IEc

Leaking Underground Storage Tank (LUST) Cleanup Cost Study

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Prepared for:

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Office of Communications, Partnerships and Analysis and Office of Underground Storage Tanks

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EXECUTIVE SUMMARY

INTRODUCTION

There are currently approximately 544,000 underground storage tanks (USTs) nationwide that store petroleum or other hazardous substances. Releases from these USTs threaten human and environmental health in various ways, primarily through the contamination of groundwater.[1] As part of EPA's mission, the Agency works with its state, territorial, tribal, and industry partners to clean up releases from leaking underground storage tanks (LUSTs). Approximately 62,000 releases are currently in cleanup. These cleanups employ a number of technologies, and can range from simple monitoring to major excavation, product removal, and/or the installation of in-situ remediation systems.[2] Due to a wide range of factors (e.g., soil type, size of release, groundwater impacts, receptor presence, etc.), cleanup costs for LUSTs vary substantially across different projects, geologic regions, and states. Due to this variability, many states or other entities leading cleanups do not have reliable information to inform their expectations regarding typical costs and durations of LUST cleanup projects. As a result, states have frequently voiced their desire for access to additional information that can help inform their understanding of cost drivers.

To assess these cost drivers, EPA's Office of Land and Emergency Management (OLEM) tasked Industrial Economics (IEc) with compiling and analyzing data across states to provide information that can inform typical project costs that states can expect when starting LUST cleanups. This report provides information regarding these project costs across three states who volunteered cleanup cost data. While different conditions across each state mean that costs may vary substantially, the analysis presented in this report is meant to provide a level of baseline information that states can reference in understanding cost and duration in their cleanup projects. Due to the varying nature of cleanups across, and even within states, this analysis is not intended to be used as a predictor of project costs or duration but rather as a guideline to help states understand project scale and what types of factors are driving costs. Ultimately, this is meant to help states make better, more cost-effective cleanup decisions.

KEY FINDINGS

- **Differences in cleanup programs between states prevent detailed comparisons of cleanup program costs and durations.** The three states that provided data for this project – Kansas, South Carolina, and Virginia – had numerous differences in the progression and activities required for cleanups. In addition, the reimbursement and contracting practices varied

[1] https://www.epa.gov/ust

[2] Throughout this report we frequently report costs and other factors across two types of project sites: 1) remedial action sites and 2) non-remedial action sites. Remedial action sites include those that go through an active remediation phase using a range of technologies to conduct cleanup activities, while non-remedial action sites go directly to closure or monitoring (specifically, monitored natural attenuation, or MNA) following any initial assessment and response.

significantly among the states limiting the ability to map costs to common categories. More detailed analysis was possible within individual states.

- **A relatively small number of high-cost sites are major drivers of costs in each state.** Median phase and total costs were (sometimes substantially) lower than average costs across all states. Specifically, total project costs averaged $300,241, $135,636, and $88,274 in Kansas, South Carolina and Virginia, respectively, compared to median costs of $265,883, $94,195, and $27,120. This, and the distribution of project costs, suggests that a small number of the most expensive sites represent major drivers of average total project costs. The higher costs reported for Kansas can largely be attributed to our data for Kansas being limited to remedial action sites, which means these total costs are not comparable to those in South Carolina and Virginia, whose data included a large number of (less-expensive) non-remedial action sites.
- **Assessment costs tend to be similar across projects of various sizes, meaning they represent a smaller percentage of total costs at higher-cost sites.** Site assessment in South Carolina, Virginia, and Kansas made up 37, 44, and 52 percent of total projects costs, respectively for projects costing over $100,000. At sites with costs totaling less than $100,000, site assessment made up an average of 83 percent of the total in South Carolina and 87 percent in Virginia.[3] Assessment costs accounted for 34 and 38 percent of total costs in Virginia and South Carolina, respectively, at sites that went to remedial action. In South Carolina, assessment costs made up an average of 50 percent of total project costs at MNA sites. A set of regression-based analyses suggests that greater spending during the assessment phase may lower spending in other phases; however, the relationship is difficult to assess on a site-by-site basis given the absence of comparable sites with and without greater assessment spending. The similar assessment costs across project sites, and lack of variability in assessment phase spending may be due to State Funds limiting the total amount of allowable assessment activity spending.
- **Typical project costs for sites that underwent remedial action varied somewhat between states.** The average total cost for these projects was $300,241 in Kansas compared to $290,519 in Virginia, and $211,956 in South Carolina. Remedial action made up a similar percentage of total costs in Kansas (47.1 percent) and South Carolina (42.7 percent), but represented a smaller share of the total in Virginia (28.3 percent).
- **Non-remedial action sites were often closed quickly, however, remedial site cleanups lasted an average of more than five years in Kansas and Virginia.** Sites that required remedial action had an average duration of 1,842 days across Kansas and Virginia, compared to 445 days for sites that did not. The average cost per day for remedial action sites was $165.44 compared to $95.47 for non-remedial action sites. Projects that exceeded five years from discovery to closure had similar average durations in Kansas (2,453 days) and Virginia (2,405). Costs per day at these sites were also similar across both states ($135.51 in Kansas and $148.32 in Virginia). The average cleanup duration of 560 days across all projects in Virginia suggests that these lengthy projects are an exception and that most projects are completed in one year or less.

[3] No sites in our dataset for Kansas had total costs of less than $100,000. As noted above, our Kansas dataset was limited to remedial action sites.

- **Projects in South Carolina had substantially longer durations than the other two states, although this was partially due to differences in reporting.** South Carolina tracks dates for individual releases (i.e., sometime allowing for multiple releases at a single site), from first reported date through no further action (NFA) date.[4] We do not think that these durations are comparable due to a number of factors, mainly, 1) South Carolina's use of the release date as a starting point, rather than the bid date which is used in Kansas and 2) substantially longer monitoring periods in South Carolina compared to the other states, particularly Virginia. The average duration from first report to NFA for a release in South Carolina was 6,123 days. As in the other two states, remedial action projects had longer average durations (6,743 days) than non-remedial action projects (5,636 days). Non-remedial action projects had average durations of 6,127 days for MNA projects, and 3,188 for non-MNA projects. The substantially longer durations in South Carolina may be due in part to longer monitoring periods after active cleanup work is complete, compared to the other two states.
- **MNA projects were less expensive than remedial projects.** This is an unsurprising result due to the less-intensive nature of these projects, but the state-level data showed these projects to be significantly less expensive in total compared to projects that underwent active remedial action. Costs for MNA cleanups were $120,244 average and $94,520 median and costs for sites that underwent active remediation were $255,491 average and $190,845 median.
- **Sites where free product was present had substantially higher costs than those where it was not, although these data were limited.** In Kansas, sites where free product was present had substantially higher costs on average ($411,198) than sites with no free product ($264,180).[5] All technology-related investigations and the subsequent results are limited by small sample size considerations.
- **Project duration is a significant driver of remedial action costs, and therefore overall site costs.** When controlling for other factors, including state, technology, and active project phase(s), project duration had a statistically significant effect on overall project costs. Based on regression analysis, a one day increase in project duration corresponds with a $116 increase in total project costs. Many factors contribute to longer cleanup durations, such as the size of the release and the complexity of the cleanup.

KEY TAKEAWAYS FOR STATES

Based on the key findings above, we highlight several factors for states to consider as they plan the future direction of their LUST cleanup programs. Given the limitations of our analysis, the considerations below should not be construed as definitive recommendations or as guarantees of any particular outcome for a state. Each state should consider the takeaways below in the context of its own LUST cleanup program.

[4] We did not calculate costs by duration in South Carolina because we were unable to associate total site costs with a specific release at multi-release sites.

[5] Kansas specified whether each site had soil, groundwater, and/or free product contamination. The sites with free product (alone or in combination with other contamination) were substantially more expensive than sites without free product.

- **To control costs, states should first look at outliers – specifically, high-cost sites which substantially increase average costs.** Average costs were 11 percent (Kansas), 31 percent (South Carolina), and 69 percent (Virginia) higher than median costs, showing the impact of these outlier sites in driving up total costs. Bringing these costs down would generate the biggest savings for the effort.
- **States should focus on reducing the duration of cleanups if they want to bring costs down.** As mentioned previously, costs per day were $165 at remedial sites and $95 at non-remedial sites. These costs become very substantial at multiyear cleanup sites.
- **States should consider the potential to improve cleanup efficiency by conducting more site assessment, particularly at more complicated sites.** While our data were limited to confirm this, our regression analysis suggested that greater spending during the assessment phase may lead to lower costs later in the project. Although the savings appear small in comparison to total costs, there was a lack of sites that spent substantially in the assessment phase. This analysis suggests greater investment in site assessment could have beneficial effects on overall project costs.
- **States should consider whether closing sites more quickly, without extensive remediation or long MNA periods, could help drive down costs without sacrificing environmental protection.** States may want to consider a model like Virginia's, where sites are closed quickly, with limited or no monitoring, if they are able to do this while still maintaining high environmental protection. As discussed above, duration is a major driver of costs, so a model that limits project duration would likely reduce overall costs.

POTENTIAL NEXT STEPS

A key finding from this study was that even states with robust data still often lack the granularity and connectedness across datasets to conduct a comprehensive analysis of key cost drivers. Most notably, these data are often limited in their ability to analyze costs associated with a specific technology. For states wishing to quantity these costs, we recommend ways in which states could reorganize their internal tracking systems to increase the ease of future analysis. In addition, further research could be done using expert elicitation to estimate technology-specific costs and other cost drivers across states. We explain these options in greater detail below:

- **State cleanup cost tracking database updates:** States could focus on consistently storing data in a central database using consistent terms and fields to allow for easier analysis in future internal or external studies. During this effort, we encountered several data limitations, many of which states identified as barriers in their own tracking. These included:
  - State databases do not consistently associate cleanup costs with specific phases of the cleanup and/or specific assessment and cleanup technologies.
  - Claims made to the State Funds are generally not captured by phase and by technology in state databases.
  - Data that are collected are not always readily accessible (e.g., PDF files); even when data are collected, they are not always in a format that facilitates analysis.

To overcome these limitations moving forward, we recommend states consider the following changes as they update their databases:

- Each database should track information consistently across all projects.
  - Fields should be consistent in tracking, even if some are not applicable to many projects.
- The databases should link costs, technologies, and site characteristics.
- States should consider their own data needs and areas of interest in future tracking when developing their databases and reporting forms.

