Why Are Toxic Clean-ups Taking So Long? The Role of Time in the Remediation of Environmentally Contaminated Sites

Tessa Davis

Occidental College

Senior Comprehensive Project: Department of Urban and Environmental Policy

Professor Rodnyansky, Professor Cha, and Professor Matsuoka

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ABSTRACT

Toxic cleanups are complex and take time. However, the longer a person is exposed to toxic elements, the worse their public health outcome. Chronic exposure, especially to chemicals such as lead, leads to a higher risk of health problems. With that in mind, generally, a faster cleanup would be better for community health. This paper investigates how long toxic cleanups take and why. Specifically, we examine sources of funding[1] for each cleanup and the poverty[2] of the community surrounding the site. This study used linear regressions to determine if poverty and funding source are significant predictors of the duration of a cleanup. Our research concluded that funding type is a significant predictor of cleanup time. Specifically, government-funded cleanups take the longest to clean. This indicates that government-funded cleanups are not efficient, resulting in increased risk to community health problems. We recommend changes in DTSC[3] structure and DTSC financial assurance[4] regulations to protect public health and prevent prolonged toxic exposure.

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[1] Funding is the money provided to pay for the cleanup of a toxic site. Funding type or party is the title of the group that pays.

[2] This paper defines poverty as the raw population percentage of each census tract that lives below twice the FPL. The Federal Poverty Line (FPL) is the "measure of income issued every year by the Department of Health and Human Services (HHS)" (Federal Poverty Level (FPL) - HealthCare.Gov Glossary, n.d.). Twice the FPL is used because of the high cost of living in California.

[3] The DTSC is the California Department of Toxic Substances Control. The DTSC's mission is to "protect California's people, communities, and environment from toxic substances, to enhance economic vitality by restoring contaminated land, and to compel manufacturers to make safer consumer products" (California, n.d.-a).

[4] Financial assurance is when owners and operators of hazardous waste facilities maintain financial resources to pay for the closure, maintenance and monitoring, and cleanup of their facilities(California, n.d.-d)

INTRODUCTION

In the United States, cleanups of contaminated sites are heavily regulated. This paper investigates environmental catastrophes and the factors that influence the speed of their clean-up. We ask three questions:

1. Is the length of time it takes to clean up environmentally contaminated sites correlated with who is financially responsible for these clean-ups?
2. Is the length of time it takes to clean up environmentally contaminated sites correlated with poverty?
3. Is the length of time it takes to clean up contaminated sites correlated with poverty and who is financially responsible for the clean-up? Restated: Does the effect of poverty on clean-up time depend on who funds the cleanup?

These research questions came to fruition through an understanding that it is in the interest of public health to clean toxic sites more efficiently. Not all cleanup sites are equivalent, their sources of funding and their surrounding communities are different. Through an examination of the related literature below, we discovered how these disparities impact the cleanup process. The process of finding and holding a responsible party[5] accountable for their contamination takes time, finding funding for sites without a responsible party is difficult, and community make-up is an important consideration when prioritizing site cleanups—communities of low-income need to be cleaned up quicker for the sake of their health.

Thus, this paper continues to build on previous research and fill gaps related to cleanup time and poverty. This study can serve as a starting point for further research into contaminated sites, their sources of funding, the health of surrounding communities, and time as a variable of importance. This research also serves to explore environmental justice[6] as it determines the role of poverty in the pace of cleanups. Through this research, communities, advocacy groups, and

[5] Responsible parties are current property owners or operators, past owners or operators at the time of pollution, people who arranged for the release of toxic substances, and people who transported the toxic substances (California, n.d.-f).

[6] As defined by the US EPA: Environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation and enforcement of environmental laws, regulations, and policies (O. US EPA, 2015a).

government agencies such as the California Department of Toxic Substances Control (DTSC)[7] and the Environmental Protection Agency (EPA)[8] will realize the significance of time as it relates to public health. They will be encouraged to rethink the clean-up process and reprioritize the clean-up of sites.

Data for these variables were independently gathered from the DTSC database, EnviroStor. Adequate sample size was acquired and analyzed through quantitative correlation analysis. The sites explored in this paper are in California and were contaminated by lead before being cleaned to DTSC standards.

For all three research questions, we used linear regressions to estimate if source of funding, poverty, or the interaction between the two are significant predictors of how long it takes to clean up contaminated sites.

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[7] The DTSC is the California Department of Toxic Substances Control. The DTSC's mission is to "protect California's people, communities, and environment from toxic substances, to enhance economic vitality by restoring contaminated land, and to compel manufacturers to make safer consumer products" (California, n.d.-a).

[8] The U. S. EPA is a federal agency tasked with environmental protection. Part of their mission is to regulate the remediation of contaminated land and toxic sites (O. US EPA, 2013).

BACKGROUND

This background section covers toxic site regulations in California and the case study of Exide. Descriptions of the financial, regulatory, and health aspects of the Exide case provide insight into the role of the DTSC, the problems communities face, and the necessity of change in public policy. California is the focus of this study because we call this state home and hold a particular interest in California's policies. Additionally, California has a certain amount of pride in its environmental initiatives and has been seen as a pioneer of environmental legislation (Davenport & Nagourney, 2017). Therefore, this paper aims to help readers and California legislators recognize how California can continue to create and introduce new environmental policies for the benefit of its citizens. Also, this research could not be performed on the entire United States because of resource issues and conflicting policies between states.

In California, contaminated land restoration is managed by the DTSC. The DTSC receives authorization from the U.S. EPA to implement the Resource Conservation and Recovery Act (RCRA)[9]. Part of the RCRA hazardous requirements is "[establishing] standards for the generation, transportation, treatment, storage, and disposal of hazardous waste in the United States" (D. staff, 2021b). Therefore, the DTSC regulates properties that interact with environmental contaminants from their beginning. Another part of the DTSC's job is "overseeing the evaluation and cleanup of contaminated properties throughout the state of California" (D. staff, 2021c). DTSC not only enforces RCRA regulations but also supervises clean-ups.

An example of the DTSC's involvement with contaminated properties is the case of Exide. Exide is a former secondary lead battery recycling plant in the City of Vernon, California. The company's operations released harmful levels of lead and arsenic into the communities surrounding the property for decades. This is an extreme health risk as "exposure to high levels of lead and arsenic increases the risk of cancer, breathing diseases, and learning problems" for the more than 100,000 people in the surrounding communities (*Background of Exide Contamination | Los Angeles County Department of Public Health - Environmental Health*, n.d.).

The facility operated from 1922 until 2014. After 1988, Exide operated under an interim-status authorization, which allows a facility to continue to operate while their permit application

[9] RCRA is the Resource Conservation and Recovery Act, which creates the framework for toxic waste management. It gives the EPA the authority to control hazardous waste (O. US EPA, 2015b).

is reviewed. In March 2014, Exide stopped operations because they needed to install new equipment to meet South Coast Air Quality Management District (SCAQMD)[10] requirements. Operations never continued because, in 2015, Exide withdrew its application for a Hazardous Waste Facility Permit after the DTSC informed Exide of its plans to deny their permit application (D. staff, 2021a). A couple of months later, the DTSC terminated the facility's interim status authorization to manage hazardous waste and requested the cleanup of the site and surrounding impacted properties (D. staff, 2021a). Exide promised $50 million for cleanup of the facility and surrounding community (Service, 2020).

In April 2016, Governor Brown signed into law AB 118. This allocated $176.6 million from the California General Fund as a loan to the Exide cleanup to prompt testing and cleanup of all residential properties, schools, parks, and childcare facilities in the preliminary investigation area (D. staff, 2021a). This helped fund the sampling of 1,500 sensitive use properties and cleanup of 50 residential properties which were completed in June 2016. However, even in 2016 residents called for faster cleanup. They'd already experienced decades of toxic exposure when Exide operated under a permit and they called for more urgency and funding from the state (*L.A.-Area and State Officials Call for Quicker Cleanup of Exide Plant Contamination - Los Angeles Times*, n.d.).

The Final Closure Implementation Plan was approved by the DTSC in late 2017. The DTSC-approved plan includes three phases. In general terms, phase one involves the removal of hazardous waste units and sampling of subsurface soil and soil gas, phase two addresses contaminated soil, and phase three includes post-closure work to implement long-term care of the property. Phase one began in November 2017 and was predicted to finish in late 2020 (D. staff, 2021a). In 2019, Governor Newsom allocated $74.5 million to address increased costs and increase the number of properties cleaned (California, n.d.-e).

However, due to the COVID-19 pandemic, cleanup operations ceased in Spring 2020. Soon after this, Exide filed for Chapter 11 bankruptcy. A United States Bankruptcy Court granted Exide Chapter 11, liquidation bankruptcy in late October 2020. This meant that Exide was no longer a viable responsible party. In the bankruptcy settlement, the state made Vernon

[10] South Coast Air Quality Management District (SCAQMD) is the air pollution agency that regulates sources of air pollution in Southern California. Each state needs to attain National Ambient Air Quality Standards (NAAQS) for certain pollutants. SCAQMD adopts and implements measures that prepare a portion of the State Implementation Plan (SIP). Part of their authority is regulating hazardous air pollutants (*Authority*, n.d.).

Environmental Response Trust (VERT)[11] the new responsible party to prevent the site from abandonment (D. staff, 2020). About $29 million was placed in the trust from the bankruptcy settlement, much less than the $50 million Exide promised (R. 09 US EPA, 2021). The rest of the cleanup is predicted to cost California taxpayers around $650 million (Twitter et al., 2020).

During these months while Exide, the DTSC, and federal courts were determining who held responsibility for funding this cleanup, the community surrounding the former facility felt the effects of dangerous lead and arsenic levels. Soil lead concentrations exceeding the DTSC's screening level for lead were identified in nearly all residential properties in the preliminary investigation area[12] (D. staff, 2021a). It was not until November 2020 that remediation started again (R. 09 US EPA, 2021). As of August 2021, phase one of three was just 64% complete (D. staff, 2021a).

In late 2021, Governor Newsom allocated $322.4 million to be allocated over three years "to complete cleanup of 3,200 parcels and add 2,700 additional parcels with soil-lead concentrations above 200 parts per million" (California, n.d.-e). In early 2022, the DTSC had cleaned 3,200 residential parcels. The DTSC has celebrated this accomplishment and asserted that its cleanup pace was the fastest across all lead cleanup projects in the country (California, n.d.-e). However, while these parcels have been remediated, there are still thousands of properties to be cleaned (*Officials Celebrate Exide Cleanup While Some Homes Still Unchecked For Lead*, 2022). 1,400 properties have yet to be sampled (California, n.d.-e). With current funds, the DTSC expects to clean all properties by March 31, 2025 (California, n.d.-c).

To summarize, Exide operated from 1922 until 2014, with around 25 years of operation under an interim permit. The facility closed in 2015, with expectations to finish site closure in 2020. However, the site was yet to be closed in 2021. As of March 18, 2022, 3,520 of 5,940 contaminated sites were cleaned. Within the preliminary investigation area, there are 10,161 parcels and only 8,601 have been sampled. The DTSC expects to clean all 5,940 parcels by 2025. However, this estimate does not include sites within the preliminary investigation area that have not been sampled, nor sites outside the preliminary investigation area that may be contaminated.

[11] The Vernon Environmental Response Trust is the trust set up by the U. S. Federal court settlement when Exide filed for bankruptcy. The EPA oversees the Trust, ensuring RCRA and DTSC Closure Plans are followed (R. 09 US EPA, 2021).

[12] The Preliminary Investigation Area is the area within a 1.7-mile radius of the site.

During this time, Governor Newsom allocated $573.5 million, whereas Exide contributed $29 million (California, n.d.-c).

The Exide case study reveals key questions about the process of clean-ups. The fact that Exide operated for about 25 years without a permanent permit prompts the following questions: How many interim permits are in effect in California today? What is the average amount of time they have been active? How can the state be held accountable for allowing Exide to operate for 33 years without a permanent permit while harming the surrounding community? Is this a common occurrence? Have other toxic sites operated with an interim permit for decades? How is environmental justice ensured when cleaning contaminated sites?

These are important questions, and this paper cannot endeavor to explore all of them. Instead, our research is focused on a specific theme: time. An overarching question we examine is: What factors determine the speed of a clean-up? The Exide property was shut down in 2015. The site only began to be actively cleaned in 2017. The government acknowledged that the site needed to be evaluated and cleaned up in 2015 and since then, the impacted community has suffered. Looking at contaminated sites across California, how long does it take to clean up a site? Determining who was financially responsible for Exide's clean-up accounted for much of the time of inaction. The Governor's budget allocations took time as well. Is the party that funds the clean-up associated with clean-up time, and therefore the health of the surrounding community? The communities impacted by Exide's contamination are "Bell, Boyle Heights, East LA, Huntington Park, and Maywood, predominantly Latino and working class communities" (Pulido et al., 2016). When considering environmental justice and looking at these variables, does the socioeconomic make-up of the surrounding community influence the pace of clean-up?

In posing and answering these questions, this research will be used by organizations serving communities impacted by contaminated sites, help reform regulatory and legal procedures surrounding cleanups, and shed light on measurable and actionable initiatives relating to environmental cleanups. For the health of communities across California and the United States, contaminated sites need to be cleaned up more efficiently, prioritized accurately, financed accountably, and undertaken with environmental justice as a core value. I hope that this research can be used by the DTSC, U. S. EPA, California's EPA chapter, USC's Program for Environmental and Regional Equity (PERE), UCSF's Environmental Research and Translation for Health (EaRTH) Center, California's Department of Public Health. and other research and policy organizations to make progress in the fields of public health, environmental justice, and health policy.

LITERATURE REVIEW

Considering the large amount of literature on environmentally contaminated sites, we will focus on the topics most relevant for this research project: time, financial responsibility, who decides financial responsibility, and environmental justice. In the section discussing time, this paper reviews literature that analyzes the importance of time to the health of communities and the prioritization of cleanups. Within our conversation on financial responsibility, the importance of funding is explored along with the benefits and drawbacks of each source of funding: responsible parties, governmental sources of funding, and voluntary parties[13]. In the section discussing how the DTSC decides who funds a cleanup, we explain the process of determining a responsible party and an orphan site[14]. Finally, in the environmental justice section, this paper explores the factual injustice of current and historical cleanup programs as well as poverty as a factor to consider when exploring public health and cleanup efficiency.

Time

Public health is protecting and improving the health of people and their communities while also working to reduce health disparities[15]. This is done by trying to prevent problems from happening or recurring through the implementation of educational programs, policy recommendations, administering services, and conducting research (*What Is Public Health?*, n.d.). Within this field, time is an important variable, especially when considering toxic sites. The longer a person is exposed to toxic elements, the worse their public health outcome. Exposure to a contaminant is defined as contact between a person and a contaminant at a specific concentration for a specific amount of time (Epidemiology, 1991). Essential to this definition is time. Both short-term (acute) as well as long-term (chronic) exposures impact human health. Chronic exposures are "continuous and repeated contact with a toxic substance over a long period of time…Over time, some chemicals, such as PCBs and lead, can build up in the body"

[13] A voluntary party is a group that agrees to cover the expenses for the cleanup of a toxic site and requests DTSC oversight, evaluation, investigation, and/or cleanup activities and have agreed to provide coverage for DTSC's administrative costs (*BF_FS_VCP.Pdf*, n.d.-b).

[14] An orphan site is hazardous site where the responsible party is unknown, or unable and unwilling to pay.

[15] As defined by the CDC, the Centers for Disease Control, "health disparities are differences in health outcomes and their causes among groups of people" (*Strategies for Reducing Health Disparities 2016 - Minority Health - CDC*, 2020).

(*About Exposure*, n.d.). The more time a person is surrounded by toxic sites, the more chances they have of being exposed to contaminants. With chronic exposure, especially to chemicals such as lead, the more risk of health problems. With that in mind, generally, a faster cleanup would be better for the community.

Time is a difficult variable to find in writings about contaminated sites. Most literature on this topic is at the federal level and does not look at each site's cleanup time as it relates to other cleanup variables. Scholars Daley and Layton (2004) looked at the Superfund program[16] as a whole and analyzed how many sites were cleaned each year. They concluded that "since 1993, over 500 Superfund sites reached the construction completion stage in remediation" (Daley & Layton, 2004). In the program's first 13 years (from 1980 to 1993), only 156 sites reached that point. Daley and Layton explore why some Superfund sites were more likely to be remediated than others, specifically looking at administrative costs, the severity of each problem, and political pressure. They found that the EPA is more likely to clean sites that were easier to remediate or had low risk (Daley & Layton, 2004). This suggests that sites with less detriment to public health are cleaned more efficiently than sites with larger public health impacts. Sites with larger risks to public health were left un-remediated for longer periods. As Superfund cleanups are funded by both government and responsible parties, this describes how cleanups, irrespective of funding, are not prioritizing public health because they are not connecting the length of time a site is left unclean with the health of the community. The EPA's mission is to protect human health and the environment (O. US EPA, 2013). However, the existing literature on time suggests that cleanups prioritize sites based on ease of cleanup, not public health urgency.

Time is also a significant variable when considering health disparities and toxic sites. Researchers Burda and Harding (2014) investigated Superfund cleanups but looked at their durations to determine if they were independent of the racial and economic profile of the site's neighborhood. They found that discrimination was prevalent at the beginning of the Superfund program but lessened over time. Specifically, Executive Order 12898, which aimed to prevent discrimination in environmental policies, was established in 1994 and was a turning point in

[16] The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) was passed in 1980. CERCLA is also known as Superfund and allows the EPA to clean up toxic sites. One aspect of CERCLA is that it requires the responsible party of the contamination to clean up the site or reimburse the government for cleanup work. If there is no responsible party, Superfund can use money from a Trust Fund, sourced from taxes (O. US EPA, 2017).

Burda and Harding's analysis (Burda & Harding, 2014). After 1994, they found that cleanups in economically burdened communities were prioritized.

These pieces of literature focus on Superfund sites and EPA regulations. This research needs to be repeated at the state level and there needs to be more research on the interaction between poverty, funding party, and time. Our research begins that process and helps identify problems with the current prioritization of cleanups.

Financial Responsibility

A good example of disagreements about financial funding responsibility can be seen in the U. S. EPA's Superfund program. The Superfund program is built on the idea that the polluter pays. The program, when possible, abides by the "Polluter Pays Principle" (Hird, 1993). The polluter pays principle means the party responsible for pollution should bear the costs of managing it (Hird, 1993). The responsible party includes current property owners or operators, past owners or operators at the time of pollution, people who arranged for the release of toxic substances, and people who transported the toxic substances (California, n.d.-f). The idea behind the polluter pays principle is that it enforces environmental law and prevents environmental harm that cannot be recovered. In that way, Superfund attempts to protect the environment, and, in the case of environmental contamination—human health. However, Hird (1993) argues that attaining funding from polluters is often not possible or is a long arduous process. This is especially true for past contaminations that are only recently discovered (Hird, 1993). Anderson (1996) agrees and, after examining the Superfund program and state programs modeled after it, declares how those responsible for funding cleanups would be more likely to provide funding if they were given benefits. With polluter pays enforcement, polluters are disincentivized to cleanup sites (Anderson, 1996). Authors Hamilton and Viscusi (1999) agree. They discuss how the financial costs of an environmental cleanup were not worth the health benefits of remediation. An example from their research is how the expected number of cancers averted by remediation was less than 0.1 cases per site. The cost per cancer case averted was over $100 million (Hamilton & Viscusi, 1999). This suggests that cleanups are extremely expensive and the health benefits from remediation are not always a priority to those who are paying. For such expensive cleanups, Anderson thinks that states should give tax benefits or other financial incentives to those responsible for funding cleanups so that the endeavor is voluntary, not mandatory (Anderson, 1996). This article suggests enforcement, or punishment for polluting, does not favor public health. Instead, financial benefits from the private sector are the solution to sluggish cleanups.

When the responsible party does not or cannot pay, federal or state funding takes its place. However, current news articles describe how federal and state money comes from taxes—either corporate or individual. Today, the federal Superfund program is funded partially by the government (with public taxes) and partially by responsible parties. The program used to be funded by taxing corporations, but that ended in 1995. From the Washington Post, Bryan Anderson addresses how Congressional funding has been steadily decreasing and less money means fewer sites being cleaned up (Anderson, 2017). They suggest that federal funding is not consistent or dependable. Taxpayers do not want to be responsible for a company's pollution and Congress is unlikely to tax corporations again. Currently, no one solution works. The literature suggests that the current funding systems as they relate to responsible parties and government funding are not effective.

Another source of funding, with little academic research, is voluntary party funding. A voluntary party is a group that agrees to cover the expenses for the cleanup of a toxic site and requests DTSC oversight, evaluation, investigation, and/or cleanup activities, and has agreed to provide coverage for DTSC's administrative costs (*BF_FS_VCP.Pdf*, n.d.-b). The basis behind this option is that sites with lower priority compete for DTSC resources. To avoid that, a site advocate can have their site cleaned up more quickly if they fund the remediation and DTSC oversight. However, this requires an advocate already willing and able to pay for the cleanup of their site.

It is clear from the above literature that attaining funding for toxic cleanups is complex and full of political and private motivations. Responsible parties have few incentivizes to efficiently clean a site and government parties face political obstacles. Only proponents with the means can become a voluntary party, making that funding option a limited solution.

Process for Determining Financial Responsibility

While examining how the DTSC determines who pays for cleanup is not a direct question in this study, it provides important context for our research. Each toxic site requires an evaluation by the DTSC to determine if there is a responsible party. The following process applies to State Superfund sites, as those sites make up most of our sample.

