squares (OLS) regression results to help us understand the relative importance of these factors simultaneously. Four of the variables in this model are positively associated with a higher incidence of shut-offs: the percentage of the population that is Black, the percentage of vacant homes in a tract, higher rates of home ownership, and the presence of older homes, specifically those built between 1940 and 1960. These results align with our expectations and previous literature examining water insecurity in higher-income countries. Invisible water insecurity occurs primarily in structurally disadvantaged subpopulations that experience poverty, which is essentially what our model indicates. Residents who owned homes built between 1940 and 1960 may have bought just before white flight decimated their home

Table 3 Ordinary least squares model results.

Independent var	Coefficient	*p*-value
Percent Black	**19.655**	**0.012**
Vacancy rate	**70.292**	**< 0.001**
Ownership rate	**60.402**	**< 0.001**
Median household income	−6.023	0.236
Disability rate	3.532	0.902
Population aged 65 +	**-0.875**	**0.011**
1940–1959 house construction	**55.135**	**< 0.001**

The bold fields are significant at the 5% level

Table 2 Select census tract characteristics by shut-off rate quartile

	Shut-off rate quartile			
	1	2	3	4
Mean shut-off rate (per 1000 people)	8.6	20.2	27.3	39
Mean percent Black	58%	89%	91%	90%
Mean median household income	$28,000	$29,000	$27,000	$28,000
Mean ownership rate	41%	54%	50%	53%
Mean poverty rate	41%	37%	40%	38%
Mean vacancy rate	26%	28%	31%	34%
Mean bach. degree attainment	7%	5%	4%	4%
Rate of construction pre-1939	50%	36%	30%	31%
Rate of construction 1940–1959	24%	49%	54%	55%
Rate of construction 1960–1979	11%	9%	10%	10%
Rate of construction 1980–1999	7%	3%	4%	2%
Rate of construction post-2000	7%	2%	3%	2%

values and did not have the financial means to leave. These homes may also require infrastructural repairs, particularly for plumbing or sanitation, that the residents cannot afford. Interestingly, however, household income is not a significant explainer of the shut-off rate. While it is impossible to determine this definitively based on this analysis, income may not be a significant explainer of Detroit's shut-off rate because the city has a Black majority population. As a result, nearly all of the Census tracts in our study area have significantly higher Black populations than would be the case in most other U.S. cities.

Table 4 displays the results of a logit model that indicate the probability of living in a tract with an above-median shut-off rate. We present model results as odds ratios. Three of the variables included in this model are notable for their large odds ratios: the percentage of Black residents, the percentage of vacant homes, and the percentage of homes built between 1940 and 1960. More residents aged 65 and over reduces the likelihood of residing in a tract with a high incidence of shut-offs, although this (barely) misses statistical significance at the 5% level. These findings are similar to the OLS model above and align with our expectations.

Discussion

In the United States, millions of people suffer from water insecurity because of water shut-offs (Lakhani, 2020; Romm et al., 2021). Unfortunately, it is difficult to assess who suffers from this invisible source of water insecurity because timely and comprehensive datasets detailing water shut-offs (and their

Table 4 Logit regression model results

Independent var	Odds ratio	p-value
Percent black	**10.642**	**0.006**
Vacancy rate	**214.453**	**< 0.001**
Ownership rate	8.719	0.101
Median household income	1	0.969
Poverty rate	2.293	0.662
Bach. degree attainment rate	< 0.001	0.088
Population aged 65 +	0.932	0.053
1940–1959 house construction	**135.267**	**< 0.001**

The bold fields are significant at the 5% level

restorations) are difficult to obtain. The results of our analysis of water shut-offs in Detroit found that the percentage of Black residents, home vacancy rates, home age, and ownership rates were all significant factors in explaining the presence of water shut-offs at the tract level. These findings align with prior work noting that suburban, primarily white, higher-income households experienced cheaper water rates and more forgiving payment plans than those offered to inner-city, primarily Black, lower-income households Moody et al. (2022). There are suggestions that water shut-offs in Detroit are discriminatory and target Black residents (ACLU Michigan, 2021). Our study provides empirical evidence that race is a substantial factor in explaining a high incidence of shut-offs, even after controlling for income.

Our analytical findings are another example of the history of structural racism in Detroit that disadvantages Black residents (Zenk et al., 2005; Hollis, 2018; McClure et al., 2019). Detroit's history of redlining fueled the segregation of Black residents from white residents (Sugrue, 1996; Zenk et al., 2005; Silverman, 2005). These practices produced disadvantages for Black residents, which are still visible today (Zenk et al., 2005; Hollis, 2018; McClure et al., 2019). For example, Hollis (2018, p. 94) concluded that Detroit's high homicide rates are "driven by concentrated disadvantage and deprivation". Zenk et al. (2005) noted that residential segregation in Detroit placed Black residents in disadvantaged neighborhoods, which reduced their access to supermarkets. Seymour and Akers (2022) found that the wave of foreclosures that followed the subprime mortgage lending crisis disproportionately affected Black residents in Detroit and created conditions that further segregated the city. Many of these homes were bought by investment firms, with Eisenberg et al. (2020) finding that children from households living in investor-owned properties in Detroit exhibited higher exposures to lead due to contaminated drinking water. This legacy of segregation also yields public disinvestment in poorer, inner-city neighborhoods in favor of spending public monies in areas with wealthier, whiter households. These outcomes create conditions that effectively continue the practice of historic redlining—perpetuating segregation between Black and white households in Detroit and continuing the transfer of wealth from the poorer, primarily Black households to richer, typically whiter households.