➢ **Expert elicitation to determine cost drivers:** Due to the challenges that we and states have faced in extracting information from state databases, an expert elicitation process could be used to estimate technology-specific and assessment-related costs in the absence of readily obtainable data from state databases. Expert elicitation has been used for previous OUST efforts, including a rulemaking to estimate the economic benefits of the proposed rule from estimated reductions in leaks, and in fields ranging from human health to code compliance. This process would involve identifying experts on LUST cleanups and providing them with baseline information pulled from this study. The experts would then be asked several targeted questions regarding specific costs of cleanup projects, possibly through multiple rounds of discussion, to reach consensus on typical costs associated with specific technologies and cleanup methods. Another potential line of questioning for the experts (in addition to or instead of technology costs) would be if/under what circumstances spending more on assessment activities reduces total cleanup costs. To explore the assessment question, we would look to supplement our current data with additional information from states, including states that have used high-resolution site characterization and traditional assessment approaches. We would share this information with the experts to inform their assessment of cost impacts.

BACKGROUND, APPROACH, AND METHODOLOGY

To conduct this analysis, IEc worked with OLEM to solicit LUST cleanup cost data from volunteer states. Initially, IEc and OLEM requested the following information from Association of State and Territorial Solid Waste Management Officials (ASTSWMO) member states:

- Cleanup cost data that is available for one or more example sites; and
- Standard cost guidelines/cost-reimbursement schedules for each state – both for the State Fund reimbursement sites and the state lead contracts.

After this initial request, IEc and OLEM followed up with states to collect additional information, including:

- A list of all LUST cleanup projects within the state in the past 10+ years;
- Details regarding the technology and/or remedial activities used to conduct each cleanup;
- Costs per project including both total costs and costs broken out by phase and technology; and
- Project status (closed or active), along with the beginning and end dates of the cleanup projects.

Many states do not capture all parts of this information in a database, or their databases have changed formats over the years. Therefore, it was challenging for states to provide detailed information on assessment and remediation activities, technologies, and their associated costs. Ultimately, four states were able to provide detailed information: Kansas (through the Kansas Bureau of Environmental Remediation), South Carolina (through the South Carolina Department of Health and Environmental Control), Tennessee (through the Tennessee Department of Environment and Conservation), and Virginia (through the Virginia Department of Environmental Quality Petroleum Division). After reviewing the data, IEc ultimately decided to drop Tennessee's data from the analysis due to the small sample size (nine completed projects).

The UST corrective action programs in the three states ultimately included in this study are similar in many ways. The corrective action costs are generally reimbursed by State funds. Owners lead most of the corrective action projects (the work is done by consultants hired by the owners), although some of the sites are led by the state. The programs control costs through systems and procedures such as pre-approval of corrective action costs, competitive bidding, cleanup goals based on site-specific risk-based end points. Kansas and South Carolina use standard forms for site assessment and corrective action plans, and South Carolina and Virginia require contractors to follow a fee schedule.

IEc reviewed the data from these three states and collaborated with OUST and each respective state to ensure completeness and accuracy in the data. Specifically, this included ensuring that each project had information regarding total costs, and at least one additional level of detail that could be used in the analysis. These additional details that IEc sought included:

- Costs by technology or project phase,
- information regarding the cleanup technology used,
- the current project status (i.e., closed or active), and,
- the duration time to closure.

Due to data gaps in some of these fields, we were unable to use all data for all parts of the analysis. Project sites that did not contain enough information to be used in any parts of the analysis (e.g., did not split out costs by technology or phase) or had costs that did not align with reasonable expectations (e.g., the sum of technology or phase costs greatly exceeded or fell well short of total costs) were dropped entirely from this study. **Exhibit 1** shows the number of sites provided by each state, along with the number ultimately used in analysis following this data culling step.

EXHIBIT 1. NUMBER OF RESPONSES AND SITES

STATE	NO. OF SITES PROVIDED	NO. OF SITES USED IN ANALYSIS	PROJECT START YEARS INCLUDED IN DATA
Kansas	53	53[1]	2010-2021
Tennessee	9	N/A	2010-2019
South Carolina	357	217	1973-2021[2]
Virginia	15,116[3]	260	2011-2021

1. Kansas provided total cost data for all sites, along with costs in the remedial action, closure, and monitoring phases. To determine costs for the remaining phases (site assessment and initial remedial response), we subtracted these remedial action, closure, and monitoring phase costs from total costs. As a result, our analysis of Kansas's data was limited beyond 12 closed sites, as it was not possible to use these final differences in costs to determine costs for site assessment and initial remedial response at sites that are still active. However, we used all 53 sites in any parts of the analysis that did not require the detailed cost breakdown by phase.
2. Although South Carolina's data included some records dating back as far as 1973, 99 percent of the projects included were from 1990 or later, and 89 percent occurred between 2000 and 2021.
3. Virginia was the only state that included non-federally regulated releases (e.g., home heating oil releases) in the data they provided. These non-federally regulated releases made up 87 percent of the cleanups in the data. Of the remaining 2,001 sites, costs were not split out by phase for the majority, meaning complete analysis could only be completed on 260 sites.

IEc conducted analysis for each state in two ways: 1) an initial analysis of the data fields provided directly by each state, and 2) an analysis of reorganized fields that were uniform across all states. The results from the initial analysis (i.e., state-specific fields) are presented in **Appendix A.** The body of this report presents analysis on the combined fields that were comparable across states. To conduct this analysis, IEc worked with the states and OUST to reorganize cost-by-phase data into the following broad categories that were mostly consistent across each state:

- **Initial Remedial Response** – activities for suspected or confirmed releases from USTs, including reporting the release to the regulator, immediate action to prevent further releases to the environment, and the identification and mitigation of any immediate hazards (e.g., fire, explosion, vapor) at the site;
- **Site Assessment** – the collection and development of information regarding the release, including the nature and estimated quantity of the release, the extent of the release and its potential intersection with drinking and surface water sources, free product investigations, and site map development;
- **Remedial Action** – the implementation of remedial techniques and methods to clean up the site and all contamination associated with the release;

- **Monitoring** – installation and implementation of a monitoring program to evaluate temporal changes in conditions (e.g., groundwater quality and elevations) at a site. Depending on the state, monitoring may be completed before, during, or after remedial action, and;
- **Closure** – costs associated with shutting the site or facility, which may or may not be a part of the overall remediation process associated with a given release.

For much of the analysis in this report we divided the projects into two broad categories – 1) those that were completed with a remedial action phase (i.e., the installation of a remedial technology), and, 2) those that were closed without undergoing an active remedial action. Specifically, these sites closed following assessment and any initial response, and/or a period of monitoring, including MNA.

For some projects we were unable to map costs to a specific phase due to the way the data were captured and organized by the states, while in some cases the recorded costs included more than one phase. While costs were able to be captured for most phases at most of the Virginia sites, we were unable to split out costs into some phases in South Carolina and Kansas's data. For example, South Carolina did not provide costs for the initial remedial response or closure phases. Kansas provided total project costs but only broke out costs for the remedial action, monitoring, and closure phases. Therefore, we assumed the difference between the total costs and the costs for the remedial action, monitoring, and closure phases provided by Kansas represent the combined initial remedial response and site assessment costs.[6] In South Carolina, it is likely that costs associated with activities that would be considered initial remedial response or closure are spread out across the phases included in South Carolina's dataset.

Exhibit 2 shows a typical timeline that projects followed in each state. Sites that went to remedial action in Kansas and South Carolina began with an initial remedial response, followed by a site assessment, the remedial action itself, closure, and monitoring. Projects that did not include remedial action in South Carolina went directly to monitoring. The monitoring phase, which occurs at some remedial action sites in Virginia occurs prior to the remedial action phase, unlike Kansas and South Carolina where the monitoring phase occurs after the remedial action. For Virginia's non-remedial action sites, monitoring occurs after site assessment at some of the sites. Some non-remedial action sites in Virginia report costs for a closure phase, while those in South Carolina do not, although these costs are likely included in the data across a different phase or phase(s).

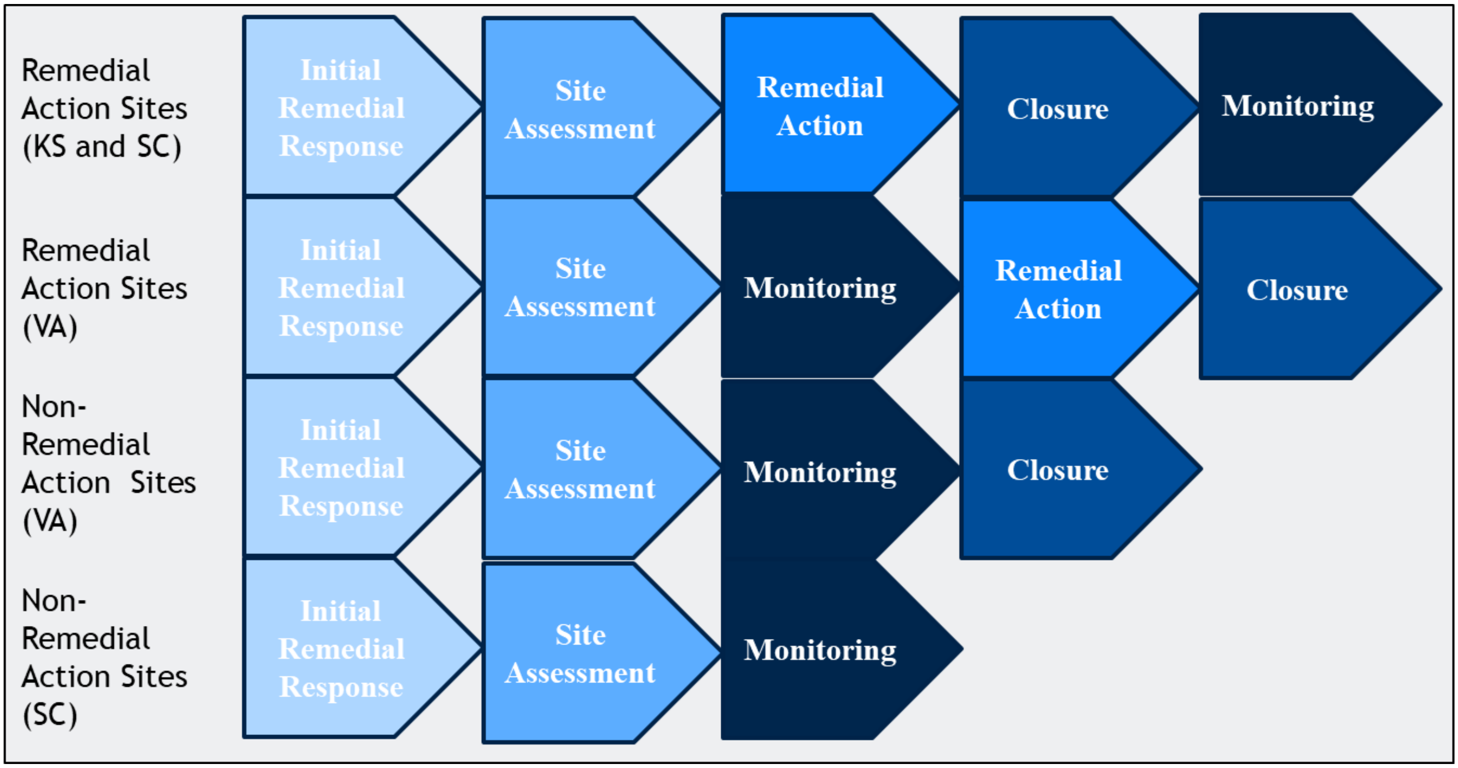
Cost data for some of the non-remedial action sites in Virginia are limited, because the costs do not exceed the required $50,000 deductible that applies to larger owners. This is in contrast to a $25,000 deductible for all owners in South Carolina and a deductible in Kansas of $3,000 plus $500 per tank.[7] The Virginia owners that have the $50,000 deductible sometimes do not pursue state funding, or stop pursuit (i.e., stop applying to the State Fund), if the project costs are unlikely to exceed the deductible of $50,000. Where lower deductibles apply to other owners, their costs generally exceed the deductible even at sites that close after site assessment, so the cost data for these sites are more complete. As a result, the project cost data for some of the non-remedial action sites in Virginia only include information for the

[6] We calculated these initial remedial response and site assessment costs at the 12 closed sites in Kansas, because active sites in the data had ongoing costs preventing us from separating out the final project and remedial action costs to determine what was spent in those unreported phases. For all analysis in this report that does not include those specific phases, we include all available data from Kansas.