As stated before, the DTSC abides by the Polluter Pays Principle. The implication is that if the responsible party does not pay, the public pays through tax dollars. Therefore, the department tries its best to find the responsible party. This can be difficult if the site is historically contaminated, and the current owner is not the responsible party. If that is the case, the DTSC "investigates if anyone sent hazardous material to a site for treatment, storage, or disposal, looks at who owns and who once owned the property, and looks at current and past operators on the land and if they had insurance policies" (*DTSC-Cost-Recovery-Summary-January-2016.Pdf*, n.d.). There needs to be a clear connection between the responsible party and the contamination—whether that be temporal, location-related, etc. This is often challenging and takes time. If a responsible party is identified, the DTSC determines if they can pay. If the responsible party can pay, the DTSC attempts to have them cover cleanup costs. This becomes more complicated if the responsible party files for bankruptcy, if an insurance policy is active, or the party has passed away and the DTSC needs to file a claim (*DTSC-Cost-Recovery-Summary-January-2016.Pdf*, n.d.).

If the responsible party is not found or cannot pay, the DTSC classifies the site as an orphan site and government funds are used. Funding for orphan sites is prioritized based on public health. Funding first goes to sites with "immediate and acute conditions requiring a time critical response" (California, n.d.-f). Second, sites with ongoing operation and maintenance of remediation systems to prevent exposure to communities or the environment are financed. Next to receive funding are sites with actual human exposure and resource impacts. Then sites with potential exposures under current conditions are backed. Last to receive support are sites with potential exposures under future conditions (California, n.d.-f). The order is interesting, as sites with the potential for preventative action come before reactive remediation opportunities. This process is contained within one funding body and the DTSC decides which sites belong in which priority ranking.

A good example of this process can be seen in the Exide case study. The situation of Exide, described in the background section, illustrates the confusion of financial liability and responsibility. The DTSC database describes the Exide situation and the various issues with funding (D. staff, 2021a). This database narrates the history of Exide, the latest Exide bankruptcy news, and the current remedial efforts. Of the latter, stalled cleanup efforts and difficulty with funding are emphasized. In situations such as Exide, there are loopholes, such as declaring bankruptcy, which restarts the process of finding another source of funding and stalls the cleanup once more. Determining financial responsibility for cleanup is a long and arduous process. Finding funding is intertwined with the cleanup's progress as sites need funding to begin remediation. This has long-lasting impacts on the progress of the cleanup and the length of time residents are exposed to toxins. This case study suggests that this process needs to be streamlined for community health.

Environmental Justice

As defined by the US EPA: environmental justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income concerning the development, implementation, and enforcement of environmental laws, regulations, and policies (O. US EPA, 2015a). Environmental justice has not been assured in the location of hazardous sites (*Toxic Waste and Race*, 2021). As described earlier, there was discrimination in the cleanup of sites as well (Burda & Harding, 2014). Burda and Harding found that discrimination was prevalent at the beginning of the Superfund program but lessened over time, especially after 1994. However, this analysis was done at the federal level. Therefore, it is unknown if location affects clean-up time at the state level.

When considering the cleanup of environmentally contaminated sites, what do regulators think about? Hird (1993) determined that the prioritization of cleanups depends on a site's potential health hazard and is not motivated by the surrounding communities' socioeconomic characteristics when examining federal Superfund cleanups. This suggests that the community health impact of contamination is at the forefront of cleanup prioritization. However, communities with different socioeconomic characteristics have different reactions to pollution. For example, more low-income communities are more likely to become ill from pollution (*Disparities in the Impact of Air Pollution*, n.d.). This suggests that the same level of pollution would affect low-income communities stronger than wealthier communities and compels us to consider is socioeconomic characteristics should be considered when prioritizing cleanups.

Many socioeconomic variables are included within the environmental justice. Poverty is a clear variable. CalEnviroScreen[17] attempts to describe disproportionate burdens of pollution due

[17] CalEnviroScreen is a tool "that helps identify California communities that are most affected by many sources of pollution, and where people are often especially vulnerable to pollution's effects". It uses "environmental, health,

to environmental injustice, including poverty. Within the CalEnviroScreen 4.0 Report, The Office of Environmental Health Hazard Assessment (OEHHA)[18] researched the influence of poverty heavily and concluded that "Poverty is an important social determinant of health…Impoverished populations are more likely than wealthier populations to experience adverse health outcomes when exposed to environmental pollution…Wealth influences health by determining one's living conditions, nutrition, occupation, and access to health care and other health promoting resources…[Low-income communities] have a higher exposure to pollutants and environmental hazards… [and] they experience increased susceptibility to poor health due to factors such as psychosocial and chronic stress…These factors combine to create environmental health disparities in low-income communities" (August, 2021, p. 0). This affirms that the clean-up of contaminated sites is especially important for communities of low income. Our research will explore this variable and determine if sites within low-income communities are cleaned up efficiently and with consideration of their population characteristics.

Addressing Gaps in the Research

Despite the research reviewed above, there are still a gaps in the literature, including the lack of research on the duration of cleanups as it intersects with both funding sources and poverty. While Burda and Harding investigated the socioeconomic aspects of communities and how they associate with cleanup duration, they did not study sources of funding or cleanups at the state level (Burda & Harding, 2014). This project helps fill that gap by examining the association between poverty and/or who is financially responsible for clean-ups and the length of time it takes to clean up contaminated sites in California. The next section will outline the key research questions, hypotheses, and methods to address this gap.

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and socioeconomic information to produce scores for every census tract in the state"(Witteborg, 2019). The data from CalEnviroScreen is from 2015-2019.

[18] The Office of Environmental Health Hazard Assessment (OEHHA) is the California state agency for assessing health risks associated with environmental contaminants. "OEHHA's mission is to protect and enhance the health of Californians and our state's environment through scientific evaluations that inform, support and guide regulatory and other actions" (Admin, 2019).

METHODS

Research Questions

1. Is the length of time it takes to clean up environmentally contaminated sites correlated with who is financially responsible for these clean-ups?
2. Is the length of time it takes to clean up environmentally contaminated sites correlated with poverty?
3. Is the length of time it takes to clean up contaminated sites correlated with poverty and who is financially responsible for the clean-up? Restated: Does the effect of poverty on clean-up time depend on who funds the clean-up?

Hypotheses

1. There is an association between funding and cleanup time—cleanups funded by responsible parties are associated with longer clean-up times; cleanups funded by voluntary parties are associated with shorter clean-up times. We hypothesized that responsible parties would take the longest to clean sites because they are motivated by profit. Voluntary parties would have the shortest cleanup time because they will not have to stall cleanups because of funding disputes.
2. There is an association between which sites were cleaned up faster and levels of poverty—sites cleaned up faster correlate with less poverty in the surrounding community. We hypothesized this because of the history of discrimination described in our literature review.
3. There is an interaction effect between levels of poverty and how clean-up sites were funded—the effect of poverty on clean-up time depends on the who funds the site. Our hypothesis is based on the history of discrimination described in our literature review and how we think that discrimination could vary based on funding source.

Sample

The population investigated is cleaned, previously contaminated sites under DTSC regulation in California. The sample is successfully cleaned up sites (i.e., no in-process cases) contaminated with lead[19] or lead and other contaminants.

When accounting for all exclusion criteria and missing data in EnviroStor[20], the final sample for this research was 170 records. This is an adequate sample size to determine an intermediate effect. In some ways this was a population level study as a random sample was not taken, rather data was gathered from all sites that met the criteria. Additionally, the amount of bias and confounding variables present in the analysis may be reduced because data was only chosen from one state (all sites under DTSC regulations) with a shared contaminant, lead. If the type of contaminant was not regulated, each site would need to be considered individually, not allowing for generalized conclusions. Each site was accessed from the database between January 23, 2022, and February 11, 2022.

The sites in our sample range from 1973 to 2018. The sample for this study is distributed across California, seen in Figure 1. The sample seems to concentrate around San Francisco, Los Angeles, and the San Joaquin Valley. As seen in Figure 2, these areas are the most densely populated parts of California. This aligns with previous research, showing most toxic sites are in highly populated areas (*Do You Live Near Toxic Waste?*, n.d.).

[19] Lead includes lead tetroxide, lead chromate, lead monoxide, lead carbonate compound, and lead tetraethyl.
[20] EnviroStor is the DTSC's data management system for tracking cleanups.

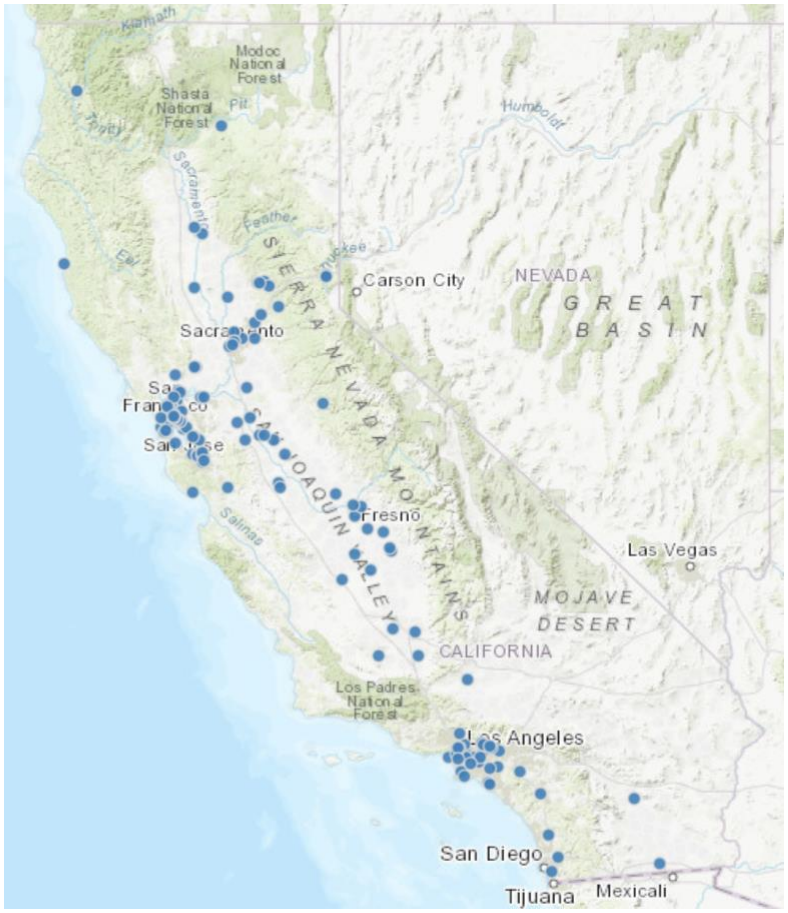

Figure 1. Geographical Distribution of Sample. This map illustrates the distribution of the toxic sites in my sample, seen as blue dots. From the map we can see that most of the sites in the sample are in the general area of San Francisco and Los Angeles, as well as along the San Joaquin Valley. This map was created using DTSC EnviroStor Data and was accessed from the California State Geoportal on April 3, 2022 (*Cleanupsites*, n.d.). The total sample is 170 sites.

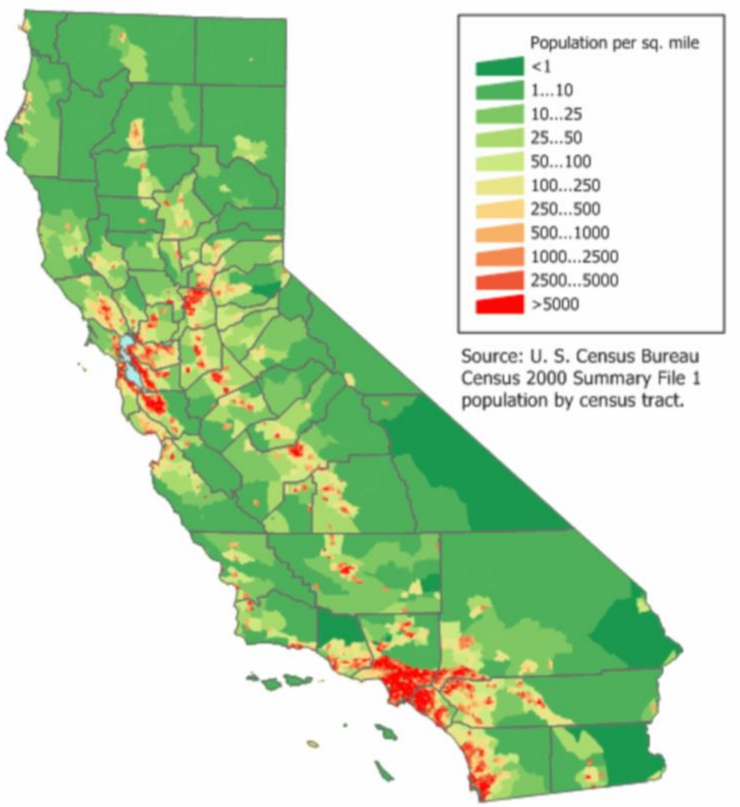

Figure 2. Population Density of California. This map describes the population density of California. The red areas are the densest parts of California. The areas of highest density are around San Francisco, Los Angeles, and the San Joaquin Valley. This map was accessed from the worldofmaps.net on April 5, 2022 (*Map of California (Population Density) : Worldofmaps.Net - Online Maps and Travel Information*, n.d.). The total sample is 170 sites.

Envirostor has a cleanup status variable to describe the department's current involvement at the site. Table A below shows the range of cleanup statuses. This study only included sites that are labeled "Certified". This status means that remediation was fully completed to the DTSC's standards. "Certified O & M" sites were not included because there is no clear end date to their remediation, making time a more difficult variable to calculate. "No Further Action" sites were not included because these sites have no confirmed contamination that posed a public health risk to begin with.

Table A. EnviroStor Cleanup Statuses. All cleanup status listed in the DTSC database are listed here along with their descriptions. This provides background for why only Certified sites were included in our sample. These definitions were taken directly from EnviroStor Glossary on September 25, 2021 (*EnviroStor Glossary.Pdf*, n.d.).

Cleanup Status	**Description**
Active	Remediation currently in process.
Backlog	Non-active sites that will become active once funds are available.
Border Zone/Haz Waste Property (BZP/HWP)	Located within 2,000 feet of a significant disposal of hazardous waste or have a significant disposal of hazardous waste.
Certified	Completed sites with previously confirmed release that are certified by DTSC or remediated under DTSC oversight.
Certified O & M – Land Use Restriction Only	Remedy is implemented and remedy results in hazardous substances remaining at the site at levels above what's required for unrestricted land use.
Certified Operations & Maintenance	Certified cleanups in place but require ongoing operations and maintenance. All planned activities to address contamination were completed, but some need to be carried out for years before complete cleanup achieved.
Hazardous Waste Disposal Land Use	Sites went through BZP/HWP evaluation, but not formally designated as either.
Inactive – Action Required	Non-active sites where remedial action is required.
Inactive – Needs Evaluation	Non-active sites where evaluation is required.
No Action Required	Phase I Environmental Assessment completed; no action required.
No Further Action	Completed sites where DTSC determined that it does not pose a problem to public health or the environment.
Referred	Identifies sites that were referred to a local agency to supervise
Referred: EPA	Identifies sites that were referred to U. S. EPA.
Referred: IWMB	Identifies sites that were referred to California Integrated Waste Management Board.
Referred: Other Agency	Identifies sites that were referred to another state or local agency.
Referred: RCRA	Identifies sites that were referred to DTSC's Hazardous Waste Management Program and are identified as RCRA.
Referred: RWQCB	Identifies sites that were referred to California Regional Water Quality Control Boards.
Referred: SMBRP	Identifies sites undergoing corrective action that were referred to DTSC's Site Mitigation and Brownfield Reuse Program.

Envirostor has a program type variable to describe certain characteristics of the cleanup site. From these variables shown in Table B, only "Corrective Action", "Federal Superfund", "State Response", "Tiered Permit", and "Voluntary Cleanup" were included in the sample. This excludes non-contaminated sites and in-process sites as well as military bases and healthcare facilities, as they are regulated differently.

Table B. EnviroStor Site Types. All site types listed in the DTSC database are listed here along with their descriptions. Also included are total count for each type included in our sample. This provides background for why certain sites were included in our sample. These definitions were taken directly from EnviroStor Glossary on September 25, 2021 (*EnviroStor Glossary.Pdf*, n.d.). Each site was accessed in EnviroStor between January 23, 2022, and February 11, 2022. Total sample size is 170 observations.

Site Type	Description	Included?	Count
Cal-Mortgage	Sites applying for their guaranteed loan insurance program for the construction, improvement and expansion of health care facilities and not expected to have had hazardous substances releases.	NO	0
Closed Base	Identifies closed military facilities with confirmed or unconfirmed releases and where DTSC is involved in investigation and/or remediation, either in a lead or support capacity.	NO	0
Corrective Action	Investigation or cleanup activities at RCRA or state-only hazardous waste facilities (that were required to obtain a permit or received a hazardous waste facility permit from DTSC or U.S. EPA).	YES	1
Evaluation	Identifies suspected contaminated sites that need or have gone through a limited investigation and assessment process. If found to have confirmed contamination, it will change from Evaluation to either a State Response or Voluntary Cleanup site type.	NO	0
Expedited Remedial Action Program (ERAP)	Identifies sites in the Expedited Remedial Action Program. These are confirmed release facilities/sites worked on by responsible parties with oversight of the cleanup by DTSC. This is a pilot program limited to 30 facilities/sites. (No ERAP facilities met our other conditions)	NO	0
Federal Superfund (NPL)	Identifies sites where the U.S. EPA proposed, listed, or delisted a site on the National Priorities List (NPL). The U.S. EPA typically has primary regulatory oversight for these sites. However, only NPLs with DTSC management were included in this sample.	YES	2
FUDS	Identifies military facilities that were Formerly Used Defense Sites (FUDS) with confirmed or unconfirmed releases and where DTSC is involved in investigation and/or remediation, either in a lead or support capacity.	NO	0
Hazardous Waste Property /	Identifies facilities/sites that went through the Hazardous Waste Property or Border Zone Property evaluation process.	NO	0

Border Zone Property Evaluation			
Historical	Identifies sites from an older database where no site type was identified. Most of these sites have a status of Referred or No Further Action. (No Historical sites met our other criteria)	NO	0
Open Base	Identifies open military facilities with confirmed or unconfirmed releases and where DTSC is involved in investigation and/or remediation, either in a lead or support capacity.	NO	0
Permitted	Facilities/sites that were required to obtain a permit or have received a hazardous waste facility permit from DTSC or U.S. EPA in accordance with the Health and Safety Code or RCRA.	NO	0
School	Identifies proposed and existing school sites that are being evaluated by DTSC for possible hazardous materials contamination. School sites are further defined as "Cleanup" (remedial actions occurred), or "Evaluation" (no remedial action occurred) based on completed activities.	NO	0
State Response	Identifies confirmed release sites where DTSC is involved in remediation, either in a lead or oversight capacity.	YES	69
Tiered Permit	A corrective action cleanup project on a hazardous waste facility that either was eligible to treat or permitted to treat waste under the Tiered Permitting system. Facilities in this category fall under the Permit by Rule (PBR) tier or Conditionally Authorized or Exempt tiers.	YES	1
Voluntary Cleanup	Identifies sites with either confirmed or unconfirmed releases, and the project proponents have requested that DTSC oversee evaluation, investigation, and/or cleanup activities and have agreed to provide coverage for DTSC's costs.	YES	96

Variables

Dependent Variable

Research Questions 1, 2, and 3

Length of time: This is an indicator of the efficiency of each cleanup. We researched this variable by looking through the documents of each site within EnviroStor. This variable was evaluated in terms of days taken to clean each site. Data permitting[21], a site's clean-up time started once contamination of the site was recognized by the DTSC. This was determined at the researcher's discretion with the information available on EnviroStor. The start date does not necessarily mean that cleanup started. This was intentional so that the variable 'time' includes the period between knowing about the health problem and completing the cleanup. During that period, funding and responsibility are often contended, therefore our research includes this period. In addition, the end date was determined by the date the site was cleaned, which was listed on each site's certification of completion paperwork. Any sites where only month and year were provided on EnviroStor were dated as the first of the month. Any sites with only year provided were dated January 1st of that year. As seen in Figure 3, the variable is skewed. Once log transformed, seen in Figure 4, time displays a normal distribution, necessary to meet the assumptions of our regression model.

[21] Not all sites had the same format describing discovery dates or dates of sampling that confirmed contamination. We used our best judgement to determine the most accurate dates. If we doubted the legitimacy of the dates provided, we excluded the site from our sample.