Presently, the delivery and charges associated with water and wastewater services in Detroit are not equitable. Detroit residents are involved in (effectively) a state-sponsored reverse subsidy where poorer households pay more for water services than wealthier households in the suburbs (Whitener, 2020). Many Detroiters also find themselves in a situation where they cannot pay for water services. Bridge Magazine highlights an example of unaffordable water, profiling a woman living on $790 in social security each month. She experienced a shut-off and has continued to live without water because she cannot afford to pay the $5,000 in plumbing repairs necessary to restore water to her home (Kurth, 2019). Many residents in Detroit find themselves in deep poverty with very little monthly income, making it challenging to pay past due bills to get water services turned on or repair homes. This entrenched poverty highlights the need for water rates that are affordable to residents. Compounding these challenges, the unbanked population in the United States is predominantly blacker and poorer than the average citizen, making it difficult to pay bills and work out a payment plan for an account in arrears (Celerier and Matray, 2014).

We note that many utility companies have affordability programs to help avoid water shut-offs for poorer residents, disabled residents, older residents, and residents on social security. However, the accessibility and reach of those programs vary widely between municipalities. The DWSD does offer several programs to help disadvantaged customers pay their bills, such as the Water Residential Assistance Program and the Low-Income Household Water Assistance Program, which gives households $650 toward their water bills (City of Detroit, n.d). However, when past-due bill amounts dramatically exceed the ability of households to pay, these programs may be insufficient in helping residents to avoid shut-offs. Studies also note that the GLWA's commitment to contribute 0.5% of its operating revenues to water assistance programs is insufficient to meet the needs of the residents of Detroit (Recchie et al., 2019).

Unaffordable water is particularly critical to address when considering the consequences of unpaid water bills and water shut-offs. In many places, the inability to pay for water means people can lose their homes (Povich, 2019; Montag, 2019). In Detroit, utilities can place a lien on homes for unpaid water bills, resulting in foreclosure if the residents fail to address the lien. Additionally, homes without water service may be deemed blighted and demolished (Detroit Blight Removal Task Force, 2014; We the People of Detroit, 2016). Homes that have had their water turned off due to nonpayment may also be deemed unfit for children (Moody et al., 2022). Illegally accessing water after a shut-off is also considered a felony subject to up to five years of imprisonment (Moody et al., 2022). Furthermore, unlike other cities in the United States, Detroit faces legal barriers that prohibit the implementation of income-based billing for water services (Guillen, 2016; Kurth, 2019; Mack et al., 2020).

Future work and limitations

That said, there are limitations to our findings. The first limitation is the cross-sectional nature of our study, meaning these results represent a snapshot of one moment in time and may be different for other periods. A second limitation is that our data are specific to Detroit and do not necessarily apply to other locales. A third limitation is the representativeness of our data on water shut-offs in 2015, given that we obtained the data from a second party. We attempted to obtain data through a separate FOIA submitted to the DWSD, but they did not respond to this request. Sadly, this appears to be a common result (We the People of Detroit, 2016; Moody et al., 2022) and part of a broader problem of municipal unresponsiveness to FOIA requests (Helderop et al., 2019). To ascertain the representativeness of the shut-off numbers in this study, we checked the number of shut-offs in our dataset against news articles from different outlets—the figures align, when comparisons are possible.

Some of these limitations offer fruitful avenues for future work. For example, with multiple consecutive years of data, time series analyses of water shut-offs would be possible. This analysis would provide a deeper understanding of the propensity of particular tracts to be cut off from water services multiple times. In addition, the analysis conducted in this paper could be extended to other study areas with different racial/ethnic mixes to see whether our results stay consistent or are context-dependent. Baltimore would make for an interesting counterpoint to Detroit. It is a racially divided and impoverished city but chose to handle collection on past due accounts differently, prioritizing shut-offs for corporate accounts and consumers

with the highest balances (Recchie et al., 2019). Future work could also investigate the link between water shut-offs and adverse physical and mental health outcomes (Gaber et al., 2021; Plum et al., 2017). Lastly, more work is needed to understand the racial dimensions of the emergency management of cities. Since 2009, six of the nine Michigan cities placed under emergency management make up 49.8% of the Black population in the state (We the People of Detroit, 2016; Recchie et al., 2019). One can argue that decisions made under emergency management have widened racial disparities between residents. More work is needed to understand the actors behind these emergency decisions and their consequences for residents of these cities.

Conclusion

"Water insecurity is a term in this report used to describe the presence of structural, systemic, and institutional arrangement that ensures everyone has consistent access to drinking water and wastewater services." (Recchie et al., 2019, pg. 5). Water shut-offs for nonpayment in Detroit are an unfortunate example of this form of invisible water security. This paper investigated the geography of water shut-offs and the factors that explain these shut-offs. The findings indicate that in Detroit, water shut-offs are linked to structural disadvantages resulting from a legacy of racism and segregation in the city.

Declarations

Conflict of interest   The authors have no conflict of interest to report.

Human and animals rights   This research did not involve human participants or animals.

Informed consent   This research did not involve research participants and thus does not require informed consent.

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