[7] Table 1 of the 2020 Annual State Fund Survey, ASTSWMO; https://astswmo.org/category/tanks/state-fund-financial-responsibility-task-force/

earliest phases (e.g., initial remedial response and site assessment), and do not include costs for the later phases if the project stopped seeking reimbursement from the State Fund.

EXHIBIT 2. TYPICAL PHASE PROGRESSION AT REMEDIAL ACTION AND NON REMEDIAL ACTION SITES ACROSS STATES



After mapping the cost data into these broad phase categories, we conducted analysis looking at average and median costs across each phase, technology, and projects as a whole. Note that due to the substantial differences across states, we do not provide these statistics across the three states combined for all parts of the analysis in this report.

We were able to conduct only limited analysis of costs for specific technologies. The cost datasets that the states were able to supply related to technology were limited in the number of sites and many of the remedial projects used multiple technologies. Further, while it was possible to determine technology(ies) used at some sites, there was often no cost data specifically associated with a given technology, and it was therefore difficult to separate costs associated with each technology from other cost drivers. As a result, there were few projects where we could parse out the costs associated with a specific technology. To try to measure some impacts of technology on total costs, we conducted a regression analysis using several ordinary least squares (OLS) regressions to account for the state-specific factors and to compare phase and technology costs across states. This is discussed further in **Appendix B**.

Because many costs across all states were associated with multiple years, we did not adjust for inflation. This may mean that costs shown through this report underestimate what would be required to complete cleanups in the reporting year (2022); however, the impact of inflation may be offset by reductions in costs for some of the technologies. Further, since states provided data for similar time periods, this likely has only a small effect on any comparisons of costs across states.

Finally, we also reviewed project costs based on duration and spending during the assessment phase to try to better capture the cost drivers in these projects. The results of these analyses are presented in this report.

The remainder of the report details specific findings from our analysis of the three states' databases.

RESULTS

CLEANUP COSTS BY PHASE

Total costs and costs by phase varied substantially across states, although this was driven in part by the type of data that each state provided (e.g., Virginia provided project data that included many cleanups that were small and/or did not require remediation while Kansas's dataset consisted of only projects that required remedial action and therefore had higher costs). **Exhibit 3** shows the average and median costs across states both for phase-specific and total project costs. These figures show:

- Projects in Kansas had the highest average total costs ($300,241), ahead of South Carolina ($135,636) and Virginia ($88,274).[8]
- Despite these overall differences, remedial action phase costs were closer across states, averaging $82,277 in Virginia, $90,513 in South Carolina $90,513, and $141,339 in Kansas.
- Virginia and Kansas had similar costs in the monitoring and closure phases (roughly $20,000-$25,000 in each state), although these were only about half the total monitoring costs in South Carolina ($44,251).[9]
- Virginia's initial remedial response and site assessment phase costs combined to nearly equal South Carolina's site assessment costs.[10] These costs fell well below the combined cost of $124,289 in Kansas for these two phases.
- Median costs were lower across all phases and total project costs for all three states, suggesting that average costs are being driven upwards by the presence of the complex, expensive sites in each state, which do not tend to be representative of a typical site.

[8] As previously mentioned, the higher costs reported for Kansas can largely be attributed to our data for Kansas being limited to remedial action sites, which means these total costs are not comparable to those in South Carolina and Virginia, whose data included a large number of (less-expensive) non-remedial action sites.

[9] Because South Carolina's data only included costs for three phases, it is likely that these costs include activities that would have been split out into other phases (i.e., initial remedial response or closure) had this information been available. This is likely driving higher costs per phase in South Carolina when compared to other states.

[10] South Carolina did not provide initial remedial response cost data. However, we think it is likely that cleanup activities for sites in South Carolina were comparable to those completed in Virginia's initial remedial response phase and are captured in site assessment and/or remedial action phase costs in South Carolina's data.

EXHIBIT 3. AVERAGE AND MEDIAN CLEANUP COSTS BY STATE - ALL SITES

PHASE	AVERAGE COSTS[a]			MEDIAN COSTS[a]		
	KANSAS	SOUTH CAROLINA[b]	VIRGINIA	KANSAS	SOUTH CAROLINA	VIRGINIA
N	*53[c]*	*217*	*260*	*53[c]*	*217*	*260*
Initial Remedial Response	$124,289[c]	--	$20,684	$163,850[c]	--	$14,466
Site Assessment		$53,390	$28,648		$41,424	$16,378
Remedial Action	$141,339	$90,513	$82,277	$130,285	$38,419	$50,056
Monitoring	$18,231	$44,521	$18,781	$17,960	$25,810	$9,867
Closure	$6,317	--	$3,782	$3,580	--	$2,036
Avg. Per Site	**$300,241**	**$135,636**	**$88,274**	**$265,883**	**$94,195**	**$27,120**

a. Average and median costs are comprised only of sites that underwent each phase (i.e., if a site did not enter a phase, it was excluded from the calculation of the average/median, rather than being treated as a $0 value).

b. Five sites in South Carolina had costs associated with an "Other/Unknown" phase. These costs averaged $27,619 at these sites, with a median of $18,946.

c. Since Kansas did not provide costs for initial remedial response or site assessment, we determined these costs to be the difference between total project costs and the remedial action costs (including monitoring and closure) that the state provided. Based on this approach, we were only able to accurately assess costs for these two phases for closed projects, as ongoing projects with costs that are still accumulating did not allow us to compare these differences. As a result, the initial remedial response and site assessment costs shown here for Kansas represent only the 12 closed sites, while the other three phases are shown with average and median costs across all 53 sites.

To compare projects at a more similar level between states, we looked at cost differences limited only to projects that conducted remedial action (typically complex, more expensive cleanups). **Exhibit 4** shows that total project costs were far more similar between states when looking only at these sites. All projects provided by Kansas included remedial action and therefore the average cost remain at $300,241, but South Carolina's average project costs increase to $211,956, while Virginia's projects with remedial action ($290,519) nearly equal the total costs of Kansas's projects. The average remedial action phase costs of $141,339 in Kansas represent 47.1 percent of total costs, fairly similar to the 42.7 percent in South Carolina. Both states had a greater share of total costs spent on remedial action than Virginia (28.3 percent).

EXHIBIT 4. AVERAGE REMEDIAL AND TOTAL CLEANUP COSTS AT SITES THAT ENTERED REMEDIAL ACTION PHASE

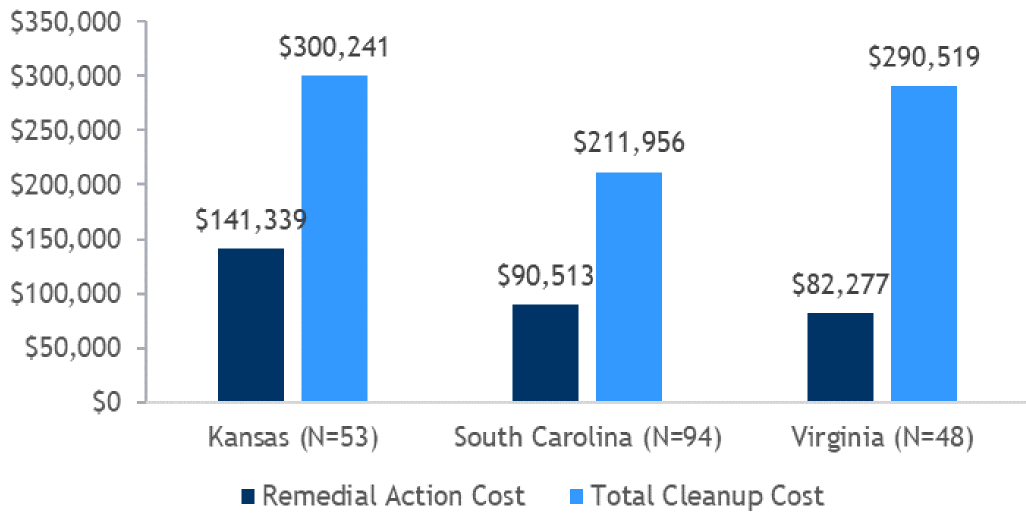
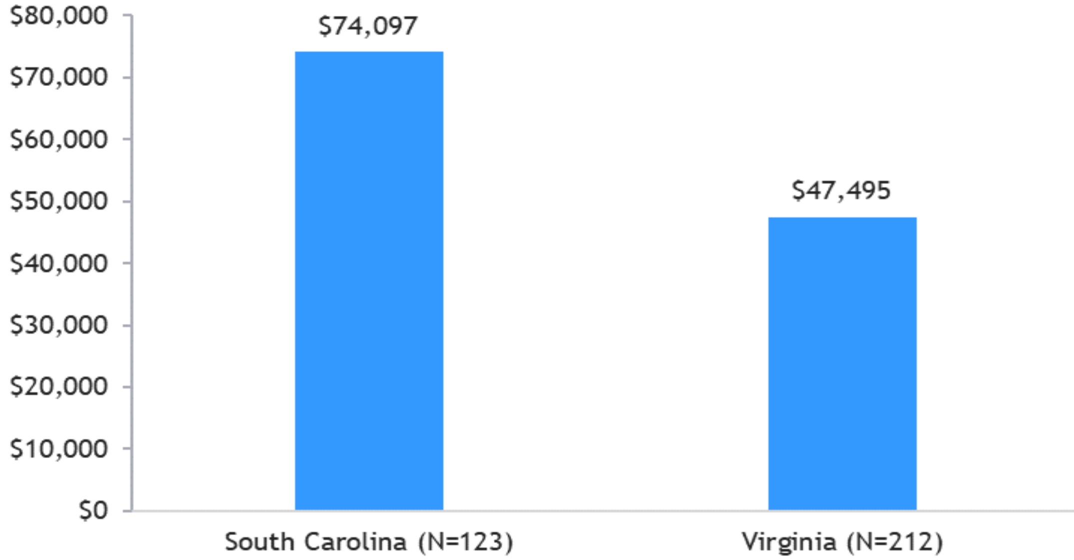


Exhibit 5 shows the average total costs for sites in South Carolina and Virginia that did not enter remedial action. These cleanups cost an average of $74,097 in South Carolina and $47,495 in Virginia. These costs represent 34.9 and 16.3 percent of the average total cost of projects that include remedial action in South Carolina and Virginia, respectively. Total average project costs for non-remedial action sites in both states were less than the average cost for the remedial phase alone in each state.