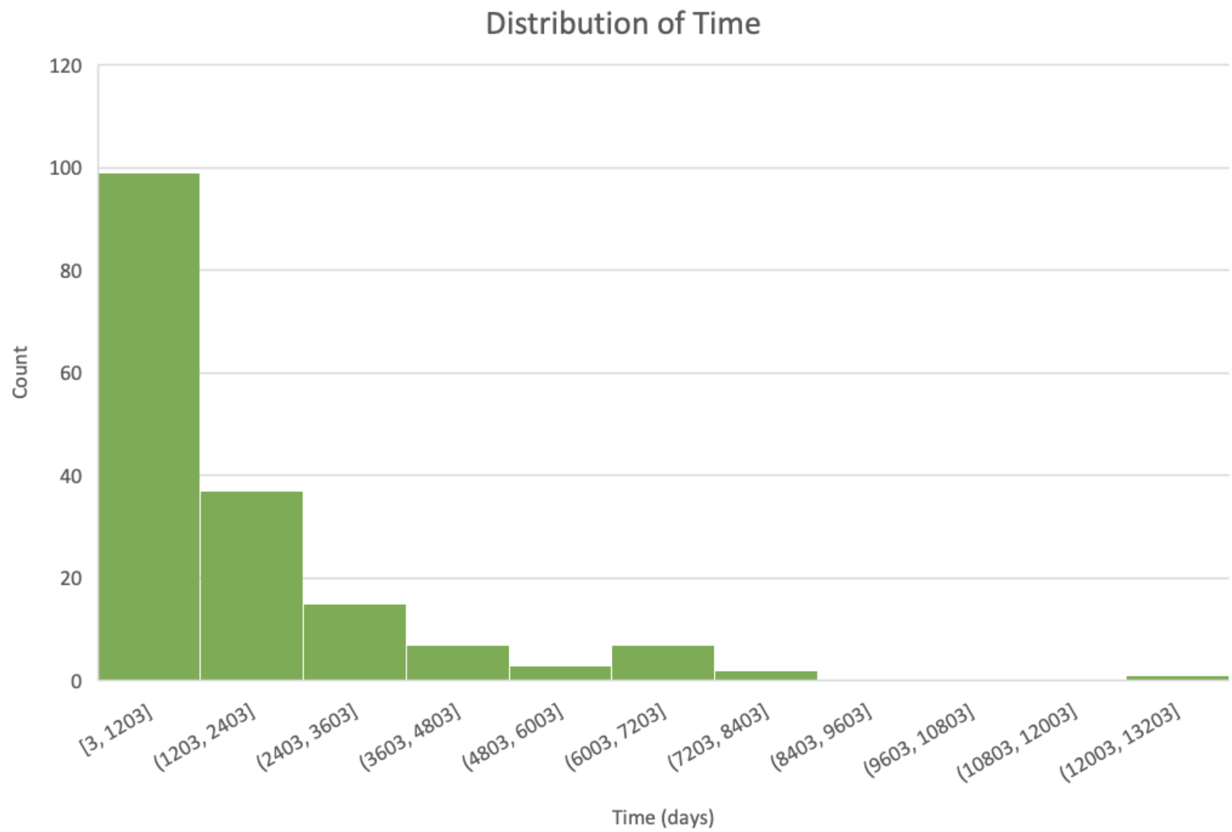

Figure 3. Histogram of the Variable Time. Histogram of time, before transformation. The variable is severely skewed to the right. Most sites were cleaned within 1203 days (more than three years), but one took as long as 13203 days (36 years) to clean. Total sample size is 170 observations.

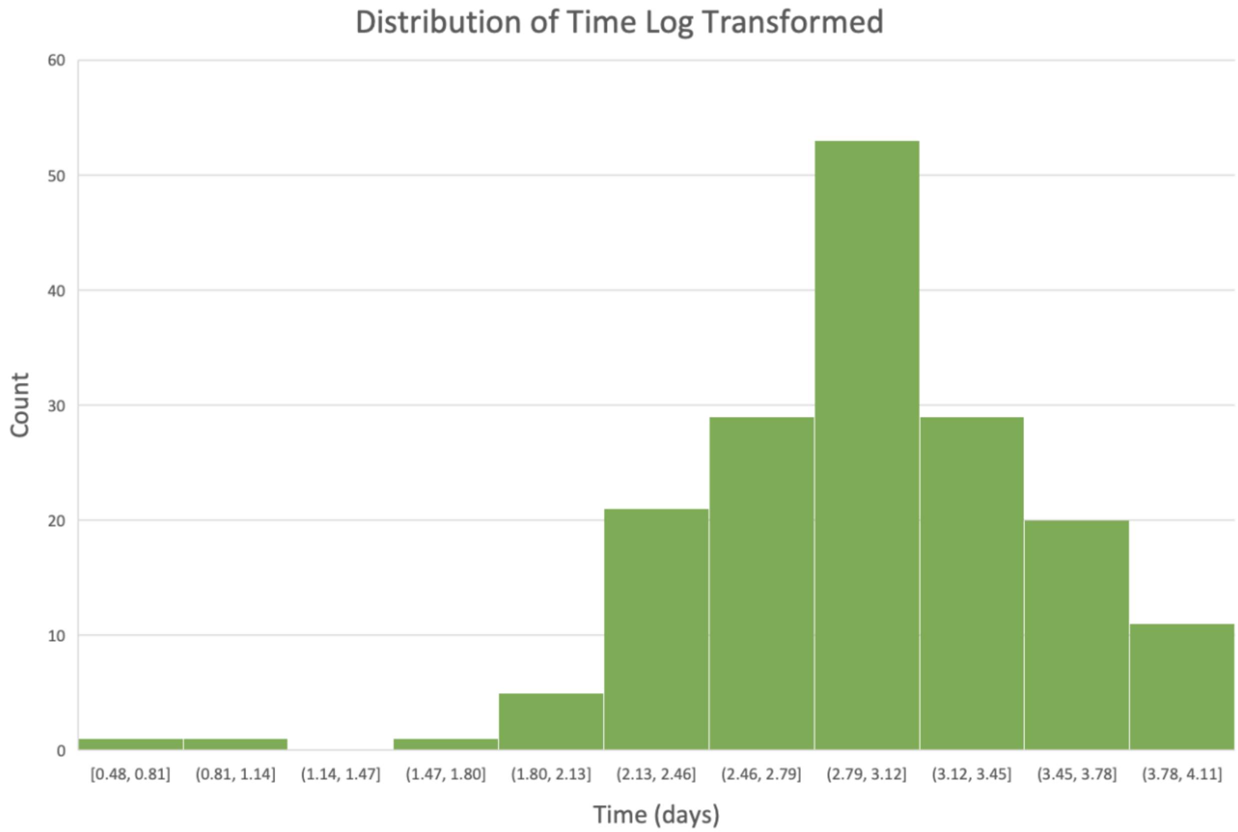

Figure 4. Histogram of the Variable Time, Log Transformed. Histogram of time, after being log transformed. The variable is distributed much more normally. However, there is a slight skew to the left. As seen in the Appendix A, Figure 11, removing the outliers does not change the skew of the histogram significantly. Total sample size is 170 observations.

Independent Variables

All Research Questions

Media: In addition to Site Type and Cleanup Status, different environmental aspects of each contaminated property may have affected how long it took to clean a site. To account for this, we added media as an independent variable to our equation. Media is defined as the material type contaminated. Table C illustrates how we organized different media types. From there, each site was assigned a number which describes how many types of media were contaminated at that site. For example, a site with surface water and soil contamination was assigned 2, because 2 media categories were contaminated. The distribution of numbers of media at each site is described in Table D.

Table C. Media Categories. This is the organization of different media types into larger categories. By organizing media by broader defining characteristics, the collection and organization of data was more straightforward. Each site was accessed in EnviroStor between January 23, 2022, and February 11, 2022.

Media Categories	**Description of Media Types**
Water	Surface water, well used for drinking water, groundwater (non-drinking), aquifer used for drinking water
Soil	Soil, sediments, surface/structure
Air	Soil vapor, indoor air
Structure	Structure

Table D. Distribution of Media
This table describes how media was organized for data analysis. After organizing data in categories, the number of categories contaminated in each site was counted. Total sample size is 170 observations.

Number of Media Categories Contaminated per Site	**Count in our Sample**
1	131
2	34
3	6

Size of Cleanup: Like media type, size, reported in acres, was a potential confounding variable when considering cleanup duration. As seen in Figure 5, size is severely skewed. Once log transformed, seen in Figure 6, size displays a normal distribution, necessary to meet the assumptions of our regression model. We attempted to make size a categorical variable as there were natural breaks in the log transformed histogram. However, this adjustment prevented our data from passing the assumptions necessary to perform a linear regression. Therefore, we kept size continuous.

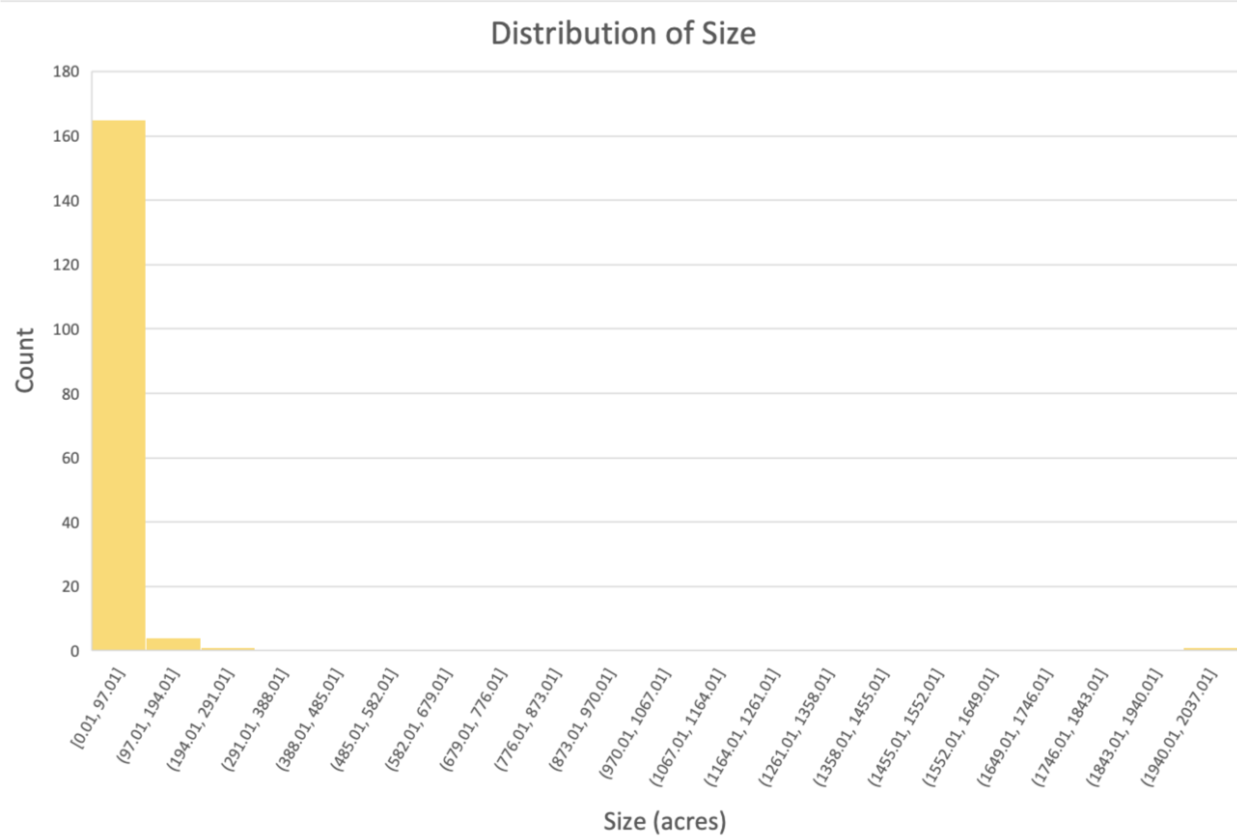

Figure 5. Distribution of Size. This figure is a histogram of size before being logged transformed. The variable is severely skewed to the right. Most sites are less than 100 acres, but one is as large as 2037 acres. Total sample size is 170 observations.

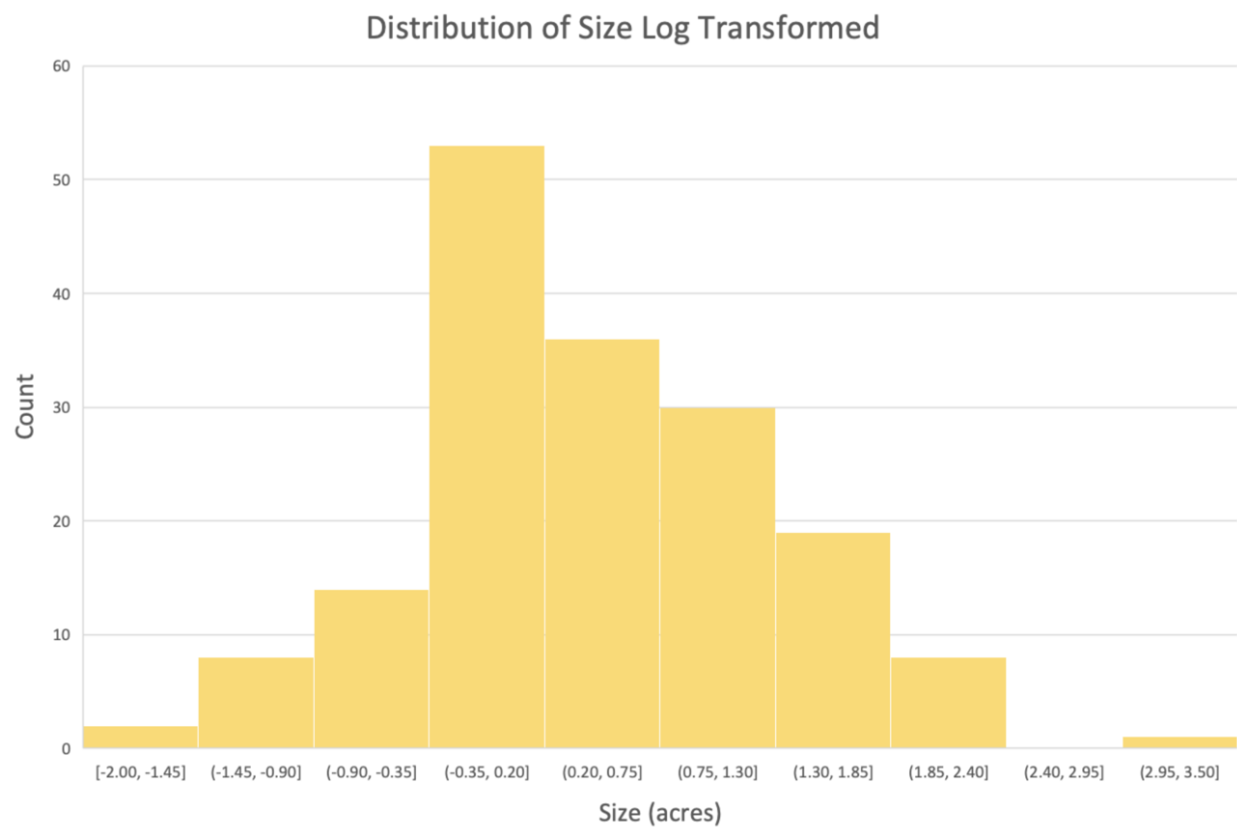

Figure 6. Distribution of Size, Log Transformed. This figure is a histogram of size after being logged transformed. The variable is no longer skewed. As seen in Appendix A, Figure 12, removing the outliers does not improve the distribution significantly. Total sample size is 170 observations.

Contaminant Type: We included sites with lead contamination because of the importance of cleaning this toxin quickly. The cleanup of lead contamination needs to be quick because lead can cause grave acute illnesses, but also severe chronic neurological illness (*Lead Poisoning - Symptoms and Causes*, n.d.). Although all sites in our sample have lead, some have lead in addition to other contaminants. The addition of more contaminants means that different techniques and methods will need to be used to clean sites in addition to more medias being affected and that can affect cleanup duration. To account for this, we organized contaminants into a binary variable of lead only or lead plus other contaminants. This is described in Table E.

Table E. Contaminant Distribution in Sample. This table describes how many sites in our sample have only lead or lead as well as other contaminants, for example other metals, pesticides, or volatile organics. Each site was accessed in EnviroStor between January 23, 2022, and February 11, 2022. The total sample size is 170 observations.

Contaminant	**Count**
Lead	47
Lead + other contaminants	124

Research Questions 1 & 3

Sources of Funding: This is one of our main variables for our analysis. Table F describes the sources of funding recognized by the DTSC. Table G describes how we organized funding types into the three categories we used for analysis: Government, Responsible Party, and Voluntary Party.

Table F. EnviroStor Funding Type. This table describes the sources of funding for contaminated sites under the DTSC. The last column describes whether the funding type is included in our analysis or not. Military bases and their related funding (MMRP, DERA, and BRAC) were not included in this research because they have different regulations and laws than other sites. The same applies to School District Funded sites. Additionally, Cal-Mortgage funding was not included because it is specific to health care facilities and their construction, improvement, and expansion, but not their clean-up. Unknown funding was not included because of lack of significant sample size, but also for ease of analysis. Site Proponent was included as a funding type as it is a type of funding particular to Voluntary Clean-ups. These definitions were taken directly from EnviroStor Glossary on September 25, 2021 (*EnviroStor Glossary.Pdf*, n.d.). Each site was accessed in EnviroStor between January 23, 2022, and February 11, 2022.

Funding Type	Description	Included?
BRAC (Base Realignment and Closure)	Department of Defense's funds used to close bases	NO
Cal-Mortgage	DTSC performs environmental assessments for the guaranteed loan insurance program for the construction, improvement, and expansion of various health care facilities.	NO

DERA (Defense Environmental Restoration Account)	Department of Defense’s funds used hazardous substances responses consistent with the Defense Environmental Restoration Program.	NO
EPA Grant	Funds provided to the DTSC through the U. S. EPA.	YES
Federal DOE-funded	Funds from the U. S. Department of Energy for grant oversight work.	YES
Joint State / Federal Funded	All or partial funding paid jointly by the State of California and the U. S. EPA	YES
MMRP	Funds from the Department of Defense’s Military Munitions Response Program. Addresses non-operational range lands with suspected or known hazards from munitions and explosives of concern.	NO
Orphan Funds	Responsible Party has not been identified, is insolvent, cannot be located, or recalcitrant or enforcement actions have not resulted in the responsible party performing the site activities. Includes state only as well as state/federal joint funds.	YES
Responsible Party	A private party or parties fund the site.	YES
School District Funded	A specific school district provides funds.	NO
Unknown Funding	At the time the DTSC recorded the site, the source of funding was unknown	NO

Site Proponent	Parties who fund a voluntary cleanup.	YES

Table G. Funding Variable. This table describes how each funding type included in our sample is organized for analysis an includes the count of each category within our sample. The total sample size is 170 observations.

Funding Variable	Description of Funding Types	Count in our Sample
Government	Orphan Funds, Joint state/federal funds, Federal DOE-funds, EPA grants, city funds (not described in the EnviroStor glossary, but seen in the database)	21
Responsible Party	Responsible Party	53
Voluntary Party	Site Proponent	97

Research Questions 2 & 3

Poverty: CalEnviroScreen is a tool "that helps identify California communities that are most affected by many sources of pollution, and where people are often especially vulnerable to pollution's effects". It uses "environmental, health, and socioeconomic information to produce scores for every census tract in the state" (Witteborg, 2019). The Federal Poverty Line (FPL) is the "measure of income issued every year by the Department of Health and Human Services (HHS)" and it is "used to determine…eligibility for certain programs and benefits, including savings on Marketplace health insurance, and Medicaid and CHIP coverage" (Federal Poverty Level (FPL) - HealthCare.Gov Glossary, n.d.). CalEnviroScreen determines what percentage of each census tract lives below twice the FPL and maps it. Twice the FPL is used because of the high cost of living in California. This study defines poverty as the raw population percentage of each census tract that lives below 200% the FPL. Additionally, poverty is evaluated as a categorical variable. Overburdened sites are in a census tract with 35% or more of their population in poverty. Sites in census tracts with less than 35% of their population in poverty are not overburdened. The New Jersey Environmental Justice Law from 2020 is the motivation behind using 35% as a cutoff for an overburdened census tract. While a New Jersey law, this is the first law in the United States to address the cumulative impact of poverty in the context of environmental justice (*NJDEP | Environmental Justice | Environmental Justice Law, Policy and Regulation*, n.d.). The data from CalEnviroScreen 4.0 is from 2015-2019. That is a potential concern as the sample for this study includes sites from 1973 to 2018. The distribution of this variable in our sample is described in Table H. A histogram of poverty as a continuous variable can be seen in Appendix A, Figure 13.

Table H. Poverty Distribution. This table describes the distribution of burdened communities in our sample. Burdened communities are defined using The New Jersey Environmental Justice Law from 2020. These data were taken from CalEnviroScreen on November 29, 2021 (August, 2021). The total sample size is 170 observations.

Community	**Poverty Percentage**	**Count in our Sample**
Burdened	More than or equal to 35% of each census tract lives below 200% the FPL	72
Not Burdened	Less than 35% of each census tract lives below 200% the FPL	99

Analysis

All research questions were analyzed using RStudio. Each question was statistically analyzed using a general linear regression model with factorial design. This method accounts for the several explanatory variables used to predict the outcome of how long it takes to clean up contaminated sites. Table I outlines our regression equations. A P-value < 0.05 was the chosen level of significance for this study because we wanted only a maximum of a 5% risk of concluding that a difference exists when there is no difference.

Table I. Research Question Equations. Regression equations for each research question.

Research Question	**GLM Equation**
1	time = a + b_{1a} * responsible party + b_{1b} * voluntary party + b_2 * size + b_3 * media + b_4 * contaminant
2	time = a+ b_1 * poverty + b_2 * media + b_3 * contaminant + b_4 * size
3	time = a+ b_{1b} * responsibly party + b_{1b} * voluntary party + b_2*poverty + b_3 * (responsible party * poverty) + b_4 * (voluntary party *poverty) + b_7 * size + b_5 * media + b_6 * contaminant

RESULTS

Research Question 1

Assumptions

To use a general linear model, specifically a multiple regression, the data needs to fit the following assumptions of a GLM:

- random sample (The sample for this study is lead contaminated sites under DTSC jurisdiction. The sample is precise and more of a population dataset, therefore the sample is not random. Therefore, this could be a source of error.)
- linearity
- normal distribution for all treatment groups
- variance equal in all treatment combinations
- no outliers

In Figure 7, we observe that the data is relatively linear, but that the spread of the data is not equal across fitted values. This suggests that equal variance is not quite observed and that there are outliers, potentially points #14, #9, and #47. In Figure 8 we observe that most of the points fit the line well, except towards the ends of the line. This suggests that, besides the outliers, the sample comes from a population that fits the normal distribution. Figure 9 displays a straight line, suggesting linearity. However, we also see that the data points are not equally spread between the fitted values, again suggesting unequal variance. As seen in Figure 10, the outliers do not seem to influence the model, as they have not crossed Cook's distance. Appendix B, Figures 14 through 17, are the same graphs run without the potential outliers. Their subsequent regression results can be seen in Appendix C, Table Q, and are not significantly different from the results run with the potential outliers. Therefore, the potential outliers were included in our study sample.