EXHIBIT 5. AVERAGE TOTAL CLEANUP COSTS AT SITES THAT DID NOT ENTER REMEDIAL ACTION PHASE



We also looked at the average and median costs across each state for closed sites only (**Exhibit 6**). Closed sites had lower total costs compared to active sites across all three states. Kansas's total costs fell to $278,388 when including only closed sites, which was still substantially higher than $130,379 in average total costs in South Carolina and $61,881 in Virginia. These lower costs are a result of the highest costed projects in each state remaining active, likely due to the larger (i.e., higher volume) and/or more complex nature of these sites preventing them from being closed quickly, which results in the projects incurring ongoing costs (see: **Cleanup Costs by Duration** Section).

As discussed above, the total project costs in Kansas are greater than those costs in South Carolina and Virginia, which may be explained, in part, by Kansas providing only sites that entered remedial action and not including the sites that closed after assessment or that went to MNA. Total project costs in South Carolina are greater than those costs in Virginia, which may be explained, in part, by South Carolina having more MNA sites than Virginia and South Carolina's longer MNA period.

EXHIBIT 6. AVERAGE AND MEDIAN CLEANUP COSTS BY STATE - CLOSED SITES ONLY

<table>
<tr><th rowspan="2">PHASE</th><th colspan="3">AVERAGE COSTS</th><th colspan="3">MEDIAN COSTS</th></tr>
<tr><th>KANSAS</th><th>SOUTH CAROLINA</th><th>VIRGINIA[a]</th><th>KANSAS</th><th>SOUTH CAROLINA</th><th>VIRGINIA[a]</th></tr>
<tr><td>N</td><td>12</td><td>27</td><td>148</td><td>12</td><td>27</td><td>148</td></tr>
<tr><td>Initial Remedial Response</td><td rowspan="2">$124,289</td><td>--</td><td>$11,049</td><td rowspan="2">$163,850</td><td>--</td><td>$7,810</td></tr>
<tr><td>Site Assessment</td><td>$53,469</td><td>$17,508</td><td>$46,180</td><td>$10,986</td></tr>
<tr><td>Remedial Action</td><td>$129,042</td><td>$71,135</td><td>$51,249</td><td>$139,934</td><td>$55,957</td><td>$24,797</td></tr>
<tr><td>Monitoring</td><td>$12,788</td><td>$50,173</td><td>$10,421</td><td>$13,264</td><td>$18,227</td><td>$7,088</td></tr>
<tr><td>Closure</td><td>$12,269</td><td>--</td><td>$3,782</td><td>$4,030</td><td>--</td><td>$2,036</td></tr>
<tr><td>Avg. Per Site</td><td>$278,388</td><td>$130,793</td><td>$61,881</td><td>$303,958</td><td>$92,288</td><td>$15,630</td></tr>
<tr><td colspan="7">a. Average and median project costs reported here in Virginia may underestimate actual project costs due to owners stopping pursuit of State Funds if the project will not reach the deductible.</td></tr>
</table>

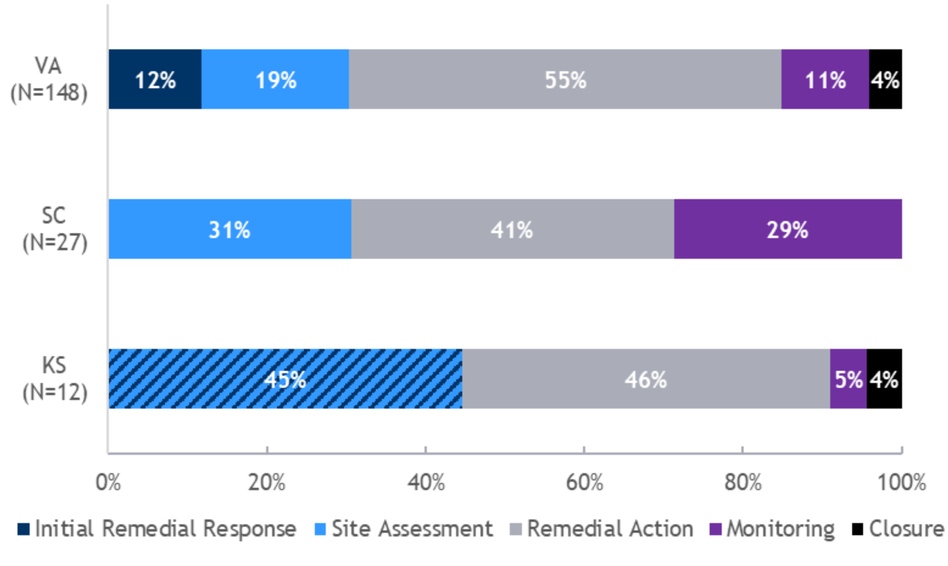
To understand the drivers of project costs, we then analyzed the share of costs per phase at closed sites to determine where project spending occurs (**Exhibit 7**).[11] The remedial action phase made up 55 percent of total costs in Virginia, slightly higher than Kansas (46 percent) and South Carolina (41 percent). Initial remedial response and site assessment costs combined to total 45 percent of costs in Kansas and 31 percent in Virginia. This was equal to the 31 percent site assessment costs in South Carolina (who did not provide initial remedial response costs). While South Carolina did not provide closure costs, its monitoring costs were the highest relative to total costs across all three states (29 percent).[12] In Virginia monitoring and closure costs combined to equal 15 percent of all costs, slightly ahead of Kansas at nine percent. Note that South Carolina's activities that would meet the criteria defined as initial remedial response and closure in other states are likely captured in other phases (e.g., initial remedial response might be grouped with remedial action). This is likely driving higher costs across these phases in South Carolina when compared to the other states.

---

[11] We limited this analysis to closed sites only as we assume that costs and the associated cost share by phase are subject to change at active sites.

[12] Per communication with South Carolina, this was likely due to a number of factors where data are compiled differently than other states, including differential in allowed rates, differences in program specifics regarding closure requirements, etc.

EXHIBIT 7. PERCENTAGE OF COSTS BY PHASE AT CLOSED SITES



Because not all sites enter, or had not yet entered, each phase (e.g., some sites never conduct remedial action, some active sites have not yet gone to closure, etc.), we also analyzed the percentage of costs dedicated to each phase when limited only to sites that had incurred costs in each given phase (**Exhibits 8-10**). Note that this includes all sites (active or closed), to show what costs may look like as projects move through specific phases.

For example, sites in Kansas that had conducted monitoring (see the "Monitoring" row in **Exhibit 8**) spent an average of six percent of all costs on these activities, along with 44 percent on initial remedial response and site assessment, 47 percent on remedial action, and three percent on closure. Site assessment made up 40 percent of costs at sites that included this phase in South Carolina, while remedial action and monitoring each made up 30 percent of total costs. At remedial action sites, the remedial action phase accounted for roughly half (49 percent) of all costs.

In Virginia, where there was the most variation between the number of sites that entered each phase, there were also the greatest differences between the share of costs. Just 13 percent of the 260 sites had initial remedial response costs, but within those projects, remedial response costs made up an average of 30 percent of the total cost. Nearly 90 percent of the projects conducted site assessments, which made up 60 percent of total average costs for those projects. Remedial action costs made up two-thirds of costs for projects that entered the remedial action phase. Most sites included monitoring costs which comprised 34 percent of the project total, while closure costs made up 13 percent of the total at the roughly one-quarter of sites that included these costs.

EXHIBIT 8. PERCENTAGE OF COSTS GIVEN A SITE ENTERED A PHASE - KANSAS[a]

PRESENT CATEGORY	N	INITIAL REMEDIAL RESPONSE & SITE ASSESSMENT	REMEDIAL ACTION	MONITORING	CLOSURE
Initial Remedial Response & Site Assessment	44	53%	40%	5%	2%
Remedial Action	53	44%	47%	6%	3%
Monitoring	51	44%	47%	6%	3%
Closure	53	44%	47%	6%	3%

a. This table shows the percentage of costs dedicated to each phase when limited to sites that incurred costs in each given phase. For example, sites in Kansas that conducted monitoring (see the "Monitoring" row) spent an average of six percent of all costs on these activities, along with 44 percent on initial remedial response and site assessment, 47 percent on remedial action, and three percent on closure. This includes active and closed sites.

EXHIBIT 9. PERCENTAGE OF COSTS GIVEN A SITE ENTERED A PHASE - SOUTH CAROLINA[a]

PRESENT CATEGORY	N	SITE ASSESSMENT	REMEDIAL ACTION	MONITORING
Site Assessment	187	40%	30%	30%
Remedial Action	82	24%	49%	27%
Monitoring	174	38%	31%	31%

a. Phase names reflect those represented in South Carolina's database and therefore exclude "initial remedial response" and "closure".

EXHIBIT 10. PERCENTAGE OF COSTS GIVEN A SITE ENTERED A PHASE - VIRGINIA

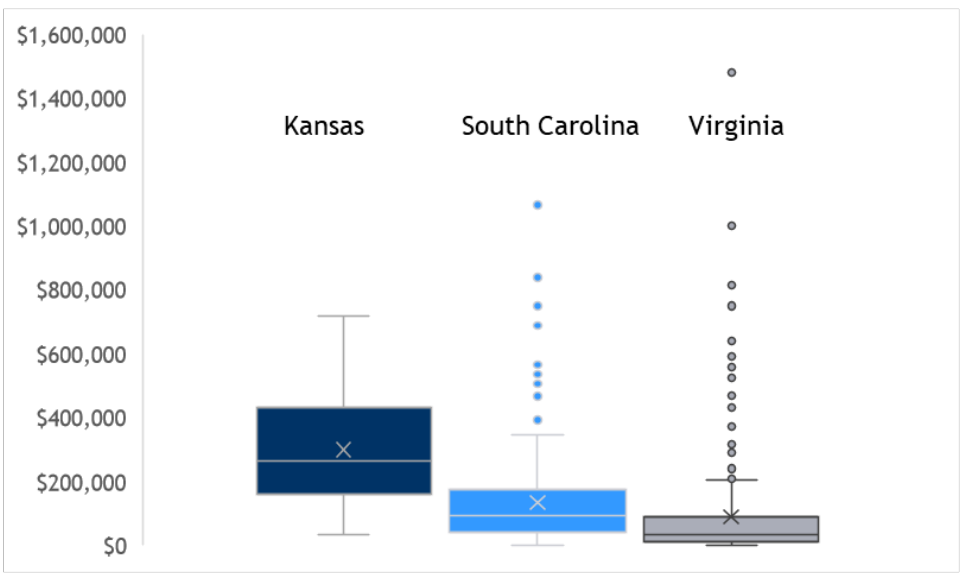
PRESENT CATEGORY	N	INITIAL REMEDIAL RESPONSE	SITE ASSESSMENT	REMEDIAL ACTION	MONITORING	CLOSURE
Initial Remedial Response	34	30%	49%	9%	12%	1%
Site Assessment	233	5%	60%	21%	14%	1%
Remedial Action	48	1%	23%	67%	6%	2%
Monitoring	236	4%	46%	15%	34%	1%
Closure	69	4%	43%	22%	18%	13%

Finally, to assess the scale and potential magnitude of these projects, we looked at the maximum costs across each phase and projects as a whole (**Exhibit 11**), along with a comparison of all project costs (**Exhibit 12**) across all project sites (closed and active). Despite having the highest average costs, the maximum total project cost in Kansas was the lowest of all three states ($719,076). Virginia had the most expensive cleanup site ($1,479,277), followed by South Carolina ($1,065,995). The maximum costs may have been influenced by the fund caps, which are $1 million per release in all three states.[13] An individual site can have more than one release, and the resulting cleanup costs can exceed $1 million for the site. The most expensive cleanup sites in South Carolina had the highest maximum costs across each of the three phases for which they reported data ($487,624 for site assessment, $720,684 for remedial action, and $341,204 for monitoring). This may have been due in part to South Carolina reporting costs in only three categories as opposed to five, resulting in more costs being grouped into those categories. The site with the greatest closure costs in Kansas more than doubled that of Virginia ($84,557 and $35,402, respectively).

EXHIBIT 11. MAXIMUM COSTS ACROSS PHASES

STATE	KANSAS	SOUTH CAROLINA	VIRGINIA
Initial Remedial Response	$238,423	--	$118,529
Site Assessment		$487,624	$159,230
Remedial Action	$376,880	$720,684	$241,886
Monitoring	$32,420	$341,204	$75,209
Closure	$84,557	--	$35,402

EXHIBIT 12. DISTRIBUTION OF COSTS AT EACH SITE BY STATE



As shown in **Exhibit 12**, South Carolina and Virginia both had many sites that were more expensive outliers than the typical sites in each respective dataset. This reflects the nature of cleanup projects where some sites are much smaller and/or more straightforward, resulting in lower costs. The distribution of project costs in these two states suggests that more expensive projects are atypical, but also major drivers

[13] State fund caps from Table 2 of the 2020 State Fund Survey, ASTSWMO https://astswmo.org/category/tanks/state-fund-financial-responsibility-task-force/

of higher average totals. **Exhibits 13** and **14** show these costs split out by remedial and non-remedial action projects only. As the figures show, maximum, minimum, median, and average costs were higher for remedial action sites than those without remedial action in both South Carolina and Virginia. However, there were substantially more outliers for non-remedial action projects in both states, which suggests that total project costs may deviate to a greater extent for these type of projects as compared to those that enter remedial action.

EXHIBIT 13. DISTRIBUTION OF COSTS AT EACH SITE BY STATE - REMEDIAL ACTION PROJECTS

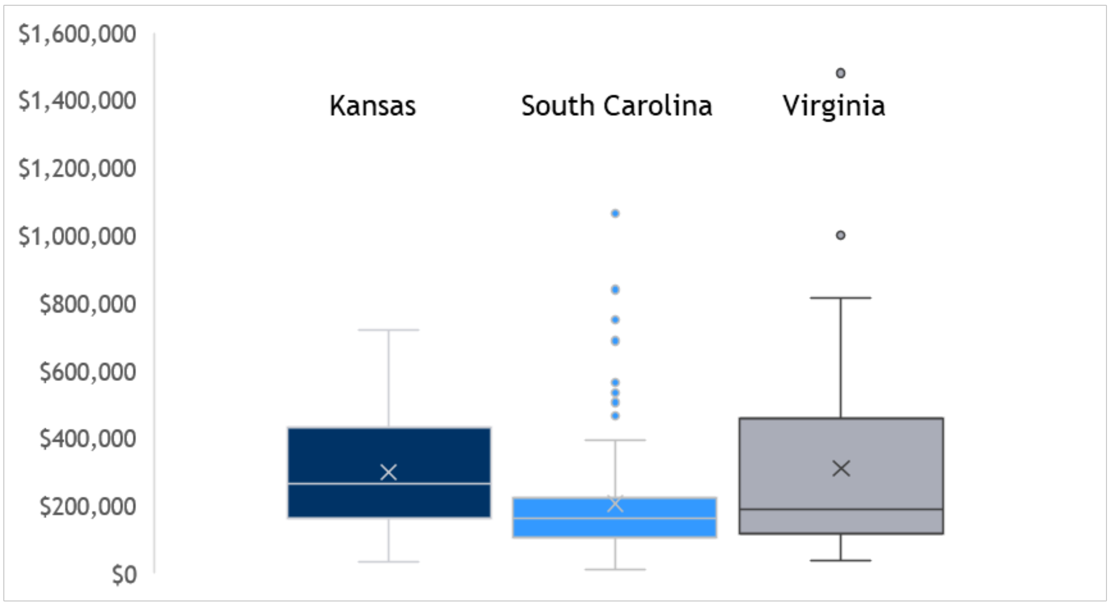
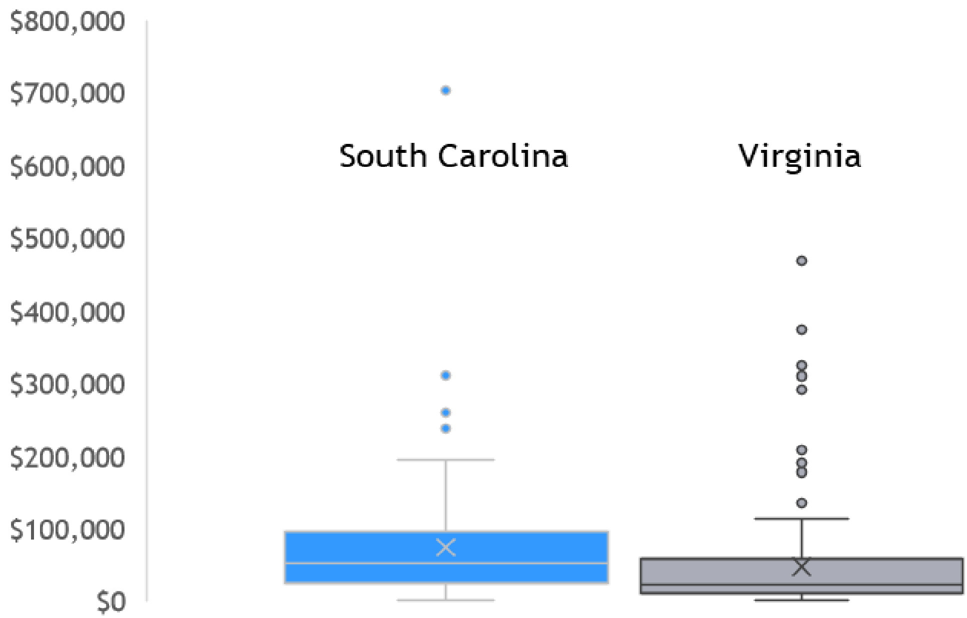


EXHIBIT 14. DISTRIBUTION OF COSTS AT EACH SITE BY STATE – NON-REMEDIAL ACTION PROJECTS[1]



[1] The site with the highest costs in South Carolina in this figure ($672,456) reported $487,624 in assessment costs and $184,832 in monitoring, with no remedial action costs. Note that while the site with the highest costs in Virginia in this figure ($468,838) did not report any costs associated with the remedial action phase, it did have monitoring costs which are typically associated with remedial action in Virginia, meaning it may have been miscoded as non-remedial action in the database.

CLEANUP COSTS BY DURATION

We analyzed Kansas and Virginia's closed site data to assess how project duration corresponds with total costs (we were unable to align costs with duration at South Carolina's sites, but discuss overall duration in South Carolina below). **Exhibit 15** shows the average total costs and costs per day based on the cleanup duration (release date to closure in Virginia, and bid date to end date in Kansas). When looking only at remedial action site project durations (i.e., projects that could be compared across states), Virginia's projects (1,756 days) were slightly shorter on average compared to Kansas's projects (2,092 days), equating to an average of 1,842 days across both states combined. However, average project costs in Virginia were slightly higher, resulting in costs per day of $165.44, compared to $148.69 in Kansas or $156.40 combined. The average duration for shorter (i.e., under five years) remedial action projects in Virginia was 1,021 days, slightly below the 1,372-day average in Kansas. For remedial action projects lasting longer than five years, the average project duration in Virginia was 2,615 days compared to 2,453 days in Kansas. Remedial action projects lasting less than five years in Virginia had average costs of $251,376, while those lasting five or more years cost an average of $556,904.

While projects with a duration of less than five years were unsurprisingly less expensive on average than those that exceeded five years, this difference was far greater in Virginia than in Kansas (a difference of over $300,000 in Virginia compared to less than $100,000 in Kansas). This was likely due to the presence of many smaller, straightforward sites in Virginia that did not enter remedial action, compared to the Kansas data which contained only sites that underwent such action.[14] For projects exceeding five years, the average duration and costs per day were similar across both states. These projects lasted an average of 2,453 days in Kansas compared to 2,405 in Virginia. Virginia's project cost of $148.32 per day was slightly above Kansas's average daily cost of $135.51. While Kansas's projects that lasted less than five years were substantially more expensive on average than Virginia's ($214,411 compared to $39,979), this was likely due to the smaller scale and lack of remedial action at many of Virginia's sites, as mentioned above. These shorter-term projects in Virginia lasted an average of just 427 days, compared to 1,372 days in Kansas. Only one project in the Kansas database reached closure in under 1,500 days (661 days), while Virginia's database included 24 sites with durations of under 100 days, with a minimum of just 21 days.

[14] While the data Kansas provided only included sites that had active remediation, many sites in Kansas do not enter active remediation, including a large number of MNA sites.