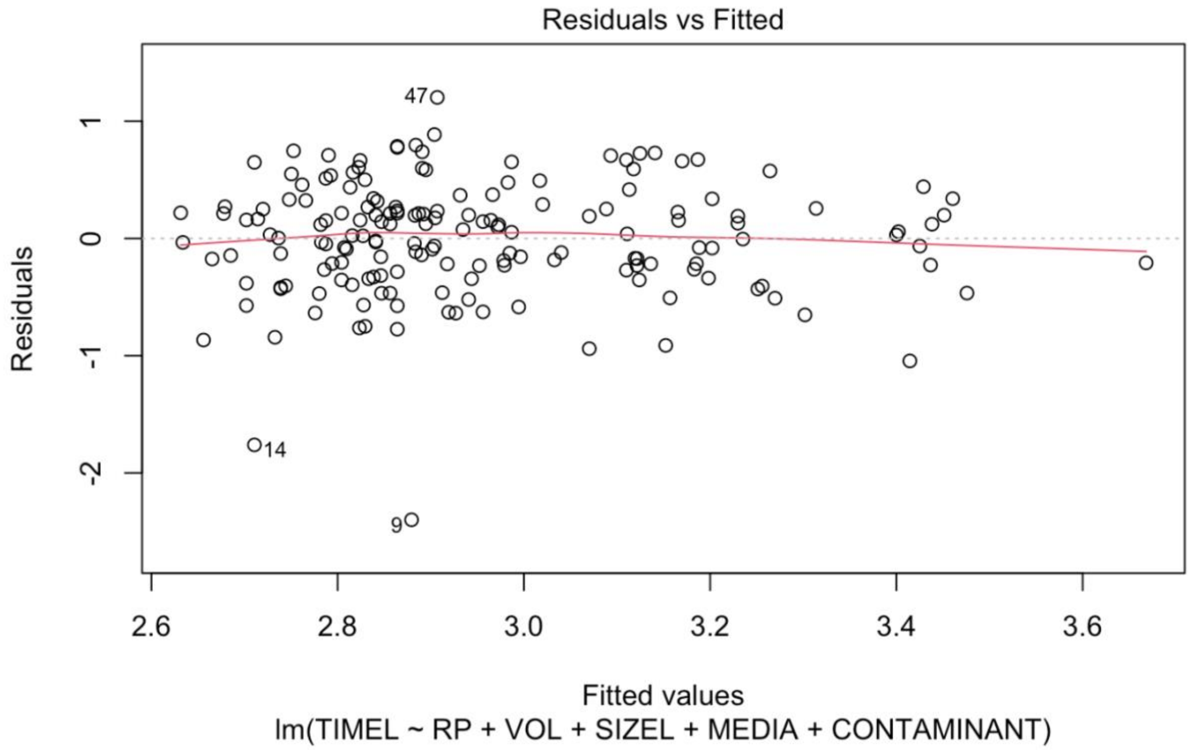

Figure 7. Question 1 Assumptions. This graph describes the linearity and equal variance of our dataset. The line is straight, suggesting linearity, but there is not an equal spread of the data across the fitted values. Appendix B, Figure 14 shows this same graph run without the outliers. The total sample size is 170.

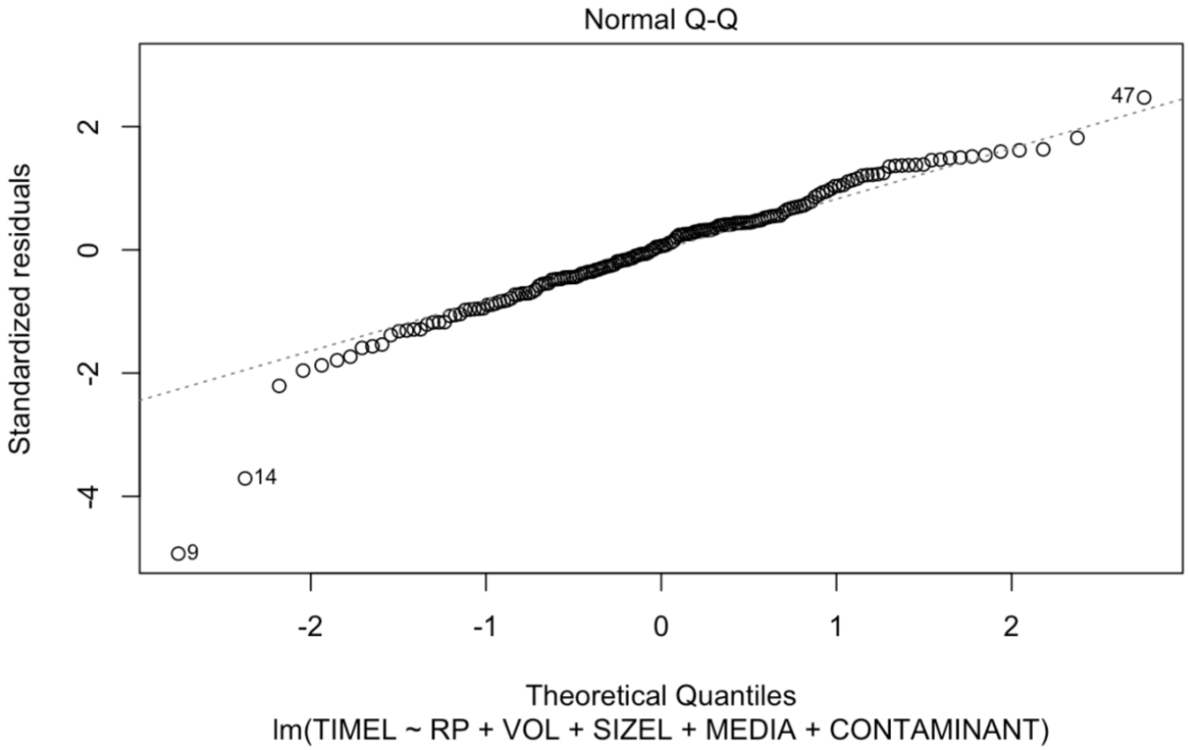

Figure 8. Question 1 Assumptions. This graph describes how the dataset compares to a normal distribution. Most of the data points fit the line, suggesting the sample comes from a normally distributed population. However, there are three outliers: #14, #9, and #47. Appendix B, Figure 15 shows this same graph run without the outliers. The total sample size is 170.

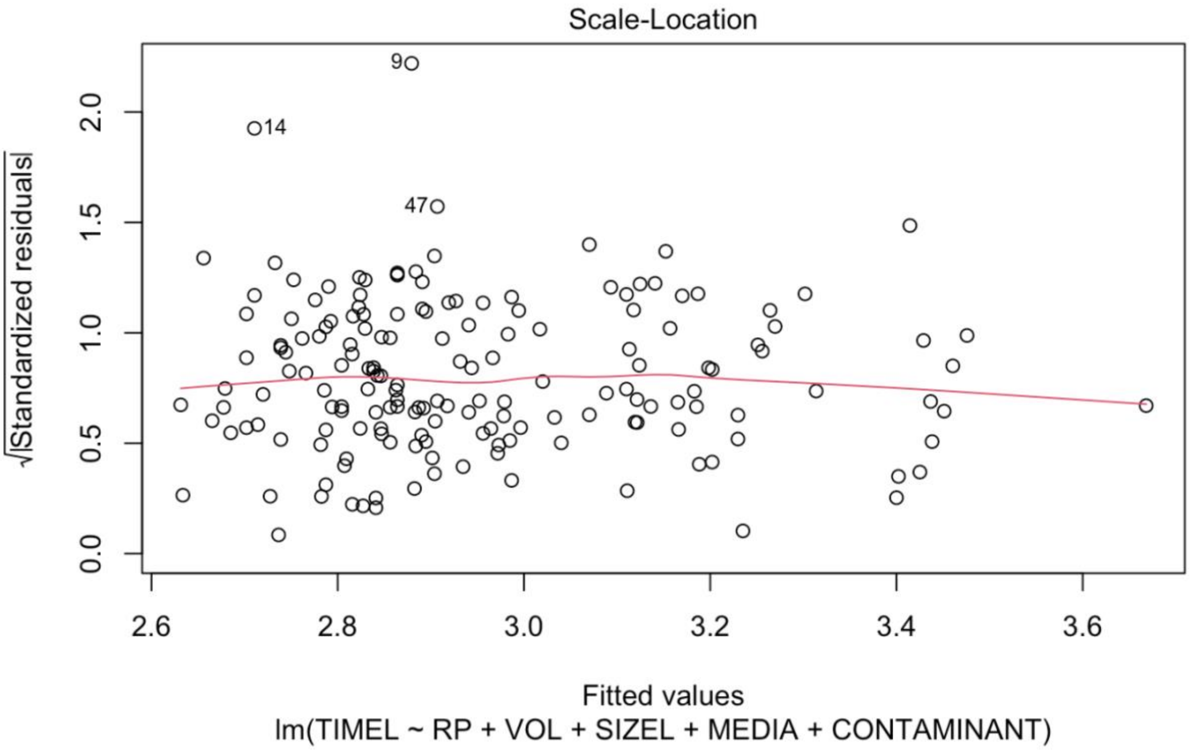

Figure 9. Question 1 Assumptions. This figure displays a straight line, suggesting linearity. However, we also see that the data points are not equally spread between the fitted values, again suggesting unequal variance. The same outliers, #14, #9, and #47, are observed. Appendix B, Figure 16 shows this same graph run without the outliers. The total sample size is 170.

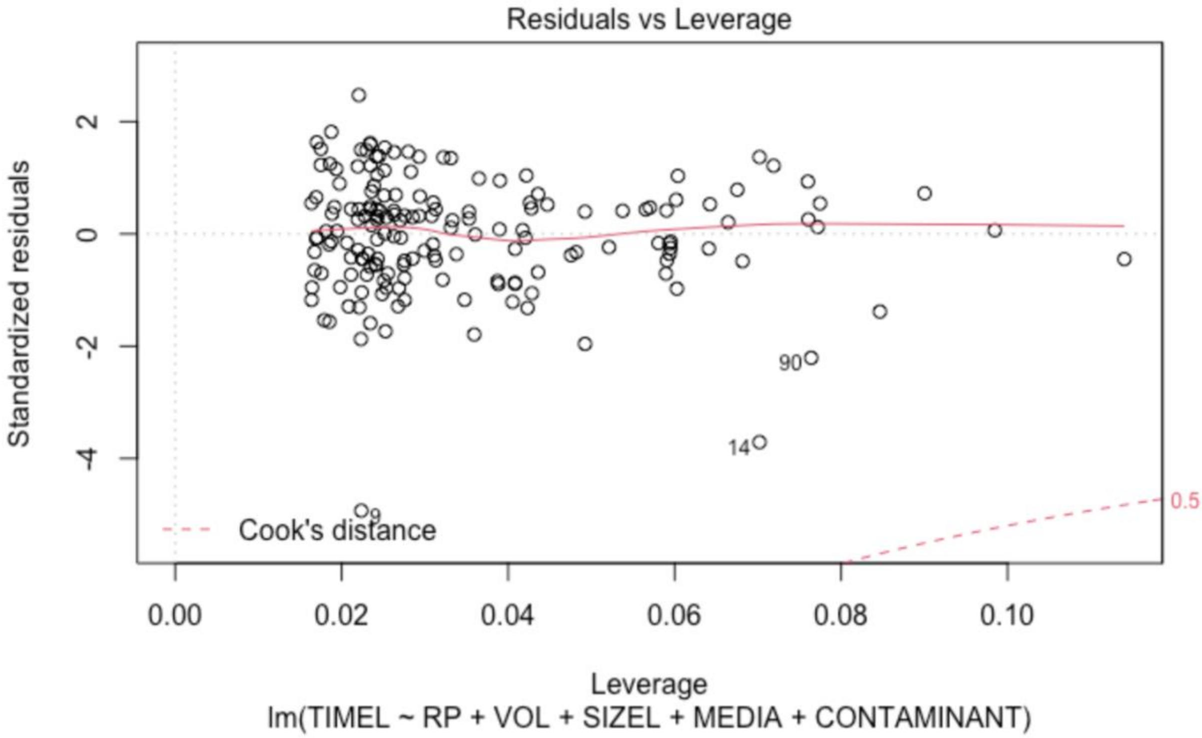

Figure 10. Question 1 Assumptions. This figure shows how the three outliers, #14, #9, and #47, do not seem to influence the model, nor have they crossed Cook's distance. Appendix B, Figure 17 shows this same graph run without the outliers. The total sample size is 170.

Results

Table J. Question 1 Results. This table displays the results for research question 1. Notably, all variables but contaminant and size are statistically significant. Size is on the threshold of significance, with a P-value < 0.1. The intercept and media are the most significant, with a P-value < 0.001. Appendix C, Table Q shows these results without the outliers.

```
Call:
lm(formula = TIMEL ~ RP + VOL + SIZEL + MEDIA + CONTAMINANT,
    data = Remediation)

Residuals:
     Min       1Q   Median       3Q      Max
-2.39935 -0.26784  0.02996  0.26931  1.20304

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  2.75717    0.14734  18.713  < 2e-16 ***
RP          -0.30125    0.13046  -2.309 0.022171 *
VOL         -0.33808    0.12108  -2.792 0.005853 **
SIZEL        0.07671    0.04451   1.723 0.086695 .
MEDIA        0.28290    0.07613   3.716 0.000277 ***
CONTAMINANT  0.12519    0.08888   1.408 0.160884
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4922 on 165 degrees of freedom
Multiple R-squared:  0.1529,    Adjusted R-squared:  0.1272
F-statistic: 5.957 on 5 and 165 DF,  p-value: 4.306e-05
```

Interpretation

Table K. Question 1 Analysis with Coefficients. Below are the interpretations of each coefficient, as it relates to our regression equation for question 1: time = a + b_{1a} * responsible party + b_{1b} * voluntary party + b_2 * size + b_3 * media + b_4 * contaminant

Funding		
Government	Responsible Party	Voluntary Party
a	a + b_{1a}	a + b_{1b}

The statistical results from our GLM analysis are seen in Table J and interpreted as described in Table K. Because time was log transformed, the coefficients for the intercept, responsible party, voluntary party, media, and contaminant used the following equation for ease of analysis: [e^(coefficient)-1] * 100. Because size was also log transformed, its coefficient used this interpretation for analysis: The coefficient is the % of change in time for every 1% increase in size.

On average, it takes 1,476 days to remediate a contaminated site when the government is funding (Estimate =2.75717, df = 165, P-value < 0.001). If a responsible party is funding, it takes 26.01% days less than if the government is funding (Estimate = -0.30125, df = 165, P-value = 0.022). This means, on average, it would take 384 days less if a site was cleaned by a responsible party than by the government. When a voluntary party is funding the cleanup, it takes 28.69% less time than if the government is funding (Estimate = -0.33808, df = 165, P-value = 0.006). This indicates that, on average, it would take 424 days less if a site was cleaned by a voluntary party than by the government. The time it takes to cleanup a site decreases when funding responsibility changes from government to responsible party or voluntary party. Additionally, for size, there is a 7.67% increase in time for every 1% increase in size (Estimate = 0.07671, df = 165, P-value = 0.087). While not statistically significant with a P-value < 0.05, size does have a P-value < 0.01 and indicates an increase of 114 days to cleanup time for every 1% increase in size. On average, there is an increase in time by 32.70% for every additional media type that is contaminated (Estimate = 0.2829, df = 165, P-value < 0.001). This describes an increase in cleanup time by 483 days for every increase in media type contaminated at a site. The explanatory variables in this equation explain 12.72% of the variation in time.

Research Question 2

Assumptions

The data fit the assumptions for question 2 similarly to question 1 as seen in Appendix D, Figures 23 through 26. The same conclusions can be made for linearity and normal distribution and the same concerns are present for the three potential outliers, #9, #14, and #47, and for the lack of equal variance. Lastly, the three potential outliers do not seem to have a large influence on the model. Appendix B, Figures 18 through 21 and Appendix C, Table R illustrate how these potential outliers do not result in significantly different findings. Therefore, the potential outliers were included in our study sample.

Results

Table L. Question 2 Results. This table displays the results for research question 2. Notably, the intercept and media type are significant, with P-values < 0.001. Appendix C, Table R shows these results without the outliers.

```
Call:
lm(formula = TIMEL ~ POVERTY + SIZEL + MEDIA + CONTAMINANT, data = Remediation)

Residuals:
     Min       1Q   Median       3Q      Max 
-2.44288 -0.30620  0.07493  0.31667  1.22296 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept)  2.46101    0.11434  21.524  < 2e-16 ***
POVERTY      0.05642    0.07865   0.717 0.474163    
SIZEL        0.05717    0.04494   1.272 0.205106    
MEDIA        0.29324    0.07720   3.798 0.000204 ***
CONTAMINANT  0.10077    0.08928   1.129 0.260660    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.5015 on 166 degrees of freedom
Multiple R-squared:  0.1154,	Adjusted R-squared:  0.09404 
F-statistic: 5.411 on 4 and 166 DF,  p-value: 0.0004037
```

Interpretation

Table M. Question 2 Analysis with Coefficients. Below are the interpretations of each coefficient, as it relates to our regression equation for question 2: time = a+ b_1 * poverty + b_2 * media + b_3 * contaminant + b_4 * size
Of consequence for the results of this question, if poverty is not statistically significant, it is not a predictor of how long a site takes to clean. That means that the coefficients of burdened and non-burdened communities are not significantly different from the intercept.

Poverty	
Not Burdened	Burdened
a	$a + b_1$

The statistical results from our GLM analysis are seen in Table L and interpreted as described in Table M. Because time was log transformed, the coefficients for the intercept, poverty, media, and contaminant used the following equation for ease of analysis:

[e^(coefficient)-1] * 100. Because size was also log transformed, its coefficient used this interpretation for analysis: The coefficient is the % of change in time for every 1% increase in size. Only the intercept and media type are statistically significant.

On average, it takes 1,072 days to remediate a contaminated site when the community is not burdened (Estimate =2.461, df = 166, P-value < 0.001). Surprisingly, poverty is not statistically significant, meaning that it is not a significant predictor of how long a site takes to clean up. This indicates that sites within burdened communities also take about 1,072 days to clean up (Burdened: Estimate = 0.05642, df = 166, P-value = 0.474). Media is significant with an increase in time by 34.08% for every addition of media type that is contaminated (Estimate = 0.29324, df = 166, P-value < 0.001). This describes an increase in cleanup time by 315 days for every addition of a different media type contaminated at a site. The explanatory variables in this equation explain 9.40 % of the variation in time.

Research Question 3

Assumptions

The data fit the assumptions for question 3 similarly to questions 1 and 2 as seen in Appendix D, Figures 27 through 30. The same conclusions can be made for linearity and normal distribution and the same concerns are present for the three potential outliers, #9, #14, and #47, and for the lack of equal variance. Lastly, the three potential outliers do not seem to have a large influence on the model. Appendix B, Figures 22 through 25 and Appendix C, Table S illustrate how these three points do not result in significantly different findings. Therefore, the potential outliers were included in our study sample.

Results

Table N. Question 3 Results. This table displays the results for research question 3. Notably, the intercept, responsible party, voluntary party, and media are all statistically significant with a P-value < 0.05. Size is also significant, but with a P-value < 0.1. Appendix C, Table S shows these results without the outliers.

```
Call:
lm(formula = TIMEL ~ RP + VOL + POVERTY + RP:POVERTY + VOL:POVERTY +
    SIZEL + MEDIA + CONTAMINANT, data = Remediation)

Residuals:
     Min       1Q   Median       3Q      Max
-2.44315 -0.29664  0.01627  0.28955  1.23772

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  2.85470    0.19494  14.644  < 2e-16 ***
RP          -0.43983    0.19869  -2.214 0.028250 *
VOL         -0.46062    0.18915  -2.435 0.015969 *
POVERTY     -0.17011    0.22413  -0.759 0.448965
SIZEL        0.07972    0.04509   1.768 0.078922 .
MEDIA        0.28980    0.07745   3.742 0.000253 ***
CONTAMINANT  0.12298    0.09118   1.349 0.179292
RP:POVERTY   0.24968    0.26406   0.946 0.345795
VOL:POVERTY  0.21271    0.24698   0.861 0.390374
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4951 on 162 degrees of freedom
Multiple R-squared:  0.1585,    Adjusted R-squared:  0.1169
F-statistic: 3.814 on 8 and 162 DF,  p-value: 0.000394
```

Interpretation

Table O. Question 3 Marginal Analysis with Coefficients. Below are the interpretations of each coefficient, as it relates to our regression equation for question 3: time = a+ b_{1b} * responsibly party + b_{1b} * voluntary party + b_2*poverty + b_3 * (responsible party * poverty) + b_4 * (voluntary party *poverty) + b_7 * size + b_5 * media + b_6 * contaminant
Of consequence for the results of this question, if a variable is not statistically significant, their coefficient is 0.

		Poverty	
Funding		Not Burdened	Burdened
	Government	a	b_2
	Responsible Party	b_{1a}	b_3
	Voluntary Party	b_{1b}	b_4

Table P. Question 3 Net Analysis with Coefficients. Below are the net interpretations of each coefficient, as it relates to our regression equation for question 3: time = a+ b_{1b} * responsibly party + b_{1b} * voluntary party + b_2*poverty + b_3 * (responsible party * poverty) + b_4 * (voluntary party *poverty) + b_7 * size + b_5 * media + b_6 * contaminant
If a variable is not statistically significant, their coefficient is 0, often resulting in no significant difference from coefficient a.