EXHIBIT 15. DURATION AND COSTS PER DAY OF CLEANUP PROJECTS IN KANSAS AND VIRGINIA

DUR-ATION/ SITE TYPE	KS				VA				COMBINED			
	N	AVG COST	AVG DUR-ATION (DAYS)	AVG COST PER DAY	N	AVG COST	AVG DUR-ATION (DAYS)	AVG COST PER DAY	N	AVG COST	AVG DUR-ATION (DAYS)	AVG COST PER DAY
Less than 5 years (All)	4	$214,411	1,372	$175.06	56	$39,979	427	$89.99	60	$51,608	490	$105.32
5+ years (All)	8	$310,376	2,453	$135.51	24	$364,125	2,405	$148.32	32	$350,688	2,417	$145.09
Remedial Action Only	12	$278,388	2,092	$148.69	48	$290,519	1,756	$165.44	60	$288,093	1,842	$156.40
Non-Remedial Action	--	--	--	--	32	$42,483	445	$95.47	32	$42,483	445	$95.47
All	**12[a]**	**$278,388**	**2,092**	**$148.69**	**80**	**$61,881**	**560**	**$93.93**	**92**	$90,121	760	$118.61

a. All Kansas sites in the study went to active remediation, and 12 of them were closed. We only calculated costs per day at closed sites.

South Carolina provided data that included both report date and no further action (NFA) date fields, which we used to analyze cleanup durations. Unlike Kansas' and Virginia's data, South Carolina's data often included these dates for multiple releases at a single site. As a result, we did not calculate costs by duration because we were unable to compare the total costs at a site with each specific release. Instead, we were able to analyze cleanup durations for individual releases **(Exhibit 16)**. As shown below, cleanup for each release in South Carolina had an average duration of nearly 17 years (6,123 days) from their first reported date through NFA being declared. Remedial action sites had longer minimum, maximum, mean, and median project durations than non-remedial action sites. Within non-remedial action sites, MNA cleanups had an average duration of 6,127 days, nearly 50 percent longer than non-remedial, non-MNA projects (4,204 days), which mainly represent sites that close after assessment. The median MNA project duration of 6,489 days was more than twice the median of these non-MNA cleanups (3,188 days).

Exhibit 17 shows the total duration for all releases at each site for both remedial action and non-remedial action projects. While there is a greater share of remedial action projects in the longest-term cleanups, this figure shows that non-remedial action projects often also have substantial durations that can span well over a decade.[15]

[15] Remedial action sites include all sites that used remedial action for at least one release at a site. We could not determine specific cleanup details for each release at multi-release sites.

EXHIBIT 16. SOUTH CAROLINA CLEANUP DURATIONS (DAYS)

	ALL RELEASES				
	ALL	REMEDIAL ACTION SITES[a]	NON-REMEDIAL ACTION SITES	*NON-REMEDIAL ACTION: MNA*	*NON-REMEDIAL ACTION: NON-MNA*
N	266	117	149	*111*	*38*
Max	12,774	12,774	11,871	*11,871*	*9,533*
Min	2	14	2	*2*	*23*
Mean	6,123	6,743	5,636	*6,127*	*4,204*
Median	6,673	7,798	5,716	*6,489*	*3,188*

a. Due to the presence of multiple releases at some sites, we were unable to separate remedial action from non-remedial action on a single release basis. Therefore, it is possible that some sites did not use active remediation to respond to a specific release that is captured in these data.

EXHIBIT 17. SOUTH CAROLINA REMEDIAL AND NON REMEDIAL ACTION PROJECT DURATIONS

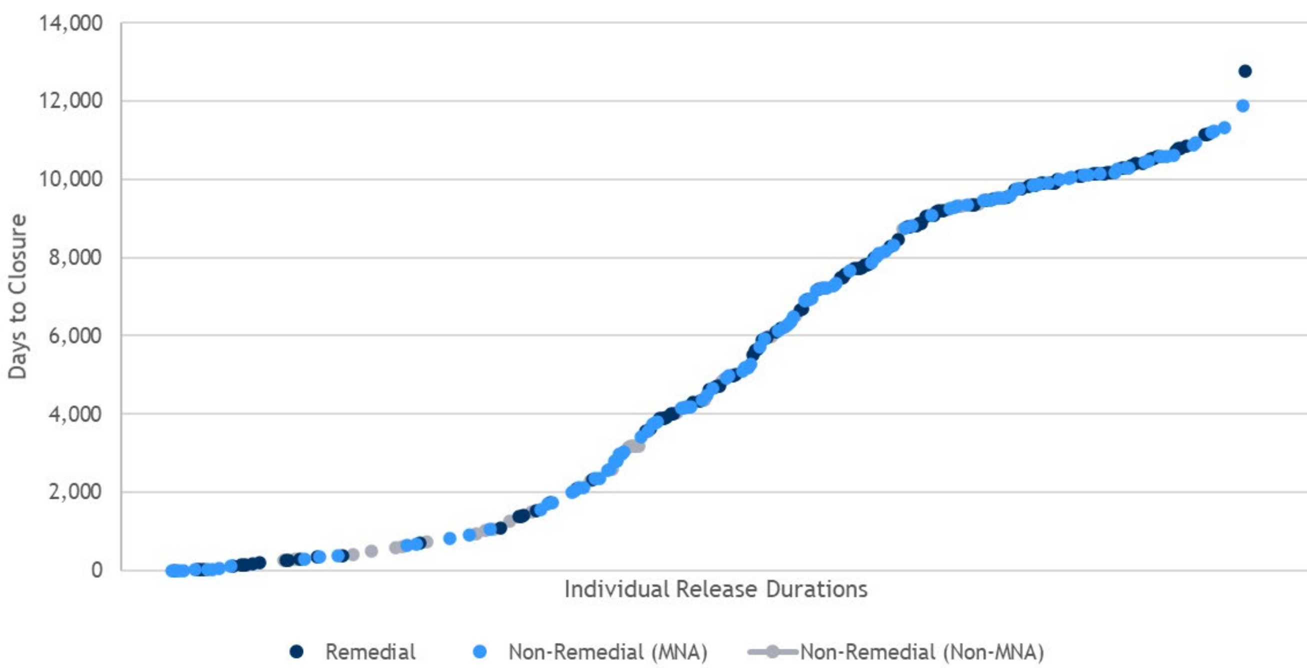


Exhibit 18 shows the range of project durations in Kansas and Virginia. As discussed above, these are fairly similar, with the main differences being driven by the lack of non-remedial sites in the Kansas data, while Virginia includes these non-remedial action sites, which tended to have substantially shorter durations. As reflected in **Exhibit 19**, South Carolina's projects had substantially greater durations than those in Virginia and Kansas. However, we do not think that these durations are comparable due to a number of factors, mainly, 1) South Carolina's use of the release date as a starting point, rather than the

bid date which is used in Kansas and 2) substantially longer monitoring periods in South Carolina compared to the other states, particularly Virginia. As shown in **Exhibit 7** above, monitoring in South Carolina makes up a far greater proportion of total project costs compared to Kansas and Virginia. While this did not drive South Carolina's overall project costs to be greater than the other two states, it does suggest that South Carolina's projects are spending more time in monitoring. This likely increases the overall project durations in South Carolina, even if their active cleanup times may be similar to the other states.

EXHIBIT 18. PROJECT DURATIONS BY STATE, IN DAYS - KANSAS AND VIRGINIA

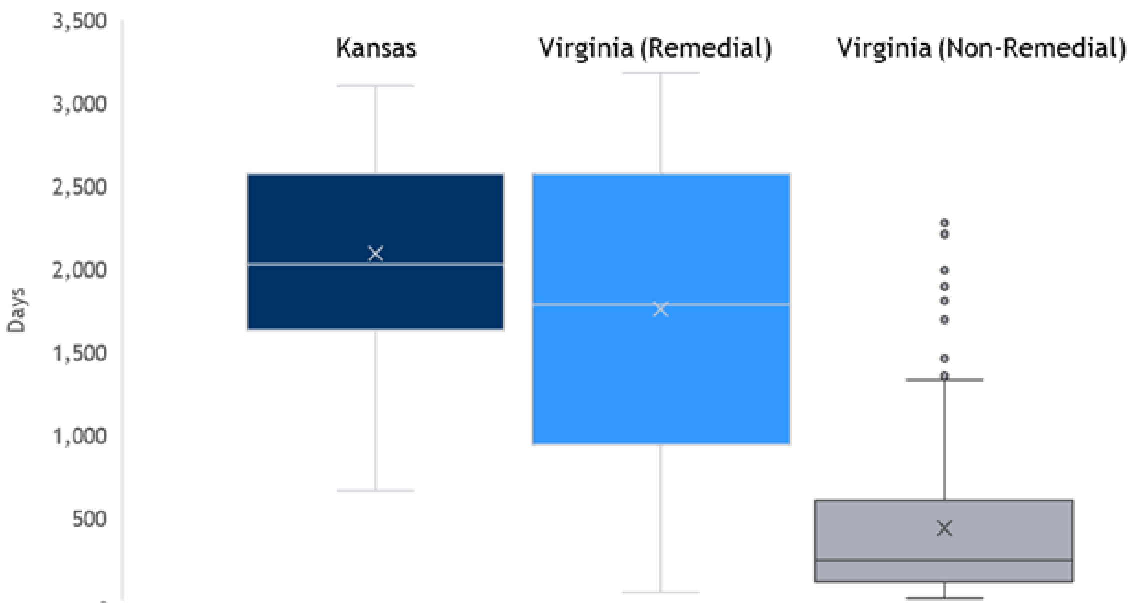
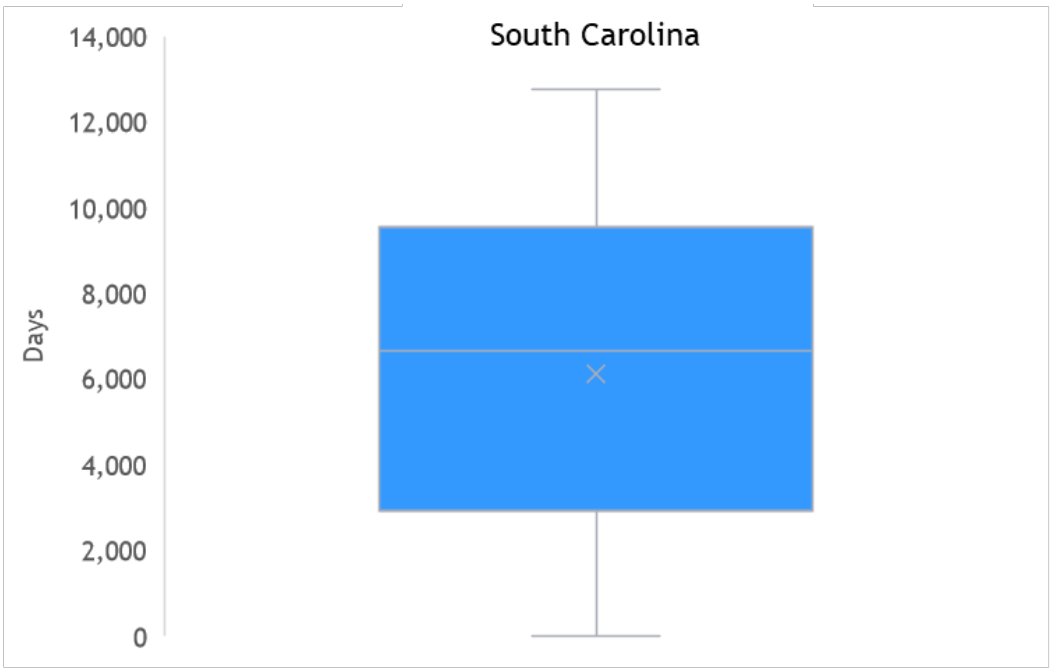


EXHIBIT 19. PROJECT DURATIONS BY STATE, IN DAYS - SOUTH CAROLINA



ASSESSMENT VERSUS TOTAL COSTS

States have expressed an interest in understanding how assessment costs relate to total project costs, and whether additional spending in the early phases of a project can ultimately reduce the total. **Exhibits 20-22** show this relationship between assessment and total costs across each state (for projects where assessment costs were reported). Generally, assessment costs were relatively similar in magnitude across all projects, meaning that they comprised a smaller percentage of overall costs as total project spending increased.