		Poverty	
Funding		Not Burdened	Burdened
	Government	a	a + b_2
	Responsible Party	a + b_{1a}	a + b_{1a} + b_2 + b_3
	Voluntary Party	a + b_{1b}	a + b_{1b} + b_2 + b_4

The statistical results from our GLM analysis are seen in Table N and interpreted as described in Table O and Table P. Because time was log transformed, the coefficients for the intercept, responsible party, voluntary party, poverty, the interaction between voluntary party and poverty, the interaction between responsible party and poverty, media and contaminant used the following equation for ease of analysis: [e^(coefficient)-1] * 100. Because size was also log transformed, its coefficient used this interpretation for analysis: The coefficient is the % of change in time for every 1% increase in size.

The intercept, responsible party, voluntary party, and media are all significant with a P-value < 0.05. Size is also significant, but with a P-value < 0.1. Poverty, contaminant, and the interaction between funding parties and poverty are not statistically significant predictors of how long a clean-up will take. On average, it takes 1,637 days to remediate a contaminated site when the government is funding and the community is not burdened (Estimate = 2.8547, df = 162, P-value < 0.001). If a responsible party is funding a cleanup in a non-burdened community, it takes 35.59% less time than when the government is funding (Estimate =-0.43983, df = 162, P-value = 0.028). This means, on average, it takes 583 less days if a responsible party funded a cleanup than if the government funded it. If a voluntary party is funding a cleanup in a non-burdened community, it takes 36.91% less time than when the government is funding (Estimate = -0.46062, df = 162, P-value = 0.016). This indicates that, on average, it takes 605 less days to clean a site if a voluntary party funds it rather than the government. Additionally, for size, there is a 7.97% increase in time for every 1% increase in size (Estimate = 0.07972, df = 162, P-value = 0.079). While only significant to a P-value < 0.01, this indicates an increase of 131 days of cleanup time for every 1% increase in size. For media, there is an increase in time by 33.61% for every addition of media type that is contaminated (Estimate = 0.2898, df = 162, P-value < 0.001). This describes an increase in cleanup time by 551 days for every addition of a different media type contaminated at a site. The explanatory variables in this equation explain 11.69% of the variation in time.

FINDINGS

The results from all our regressions support that funding party, media, and, to a lesser extent, property size (to a lesser significance) are good predictors of how long a remediation will take. To summarize, cleanups funded by voluntary parties and responsible parties take less time than government-funded cleanups. Voluntary parties are the most efficient, then responsible parties. Our research also, surprisingly, indicates that poverty is not a good predictor of cleanup duration.

Our results are not what we hypothesized: We had hypothesized that responsible party cleanups would take longer than government-funded cleanups and that voluntary party cleanups would take a shorter amount of time. Our hypothesis concerning voluntary party cleanups concurs with our results. The DTSC's entire purpose for introducing this funding option was to make cleanups more efficient and this study does indicate their purpose was successful (*BF_FS_VCP.Pdf*, n.d.-b). However, we had hypothesized that government-funded sites would be cleaned more quickly than responsible parties because we assumed that responsible parties would stall cleanups by attempting to escape responsibility. Our results contradict that and indicate that there are some factors involved in the process that we had not considered. For example, throughout this study, we have observed that government oversight and regulation of contaminated sites is unorganized, and this could prevent adequate prioritization and remediation of sites. Additionally, the various processes each cleanup needs to endure before remediation, while essential, takes time and can delay cleanups. Also, for cleanups to funded by the government, they cannot have a responsible party. Therefore, there may have been a stalled period where the financial responsibility transferred from the responsible party to the government. Lastly, government funding is limited and difficult to acquire. While our results were not as hypothesized, they agree with research done by Kate Golden (2012). Golden found that the bureaucratic processes within the EPA along with limited federal funds prevented the agency from cleaning sites and protecting the public health of communities (Kate Golden, 2012).

Our results show that there could be more than a year's worth of differences between government and voluntary or responsible party-funded cleanups. The fact that funding is a statistically significant variable in how long it takes to make communities safe is something that researchers and the DTSC need to be aware of. Funding is essential to cleaning toxic sites but should not be a defining factor for how long it takes to remove hazardous material from communities.

We had also hypothesized that poverty would be a significant predictor of time—sites located in burdened communities would take longer than sites located in non-burdened communities. Our results indicate that poverty is not a good predictor of time. If proved correct with future research, this result indicates that cleanups in burdened communities are not any slower than cleanup in wealthier communities. However, cleanups are not any faster either. This is potentially detrimental when considering how low-income communities are more vulnerable to pollution (*Disparities in the Impact of Air Pollution*, n.d.). While our results are not as we hypothesized, they do align with research from Hird (1993). They found that the pace of EPA cleanups depends on the site's hazard, not the socioeconomic characteristics of their community (Hird, 1993).

Of our additional variables, media and property size are good indicators of how long cleanup will take. This suggests that larger-sized cleanups with multiple media types contaminated need more support and resources from the DTSC.

POLICY RECOMMENDATION

From our research, we determined that the duration of cleanups can be predicted by the funding party. Sites funded by the government take much longer to clean than sites funded by responsible parties and voluntary parties. Hoping to reduce cleanup duration and protect public health, what can the DTSC change to address this discrepancy? One way to explore this is to determine what can be learned from cleanups funded by responsible parties and/or voluntary parties. The biggest difference between voluntary party funding and government funding is that voluntary parties have the required funding from the start. They approach each cleanup with the funds necessary to clean it whereas responsible parties and the government do not. Responsible parties, unlike the government, can escape responsibility through bankruptcy or by simply not having enough funds. Additionally, responsible parties have fewer bureaucratic processes to go through. These are the most obvious differences, but there needs to be more research exploring the reasons behind this finding.

With this knowledge, there are many options the DTSC and communities could take to confront this disparity. One option includes creating an oversight committee within the DTSC to specifically address the speed of each cleanup and improve the department's organization. However, there is the potential that this promotes more bureaucratic stalling. Another option is examining the language of DTSC regulations and including time-sensitive requirements for when certain processes should be completed. While this would create a time standard, there is the potential that this prevents quality cleanups and valuable community participation. One more to consider is simply streamlining the paperwork process within the DTSC to promote better recordkeeping and faster communication. However, the two policies we recommend relate to DTSC funding structure and financial assurance.

Our research clearly outlines how funding impacts cleanup duration. Separating the two would prevent cleanup delays and protect public health. Currently, DTSC has departments for cleanup management as well as a department of accounting (*2016 Programs and Accomplishments Report*, 2016). While cleanup and funding are different departments, cleanups depend on funding. There needs to be a policy that provides the necessary funding to allow the DTSC to immediately clean sites, no matter the funding status. For example, a responsible party declaring bankruptcy would not stall a cleanup. There is the potential concern that this motivates responsible parties to not pay back the expenses, but the public health benefits outweigh this drawback. Another concern is where this money would come from. The DTSC receives money from the Governor's proposed budget. One suggestion is the DTSC and the Governor allocate a standard percentage of money from the state budget to this endeavor. Another option is creating a tax, specifically for this purpose. While politically unpopular, the public health of communities is important and should be prioritized in California.

Our second recommendation gets to the core of this issue—there isn't enough funding for each cleanup. To prevent toxic releases and more cleanups without responsible party funding, we recommend reevaluating financial assurance. Financial assurance is when owners and operators of hazardous waste facilities maintain financial resources to pay for the closure, maintenance and monitoring, and cleanup of their facilities. Only sites with closure costs greater than $10,000 and specific recycling facilities are required to have this. Financial assurance has been required by the DTSC since 1991 (California, n.d.-d). DTSC regulations require facilities to consistently show proof of financial assurance every time the current estimate of closure or maintenance increases. Financial assurances for cleanups depend on the type of release. To prepare for sudden accidental occurrences, the owner or operator should be able to show annually $2 million in financial assurances. For non-sudden accidental occurrences, the owner or operator should be able to show at least $6 million in financial assurances. In the case an owner or operator combines the two types of occurrences in one fund, they must show financial assurance equal to $8 million annually. If the DTSC verifies that these minimum amounts "are not consistent with the degree and duration of risk associated with transfer, treatment, storage, or disposal at the facility or group of facilities" the DTSC can increase the required amount of financial assurance (*OEAR_FR_final.Pdf*, n.d.).

The current financial assurance system seems like a full-proof plan to account for a variety of situations and circumstances. However, as seen in the case of Exide, this is not working. Exide paid $26.4 million in financial assurance funds for a cleanup that costs hundreds of millions of dollars (California, n.d.-b). We recommend that this assurance system be severer and better regulated. The DTSC should evaluate each facility to determine its financial assurance fund and include aspects such as media type and property size, as supported by our research. Not only should the DTSC evaluate each site independently, but they should be evaluated annually. Research by Alberini and Austin (2002) suggests more strict assurance costs would instill in facilities financial responsibility and promote their careful handling of toxic wastes (Alberini &

Austin, 2002). Their research suggests that strict assurance requirements would prevent hazardous releases, protecting community wellbeing. This policy would be politically unpopular, but it has the potential to protect community health by hastening cleanups and preventing them in the first place.

CONCLUSION

In this study, we asked if funding source, poverty, and the interaction between the two are good predictors of cleanup duration. We discovered that who funds the cleanup is a significant predictor of how long a cleanup takes. Not only this, but we also determined that how many media types were contaminated and how big the property is both predict how long a cleanup will take. To address these findings, we made two policy recommendations, one to reorganize the DTSC and the other to reevaluate the permit assurance requirement. We hope that these findings are utilized by the DTSC and nonprofit agencies to increase the speed of cleanups and protect the health of California communities.

Our study does have limitations that readers should keep in mind when considering our results. While most of the assumptions were met for our general linear model, an equal variance was the exception. This variance could have had an impact on significance as it increases the variability in the data, decreasing statistical power. Another limitation is that property size is not necessarily accurate to the contaminated area. The site of concern could be an acre, but the contaminated part could be half of that acre. This could account for the variation of statistical significance for size seen in our results. Additionally, poverty is used as a predictor of an overburdened community. However, there are many other variables, such as race and unemployment rate, that should be considered. Additionally, our sample includes sites from 1973 to 2018, and our data on poverty was from 2015-2019. This could have skewed our results. As stated, our data was collected from various decades. The DTSC's performance could be on an upward trend, above the averages seen in this model. Therefore, the predictive quality of our model could be inaccurate for future DTSC performance. Also, our sample was manually collected—the variable time is subject to delayed updates of the EnviroStor database as well as the researcher's bias when determining start and end dates of remediation. It is important to note that the speed of a cleanup is not necessarily related to the quality of the cleanup. The DTSC and EPA clean each toxic site to a certain set of standards. But our paper does not research if a faster cleanup is associated with a cleanup of higher quality – that is important research that will support and qualify our research. Lastly, this study does not prove causation and only estimates the linear relationship between variables.

There are future analyses that should be considered when analyzing the DTSC and its efficiency in addressing harmful situations. This research should be repeated with a larger, more inclusive sample to detect small changes in the time it takes to clean hazardous sites. Future duplications should also include more confounding variables to acknowledge that the DTSC clean-up process is not straightforward and varies from site to site. Additionally, some funding disputes occur after a cleanup. That is not investigated in this study and should be investigated. Also, future research should analyze the amount of time the contaminating facilities were actively releasing before being recognized by the DTSC as a hazardous site. Moreover, future research should explore policy solutions addressing permitting of hazardous facilities, as the current system allowed Exide an interim permit for decades. Future studies could also consider how quickly the DTSC responds to community discoveries of potential toxic releases. Also, to address geographic disparities related to toxic cleanup durations, we suggest a study involving GIS (Geographic Information System) mapping.

Despite the above limitations, it is our understanding that this research provides an important starting point for future research on toxic sites, specifically looking at the variable of time as an indicator of cleanup efficiency. We hope this research is used by community, research, and policy organizations to make progress in the fields of public health, environmental justice, and health policy.

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APPENDIX A
Histograms

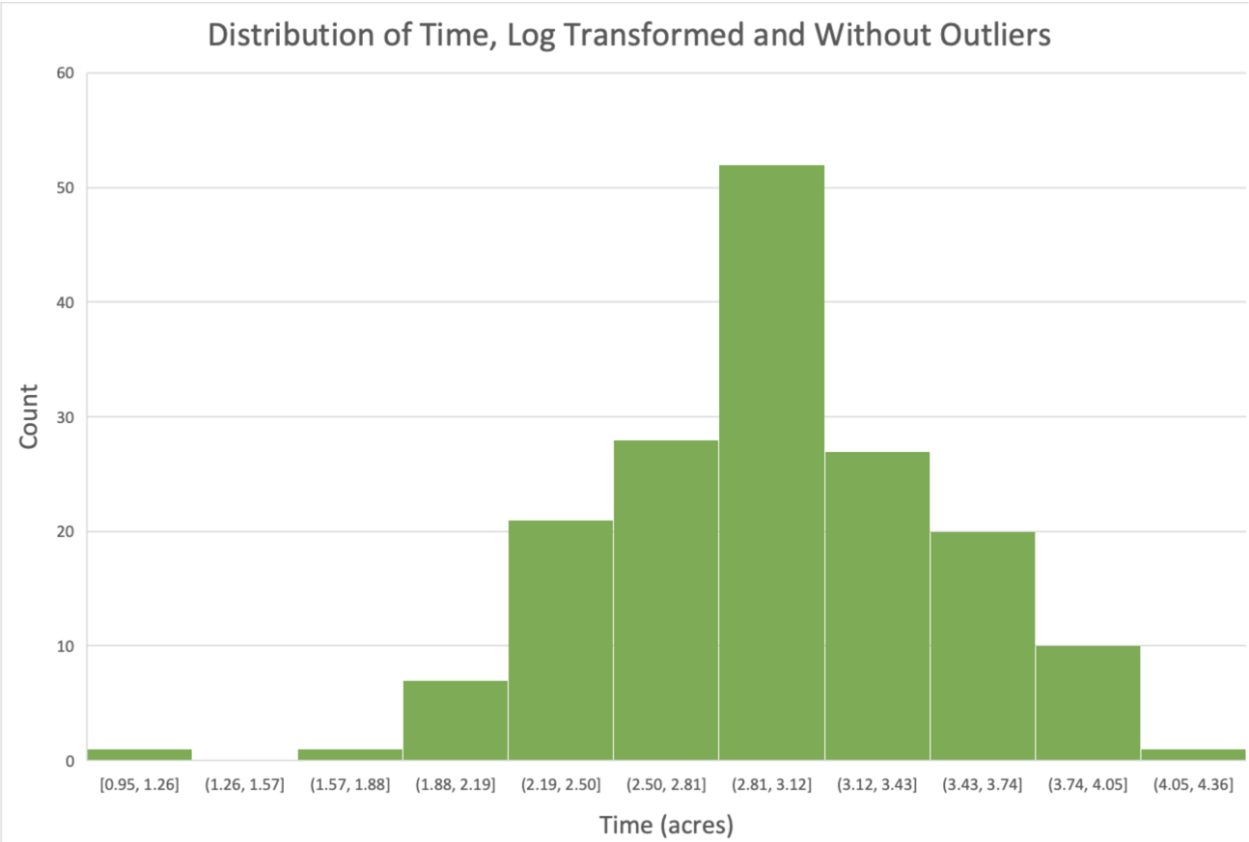

Figure 11. Distribution of Time, Log Transformed and Without Outliers. The graph is still slightly skewed left, but less than with outliers.

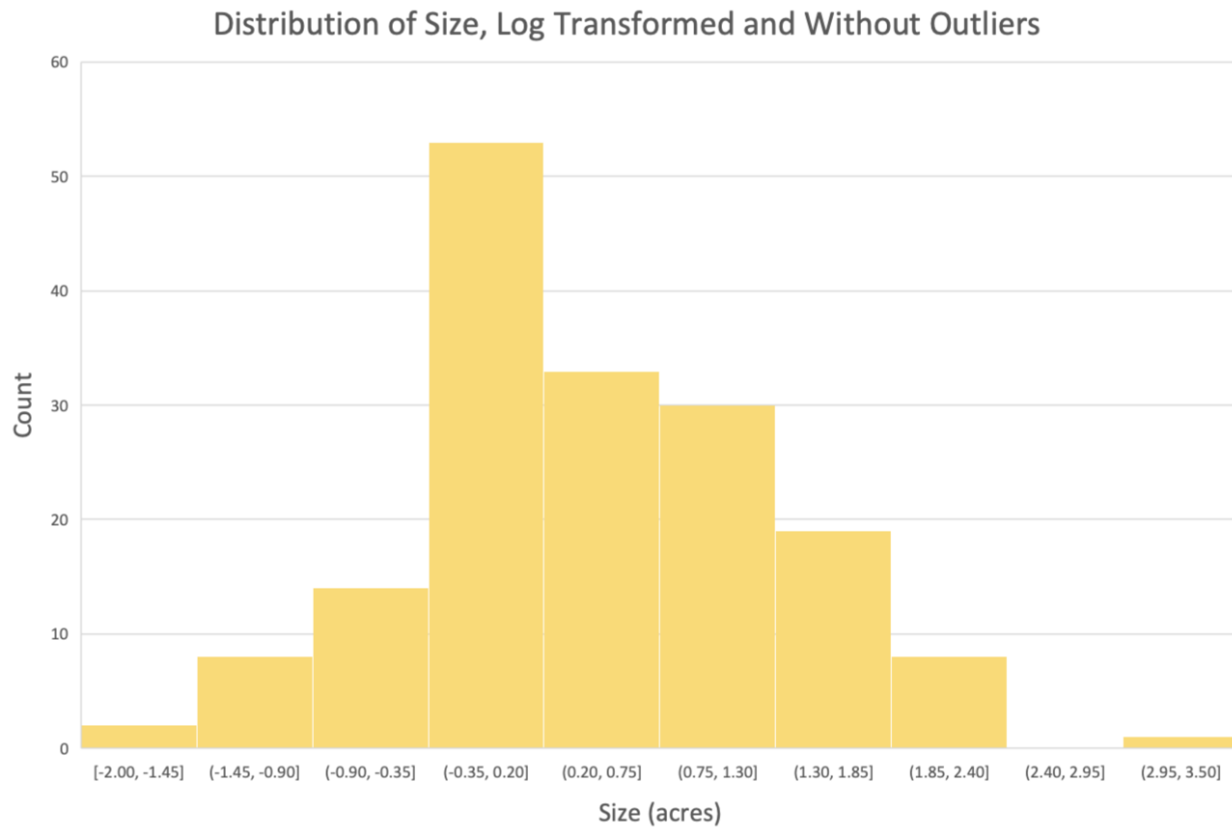

Figure 12. Distribution of Size, Log Transformed and Without Outliers. The graph is still not perfectly normal, but better than with outliers.

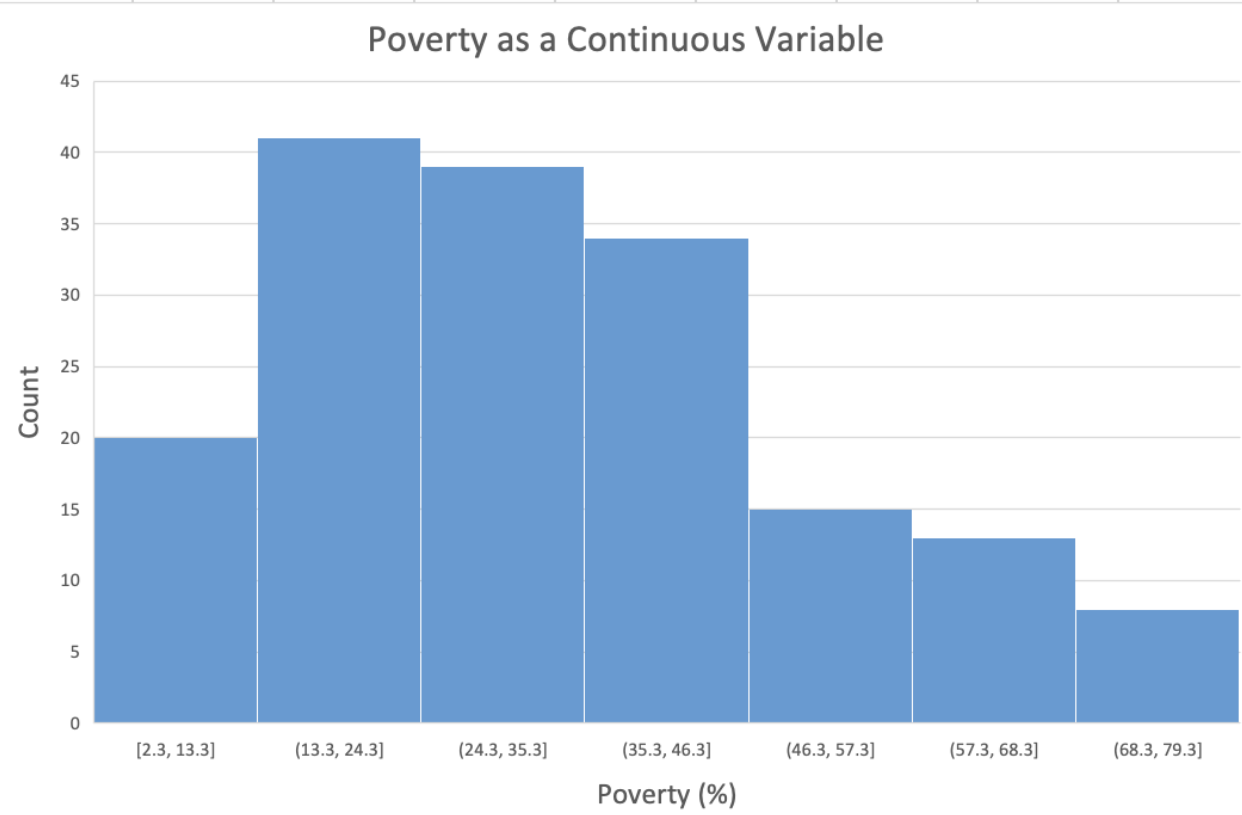

Figure 13. Distribution of Poverty, Continuous. The graph is relatively normal and there is a slight break at 35%, supporting our decision to make this variable categorical.