In South Carolina, site assessment accounted for an average of 61 percent of project costs across each individual site. However, these costs accounted for just 37 percent of costs in projects exceeding $100,000, compared to 83 percent of total costs for cleanups below that threshold. Similarly, in Virginia assessment costs averaged 87 percent of the project total at the site level, but only 44 percent of the total for projects costing over $100,000 altogether. This high percentage of assessment costs compared to the totals was largely due to assessment costs making up 100 percent of reported totals at 54 of the 102 closed sites included in this analysis. In Kansas, assessment and initial remedial response costs (i.e., the difference between reported and total costs) made up 52 percent of total costs on average. The remaining three phases, which were the costs covered in the site remediation plan (SRP) data that Kansas provided, accounted for the remaining 48 percent.

EXHIBIT 20. ASSESSMENT VS. TOTAL COSTS AT CLOSED SITES - KANSAS

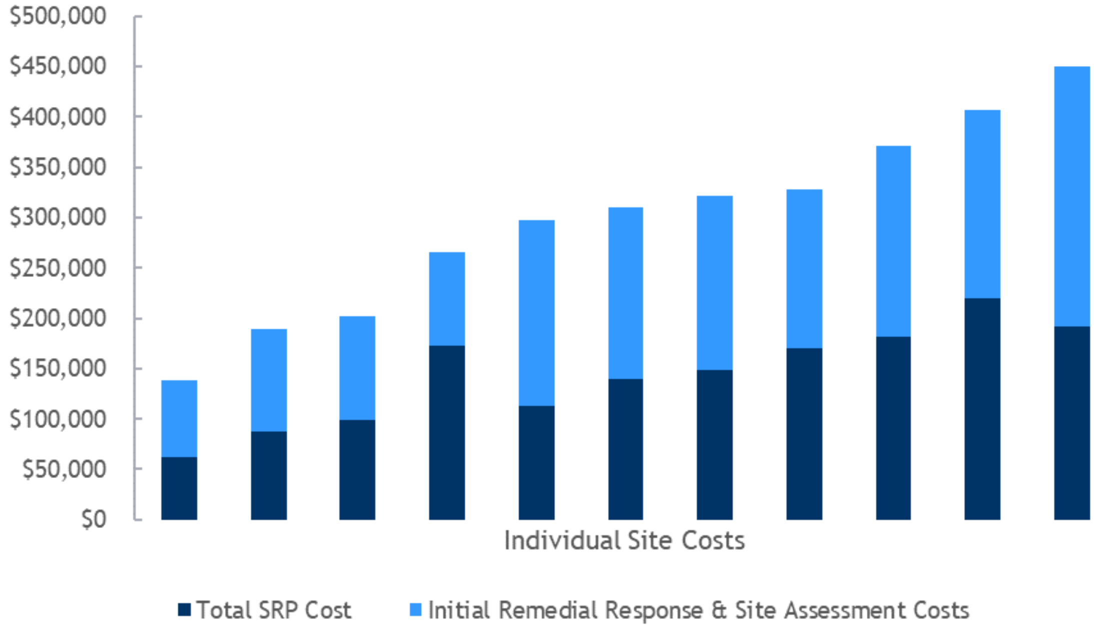


EXHIBIT 21. ASSESSMENT VS. TOTAL COSTS AT CLOSED SITES - SOUTH CAROLINA

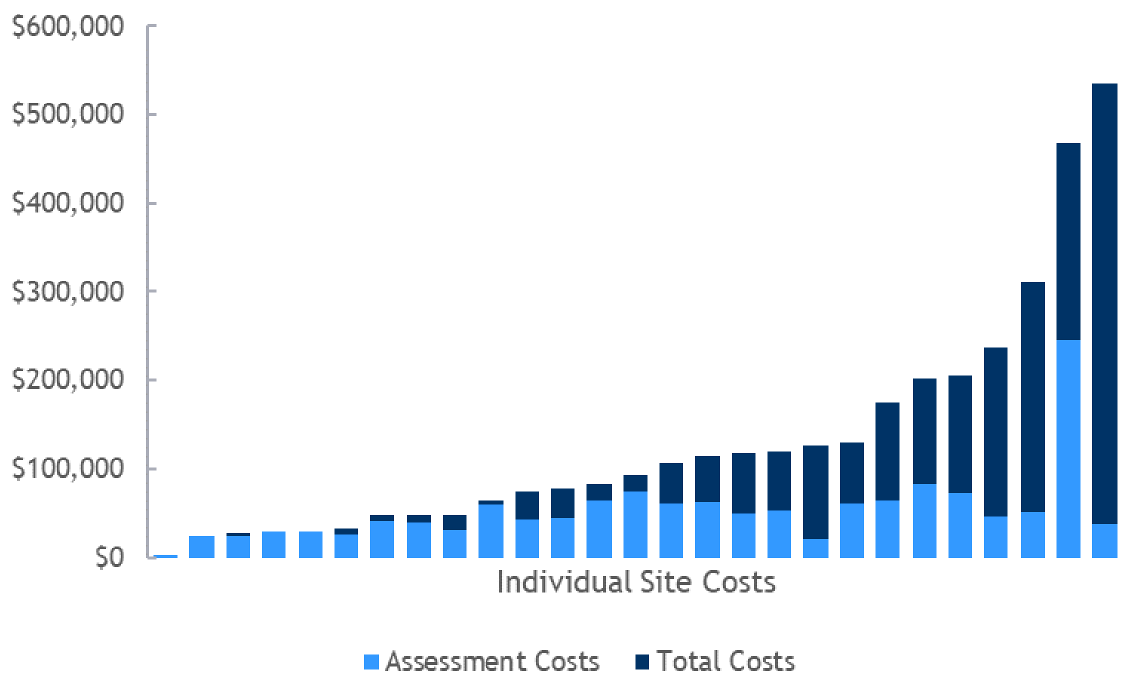
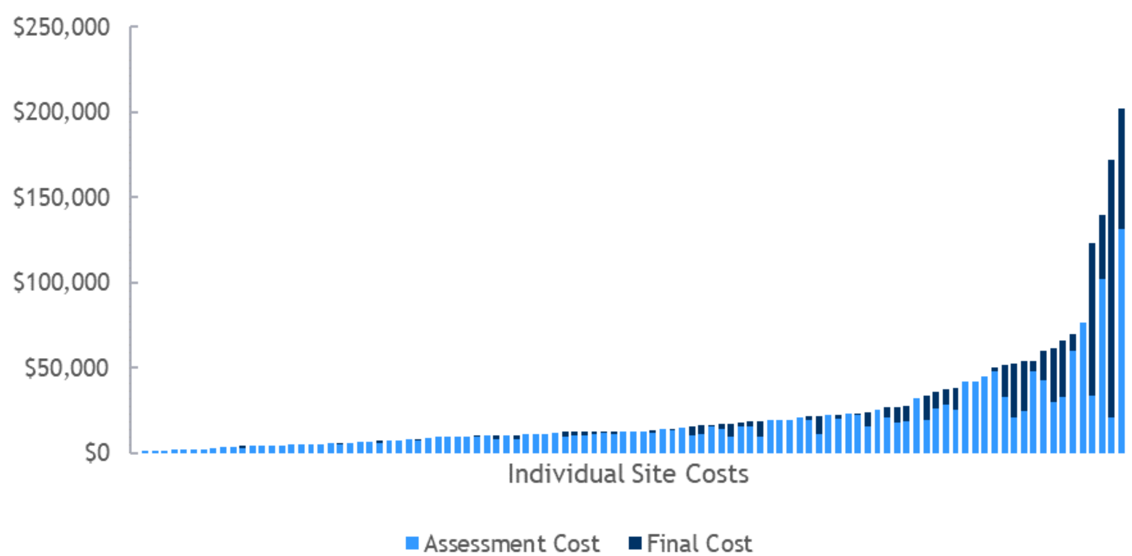


EXHIBIT 22. ASSESSMENT VS. TOTAL COSTS AT CLOSED SITES - VIRGINIA



Exhibits 23 and 24 show assessment and total costs at closed, remedial action sites in South Carolina and Virginia, respectively. Similar to the sites shown above (which included non-remedial action sites), assessment costs tended to be fairly similar across projects, meaning that assessment made up a smaller percentage of the total project costs at sites that were ultimately more expensive. Assessment made up a slightly smaller percentage of the total costs in both states compared to the share it made up when looking at all sites with project costs of $100,000 or more. In Virginia, the assessment phase represented 34 percent of total costs, while in South Carolina 38 percent of the total project costs were devoted to assessment at the average remedial action site. This lower percentage of assessment to total costs at remedial action sites compared to all sites likely reflects that remedial action projects have substantial costs devoted to that phase, and therefore a smaller share ultimately goes toward assessment.