APPENDIX B
Assumptions Without Outliers

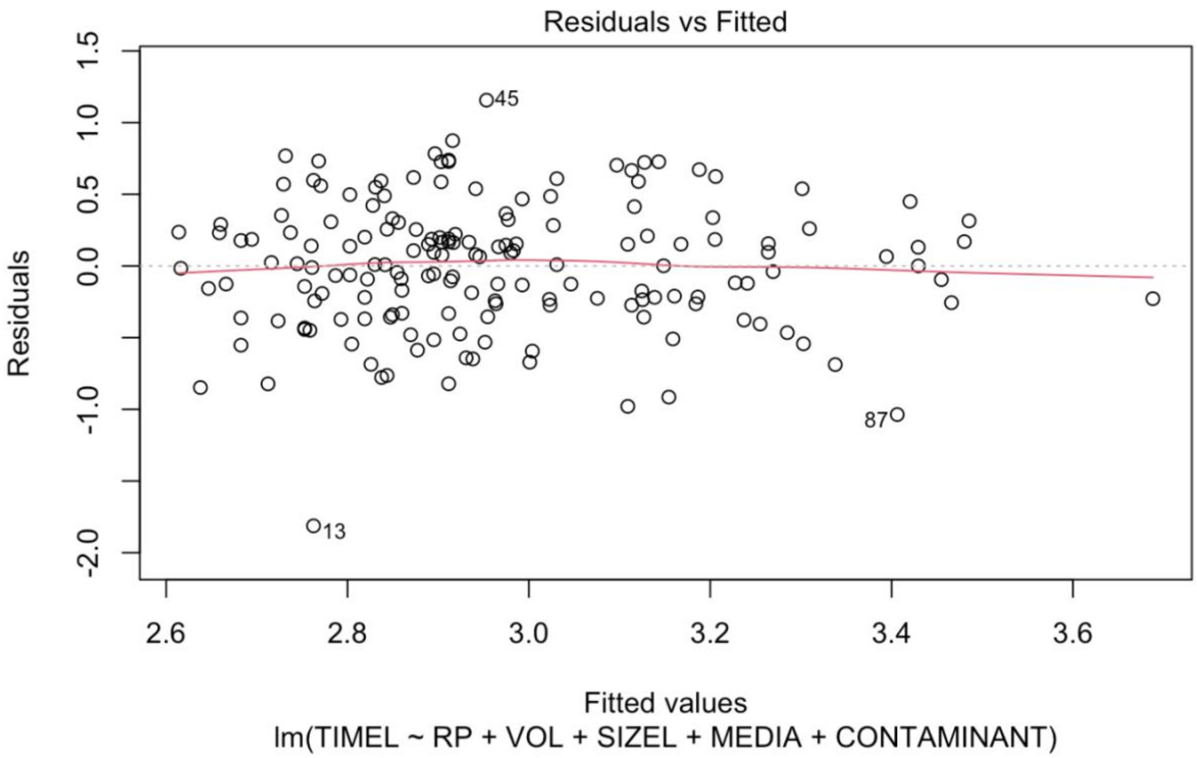

Figure 14. Question 1 Assumptions Without Outliers. This figure shows the assumption without the three outliers. The total sample size is 170.

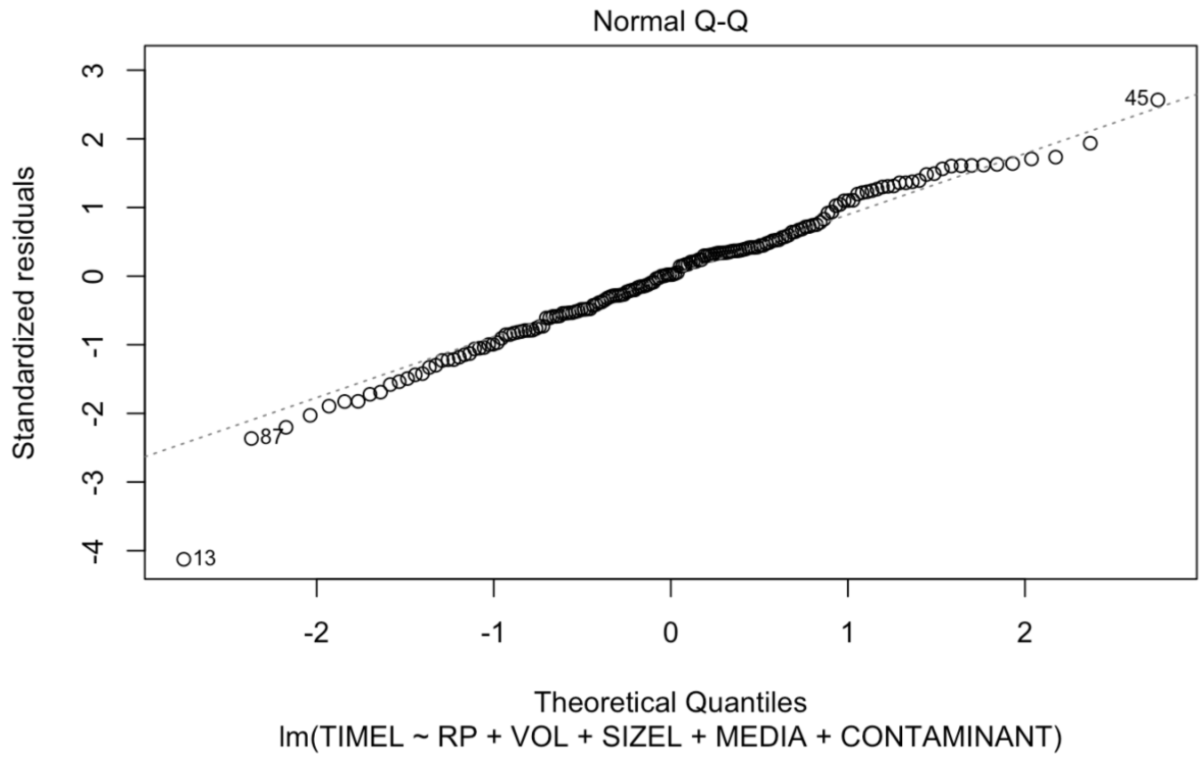

Figure 15. Question 1 Assumptions Without Outliers. This figure shows the assumption without the three outliers. The total sample size is 170.

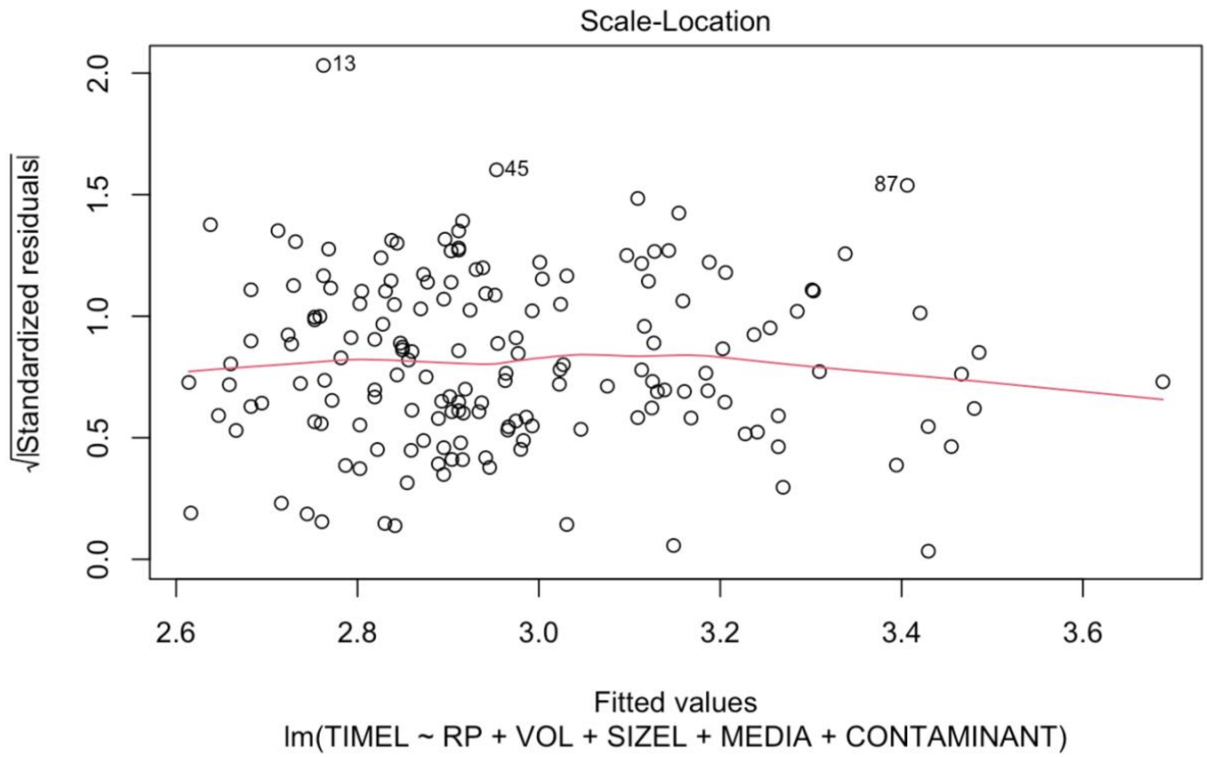

Figure 16. Question 1 Assumptions Without Outliers. This figure shows the assumption without the three outliers. The total sample size is 170.

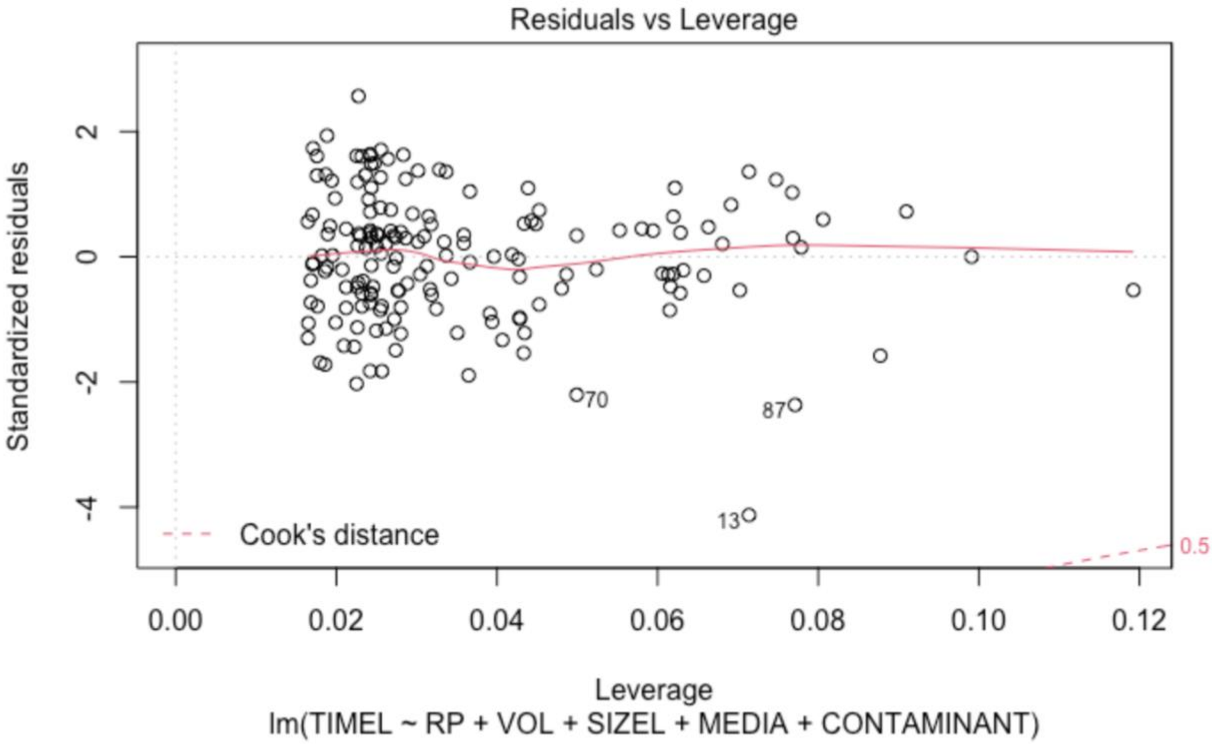

Figure 17. Question 1 Assumptions Without Outliers. This figure shows the assumption without the three outliers. The total sample size is 170.

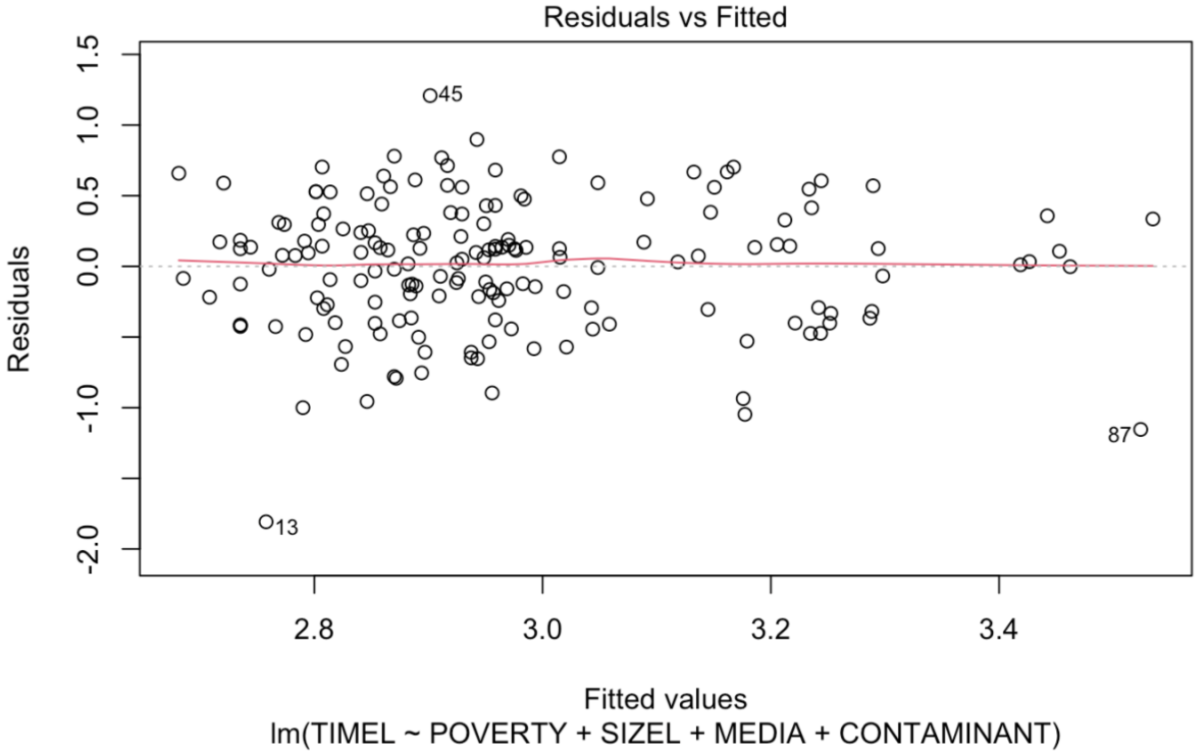

Figure 18. Question 2 Assumptions Without Outliers. This figure shows the assumption without the three outliers. The total sample size is 170.

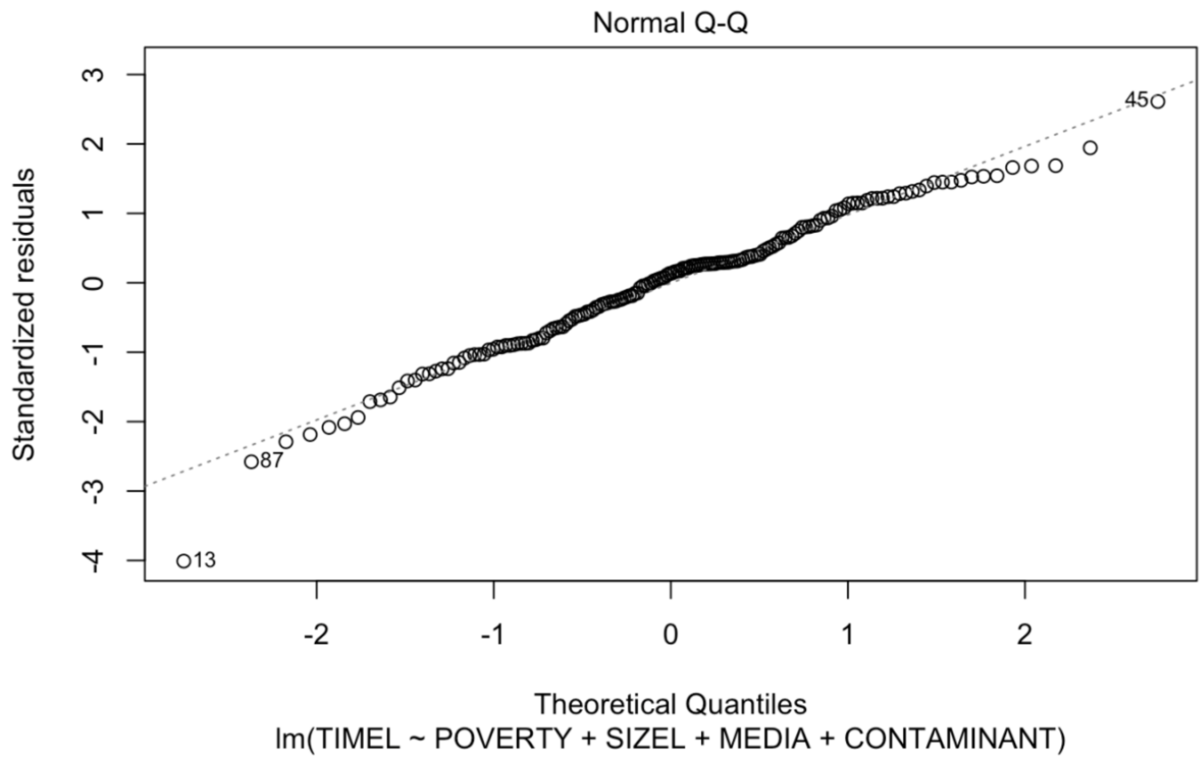

Figure 19. Question 2 Assumptions Without Outliers. This figure shows the assumption without the three outliers. The total sample size is 170.

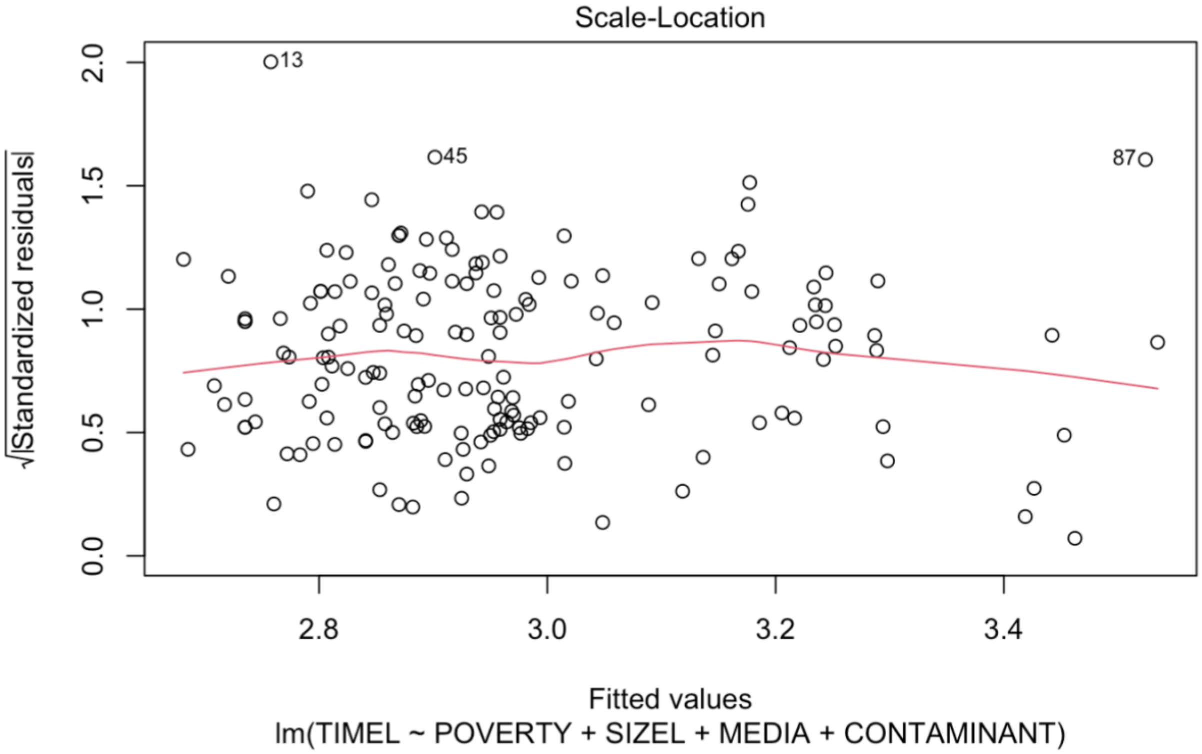

Figure 20. Question 2 Assumptions Without Outliers. This figure shows the assumption without the three outliers. The total sample size is 170.

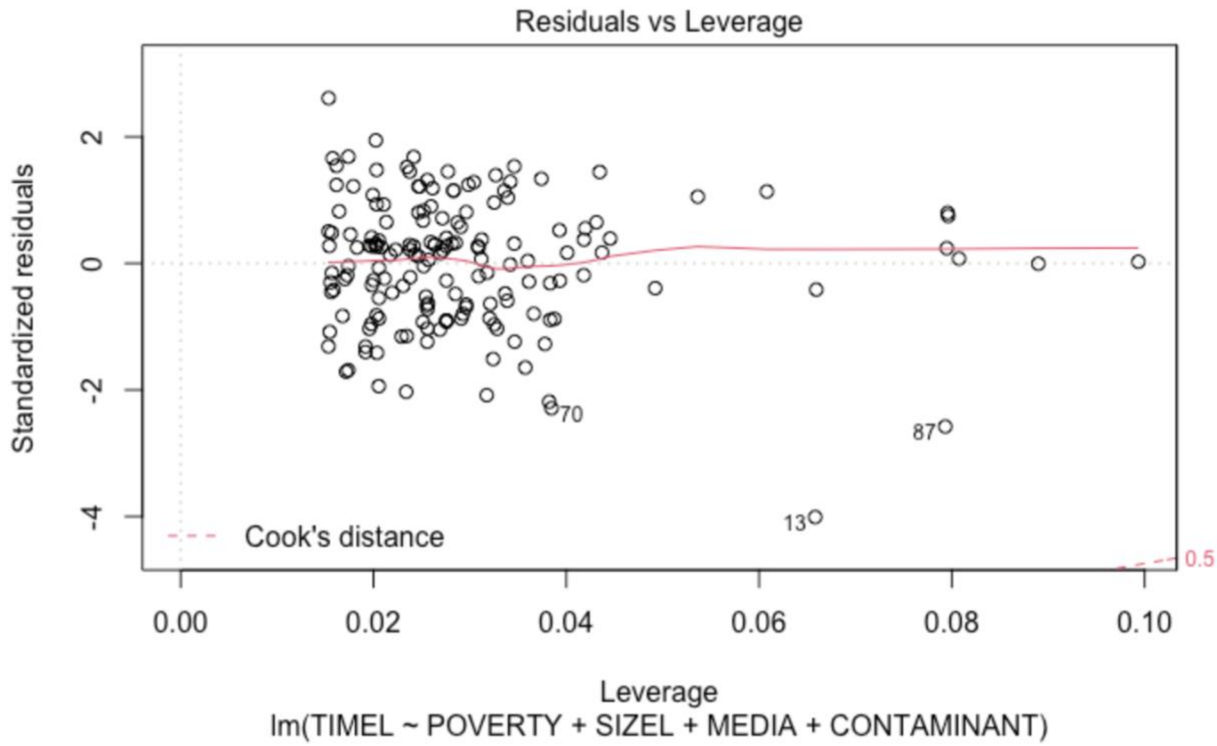

Figure 21. Question 2 Assumptions Without Outliers. This figure shows the assumption without the three outliers. The total sample size is 170.

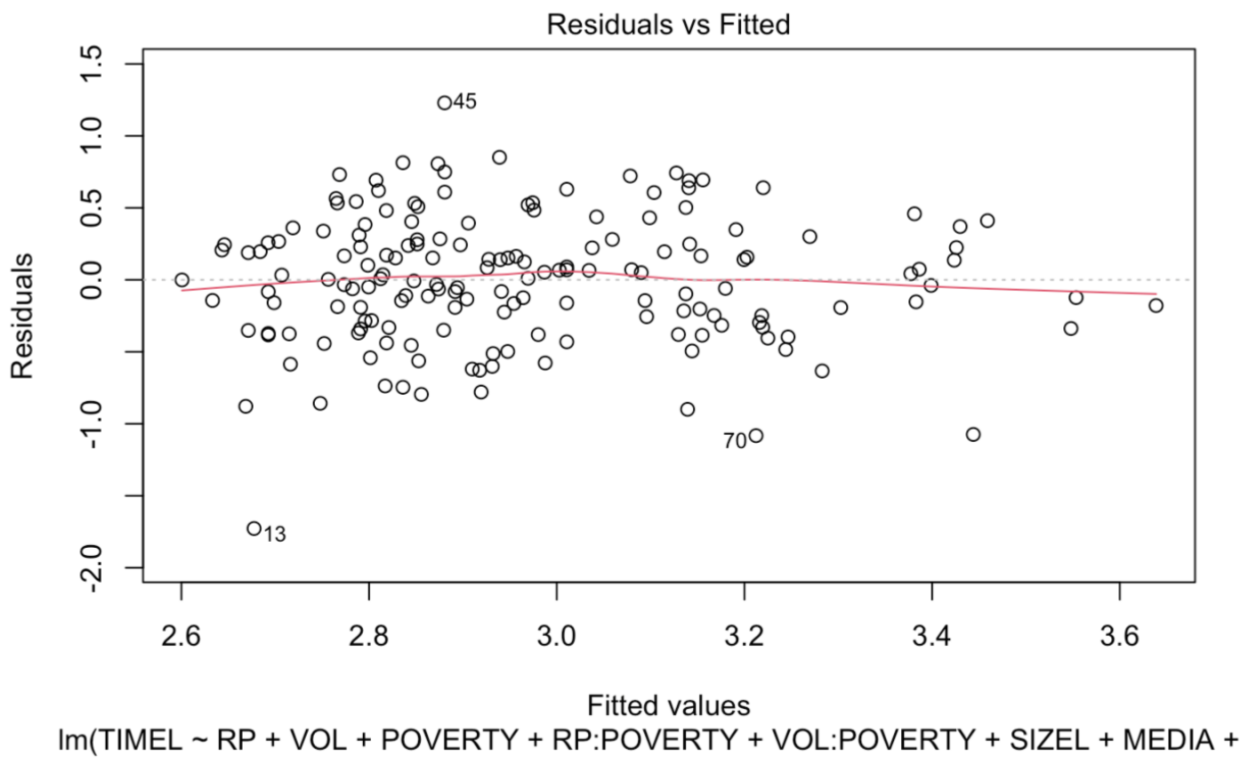

Figure 22. Question 3 Assumptions Without Outliers. This figure shows the assumption without the three outliers. The total sample size is 170.

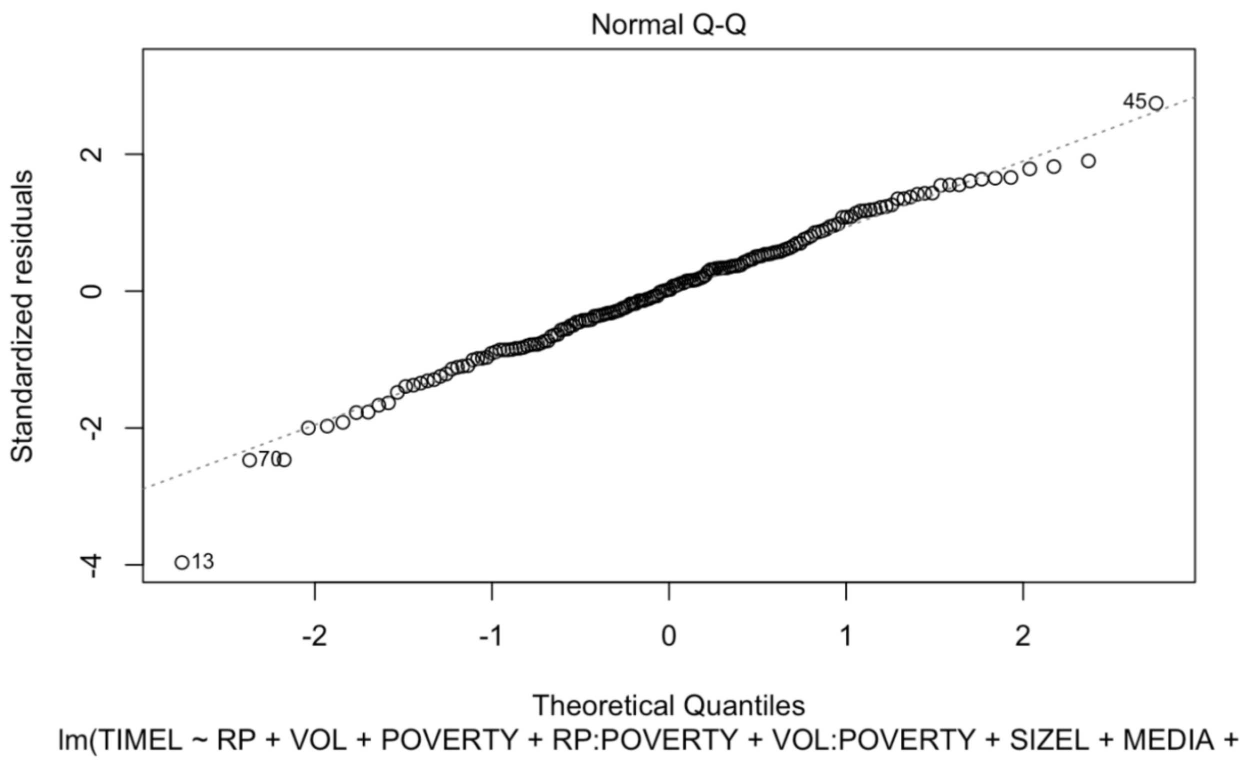

Figure 23. Question 3 Assumptions Without Outliers. This figure shows the assumption without the three outliers. The total sample size is 170.

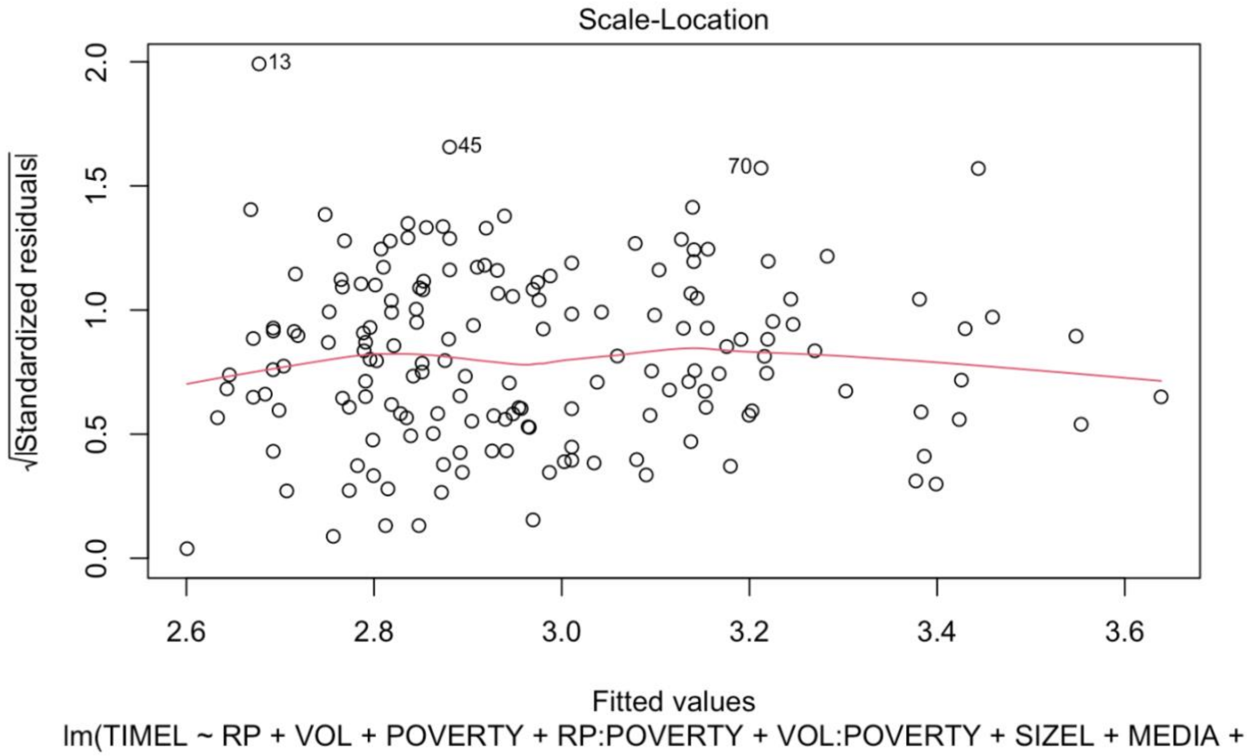

Figure 24. Question 3 Assumptions Without Outliers. This figure shows the assumption without the three outliers. The total sample size is 170.

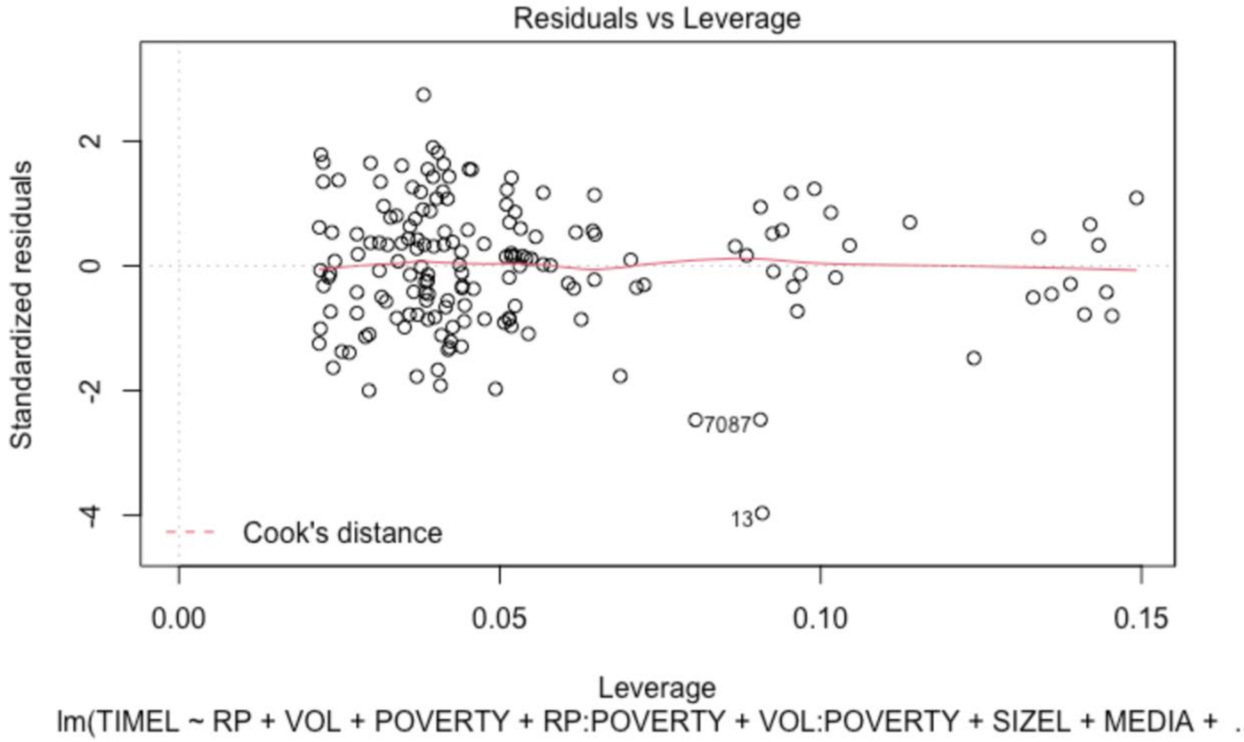

Figure 25. Question 3 Assumptions Without Outliers. This figure shows the assumption without the three outliers. The total sample size is 170.

APPENDIX C
Results without Outliers

Table Q. Question 1 Result Without Outliers. This table displays the results for research question 1, without the outliers. Notably, The R-squared value is less than the results with outliers.

```
Call:
lm(formula = TIMEL ~ RP + VOL + SIZEL + MEDIA + CONTAMINANT,
    data = Remediation2)

Residuals:
     Min       1Q   Median       3Q      Max 
-1.81253 -0.26646  0.00951  0.26620  1.15669 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept)  2.77433    0.13718  20.224  < 2e-16 ***
RP          -0.29362    0.12386  -2.371 0.018934 *  
VOL         -0.36384    0.11452  -3.177 0.001782 ** 
SIZEL        0.07452    0.04127   1.806 0.072840 .  
MEDIA        0.27201    0.07085   3.839 0.000177 ***
CONTAMINANT  0.15886    0.08328   1.908 0.058216 .  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4559 on 162 degrees of freedom
Multiple R-squared:  0.1781,	Adjusted R-squared:  0.1528 
F-statistic: 7.023 on 5 and 162 DF,  p-value: 5.752e-06
```

Table R. Question 2 Result Without Outliers. This table displays the results for research question 2, without the outliers. Notably, The R-squared value is less than the results with outliers.

```
Call:
lm(formula = TIMEL ~ POVERTY + SIZEL + MEDIA + CONTAMINANT, data = Remediation2)

Residuals:
     Min       1Q   Median       3Q      Max 
-1.80769 -0.30828  0.06305  0.30396  1.20855 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept)  2.46024    0.10712  22.967  < 2e-16 ***
POVERTY      0.08855    0.07405   1.196 0.233510    
SIZEL        0.05616    0.04180   1.343 0.181006    
MEDIA        0.27488    0.07227   3.804 0.000201 ***
CONTAMINANT  0.13488    0.08381   1.609 0.109463    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4665 on 163 degrees of freedom
Multiple R-squared:  0.1344,    Adjusted R-squared:  0.1131 
F-statistic: 6.326 on 4 and 163 DF,  p-value: 9.32e-05
```

Table S. Question 3 Result Without Outliers. This table displays the results for research question 3, without the outliers. Notably, The R-squared value is less than the results with outliers.

```
Call:
lm(formula = TIMEL ~ RP + VOL + POVERTY + RP:POVERTY + VOL:POVERTY + 
    SIZEL + MEDIA + CONTAMINANT, data = Remediation2)

Residuals:
     Min       1Q   Median       3Q      Max 
-1.72744 -0.30096  0.00916  0.27927  1.22950 

Coefficients:
            Estimate Std. Error t value Pr(>|t|)    
(Intercept)  2.85434    0.18009  15.850  < 2e-16 ***
RP          -0.44276    0.18335  -2.415 0.016877 *  
VOL         -0.46409    0.17456  -2.659 0.008647 ** 
POVERTY     -0.13719    0.20967  -0.654 0.513853    
SIZEL        0.07932    0.04163   1.905 0.058553 .  
MEDIA        0.28101    0.07168   3.920 0.000131 ***
CONTAMINANT  0.14349    0.08545   1.679 0.095062 .  
RP:POVERTY   0.31176    0.24808   1.257 0.210708    
VOL:POVERTY  0.18210    0.23048   0.790 0.430634    
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.4568 on 159 degrees of freedom
Multiple R-squared:  0.1902,    Adjusted R-squared:  0.1495 
F-statistic: 4.669 on 8 and 159 DF,  p-value: 3.786e-05
```

APPENDIX D
Assumptions for Questions 2 and 3

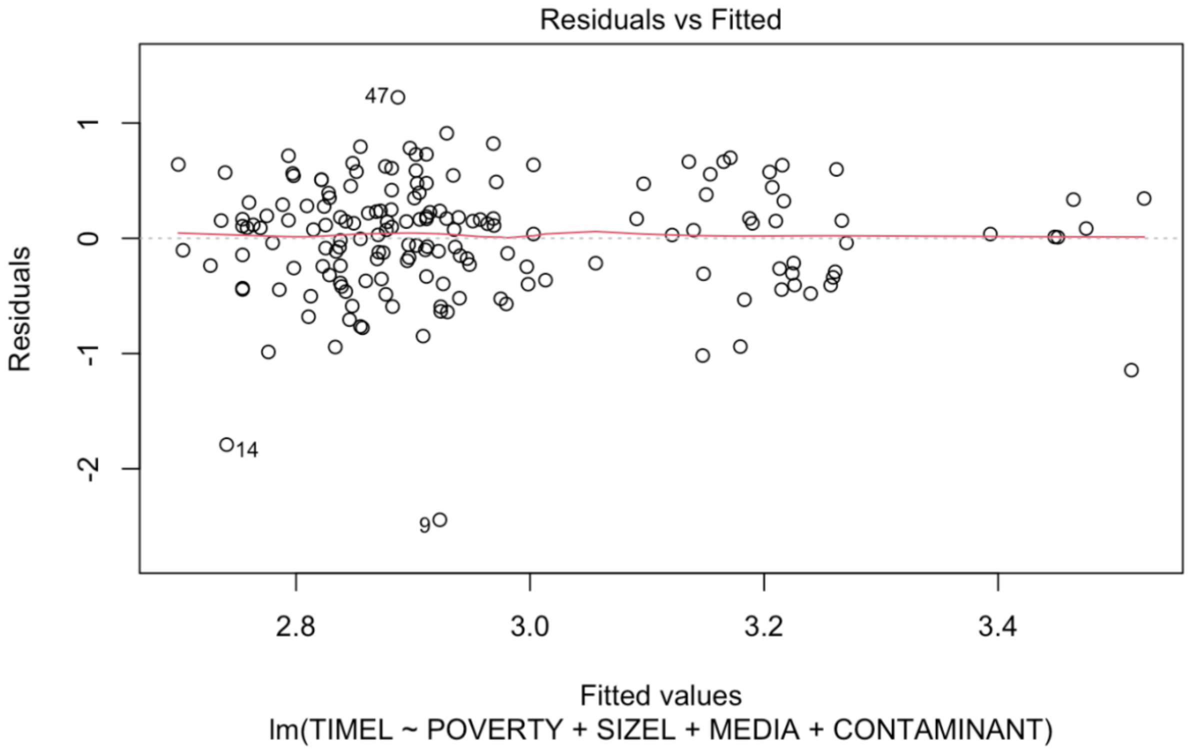

Figure 26. Question 2 Assumptions. This figure shows how the three outliers, #14, #9, and #47, do not seem to influence the model, nor have they crossed Cook's distance. The total sample size is 170.

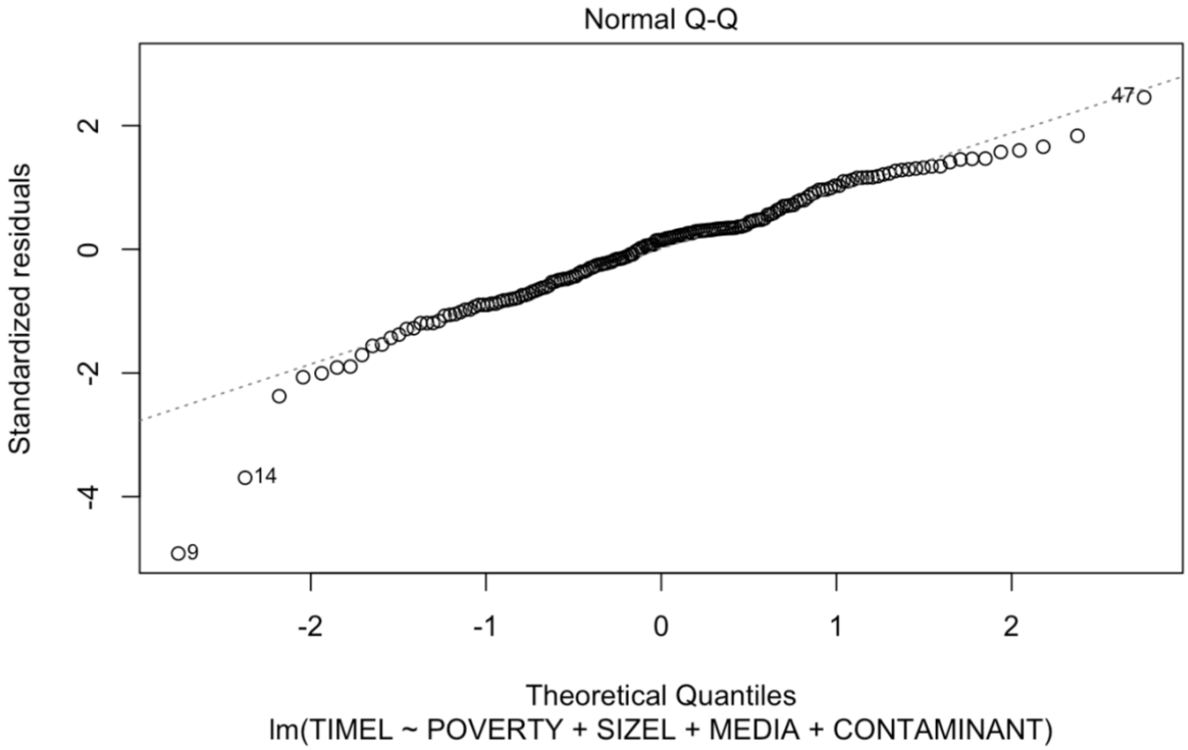

Figure 27. Question 2 Assumptions. This figure shows how the three outliers, #14, #9, and #47, do not seem to influence the model, nor have they crossed Cook's distance. The total sample size is 170.

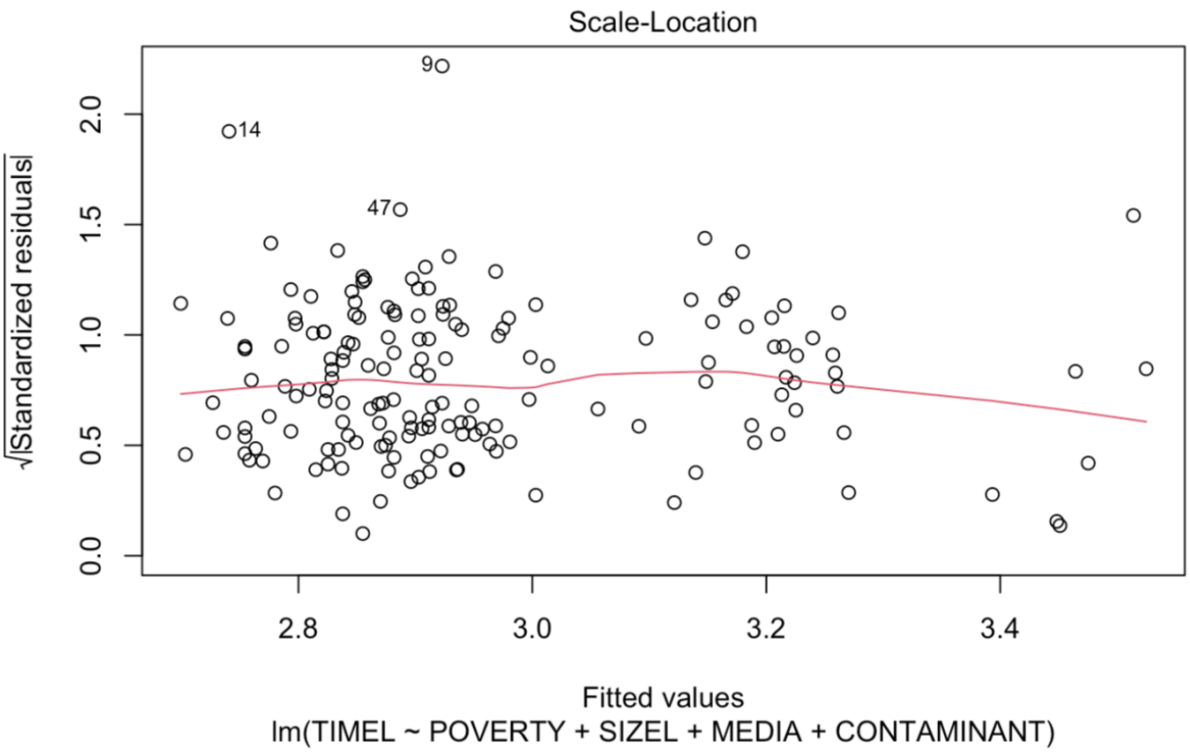

Figure 28. Question 2 Assumptions. This figure shows how the three outliers, #14, #9, and #47, do not seem to influence the model, nor have they crossed Cook's distance. The total sample size is 170.

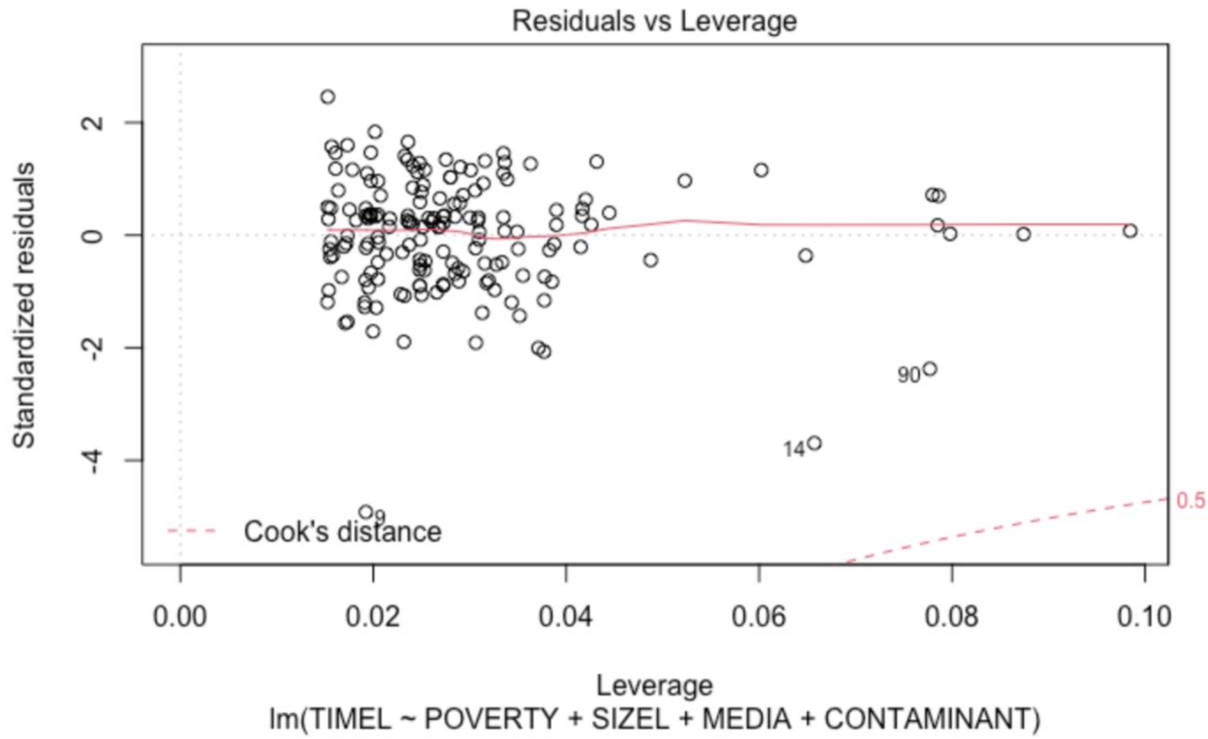

Figure 29. Question 2 Assumptions. This figure shows how the three outliers, #14, #9, and #47, do not seem to influence the model, nor have they crossed Cook's distance. The total sample size is 170.

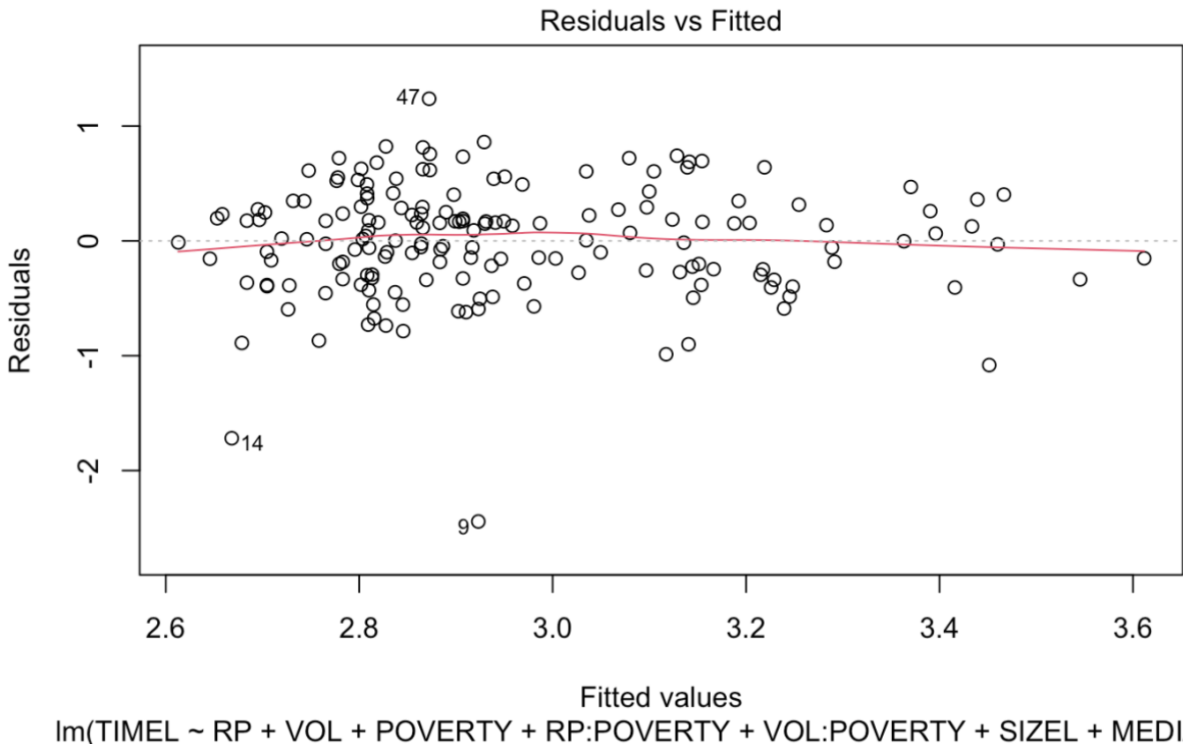

Figure 30. Question 3 Assumptions. This figure shows how the three outliers, #14, #9, and #47, do not seem to influence the model, nor have they crossed Cook's distance. The total sample size is 170.

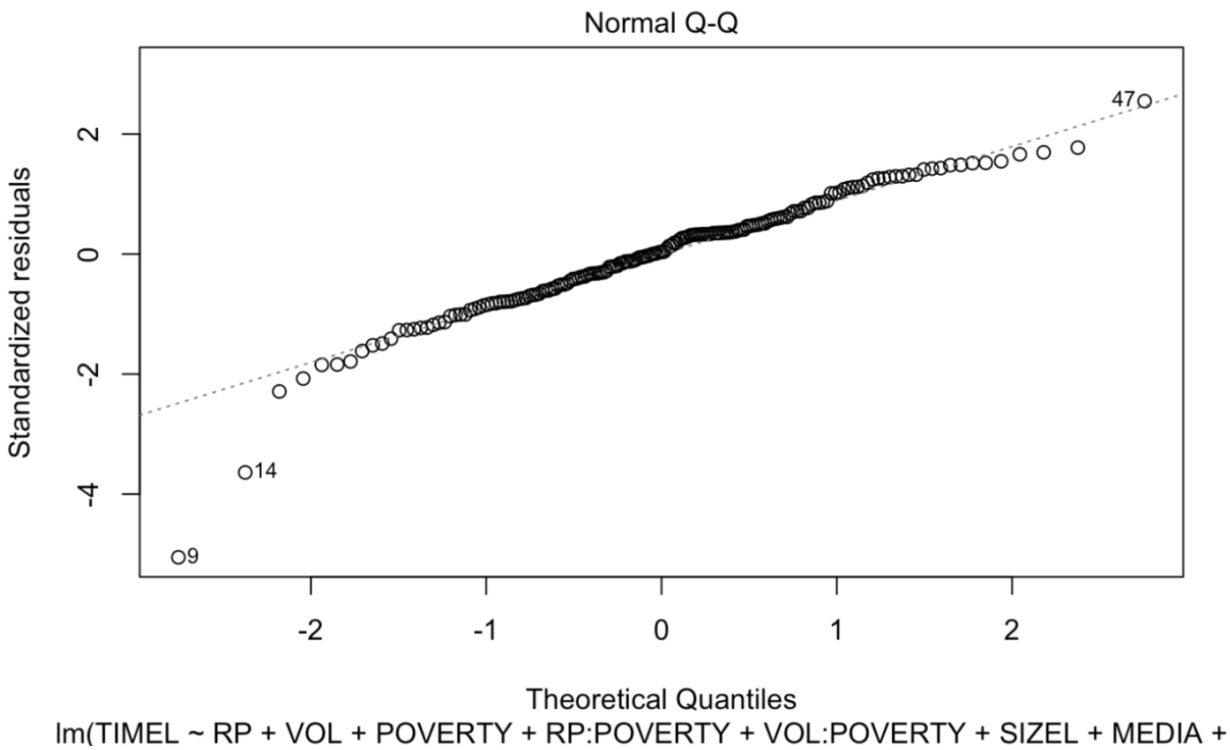

Figure 31. Question 3 Assumptions. This figure shows how the three outliers, #14, #9, and #47, do not seem to influence the model, nor have they crossed Cook's distance. The total sample size is 170.

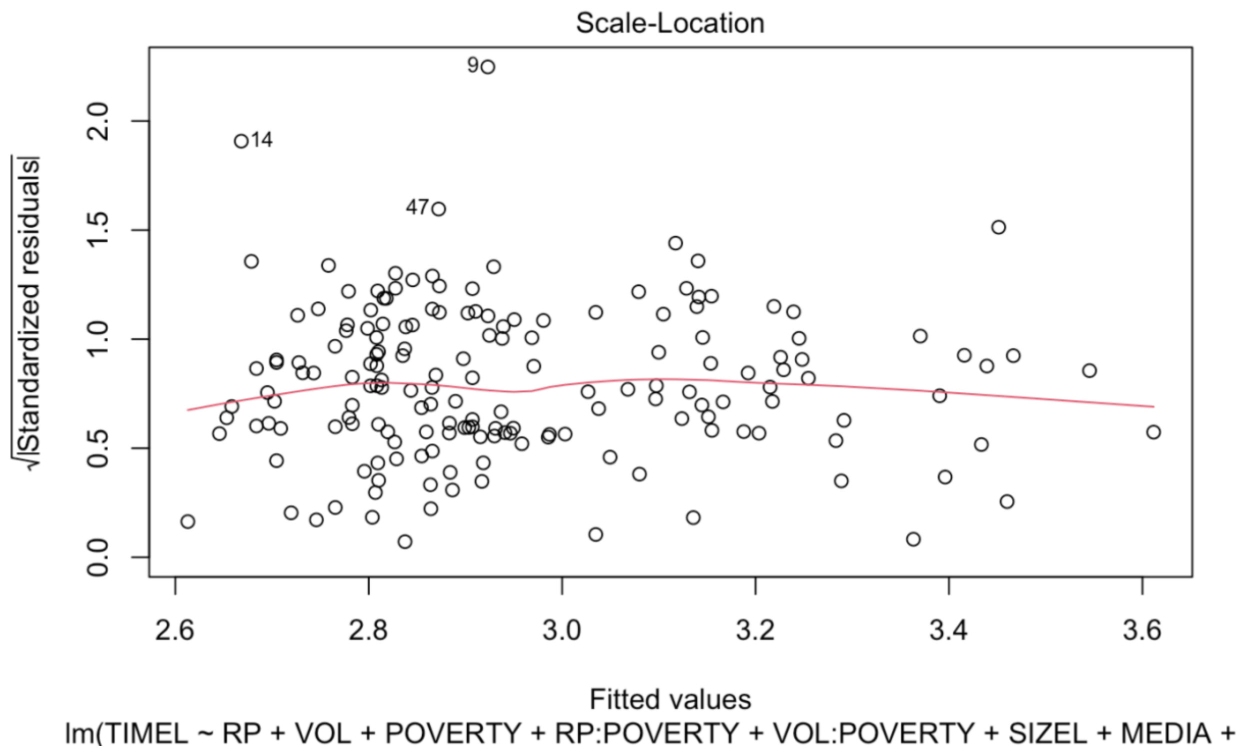

Figure 32. Question 3 Assumptions. This figure shows how the three outliers, #14, #9, and #47, do not seem to influence the model, nor have they crossed Cook's distance. The total sample size is 170.

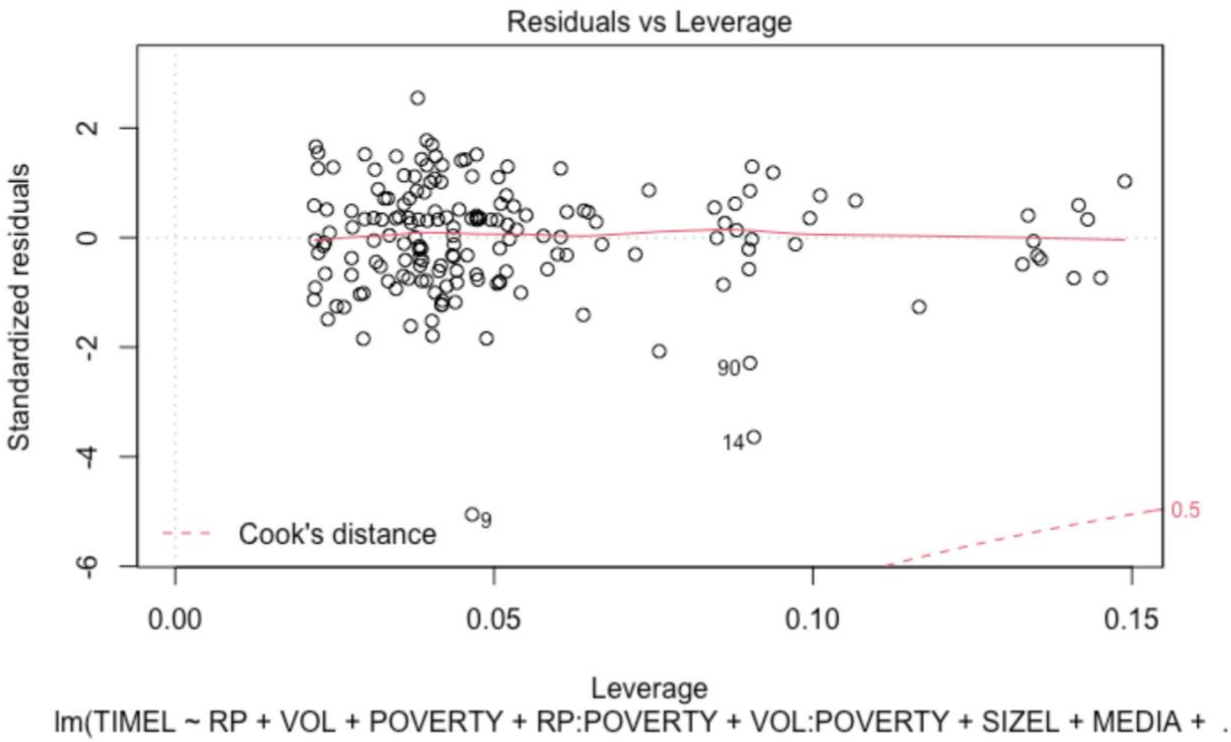

Figure 33. Question 3 Assumptions. This figure shows how the three outliers, #14, #9, and #47, do not seem to influence the model, nor have they crossed Cook's distance. The total sample size is 170.