EXHIBIT 23. ASSESSMENT VS. TOTAL COSTS AT CLOSED REMEDIAL ACTION SITES - SOUTH CAROLINA

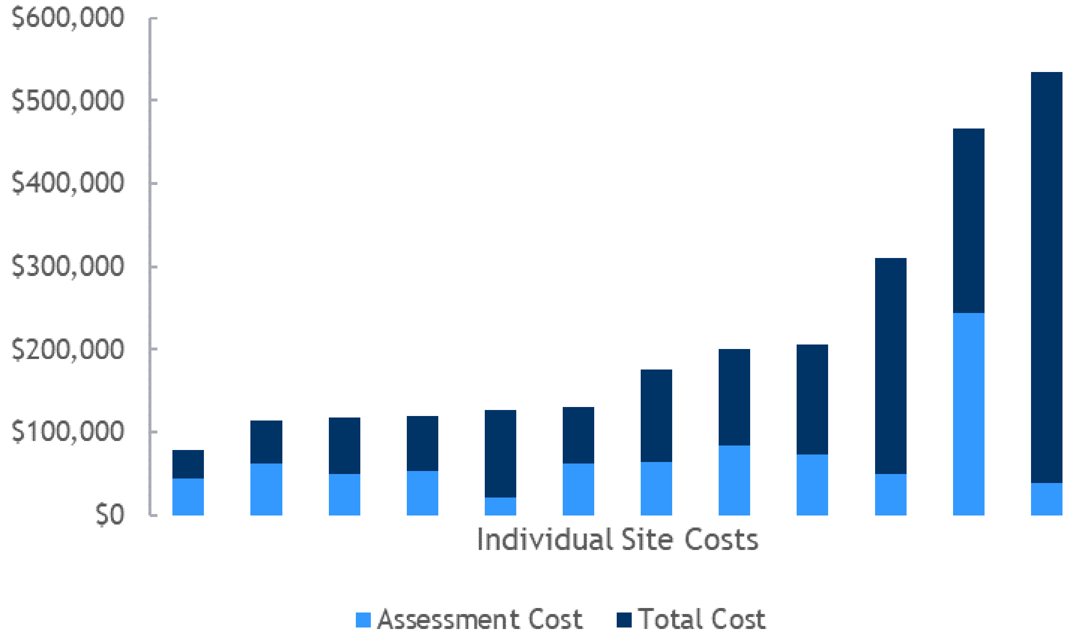
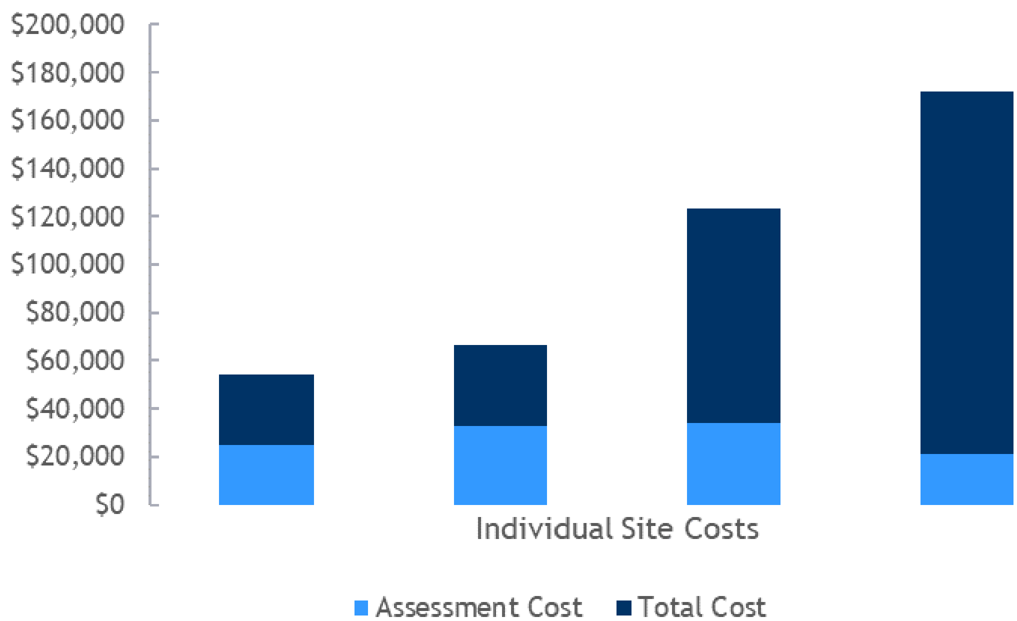


EXHIBIT 24. ASSESSMENT VS. TOTAL COSTS AT CLOSED REMEDIAL ACTION SITES - VIRGINIA



Exhibits 25 through **27** show a further comparison of the relationship between assessment versus total costs for each project in South Carolina and Virginia. As **Exhibit 25** shows, higher assessment costs are typically associated with higher overall project costs, although projects with the greatest total costs do not necessarily have the highest assessment costs. This is further highlighted in **Exhibit 26** (remedial action sites only), which shows fairly similar assessment costs at all remedial action sites, regardless of total project costs. This may suggest that assessment spending will typically be similar at remedial action sites, regardless of the ultimate project scale and cost. Finally, **Exhibit 27** shows site assessment and total project costs at non-remedial action sites, split out by MNA and assessment only sites. As the figure shows, these sites tended to be fairly similar in terms of both assessment and total project costs. MNA projects tended to have slightly higher assessment and total project costs, along with a slightly higher ratio of assessment to total project costs, however there were fairly small differences between the two groups. At the 164 sites in South Carolina that went to MNA, assessment costs averaged $49,274 compared to $42,893 spent in the monitoring phase and total project costs of $120,244. On a project by project basis, assessment costs made up an average of 50.4 percent of total project costs at these MNA sites.

The data do not allow a definitive determination of the relationship between higher spending in the initial assessment phase and the ultimate total project costs because it cannot be known what costs may have ultimately been had more or less spending been devoted to assessment. However, these results do suggest that at higher-cost cleanup sites states may expect assessment to represent approximately one-third to one-half of total spending (although some exceptions exist).

EXHIBIT 25. ASSESSMENT VS. TOTAL CLEANUP

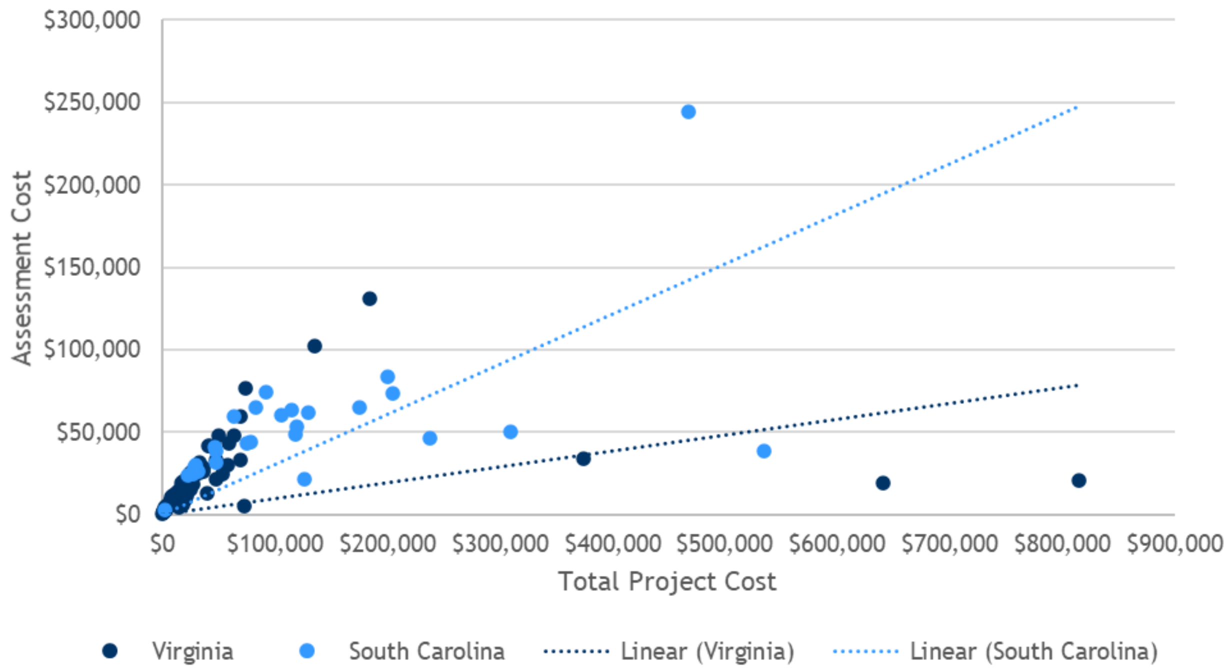


EXHIBIT 26. ASSESSMENT VS. TOTAL COSTS AT CLOSED REMEDIAL ACTION SITES

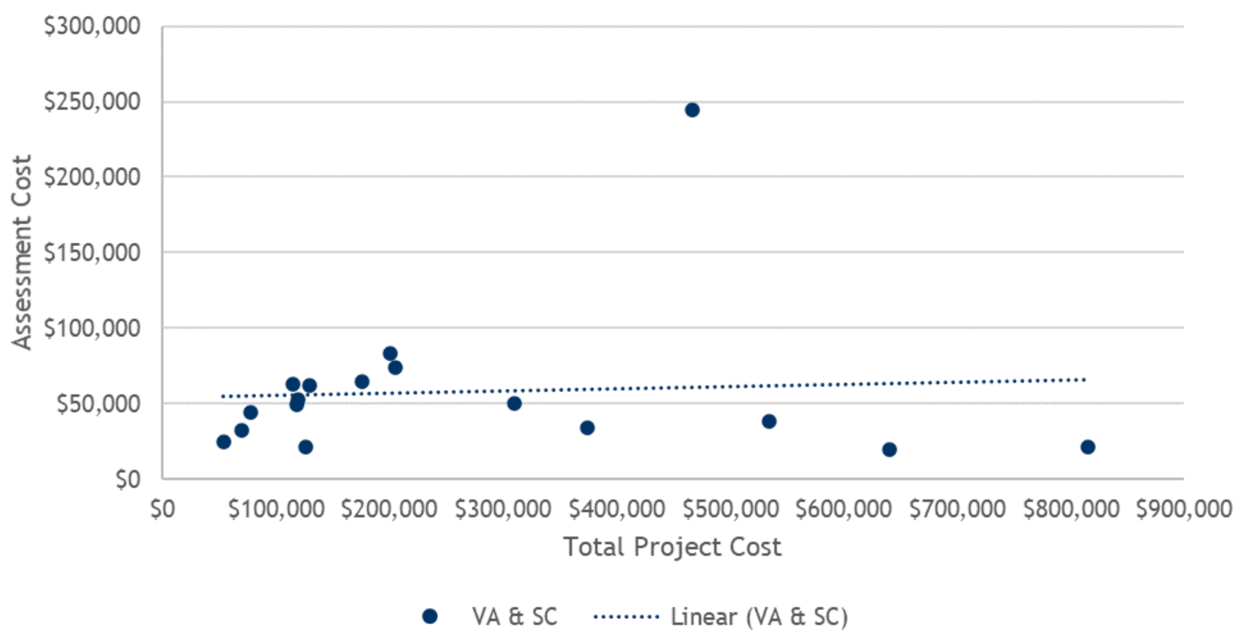
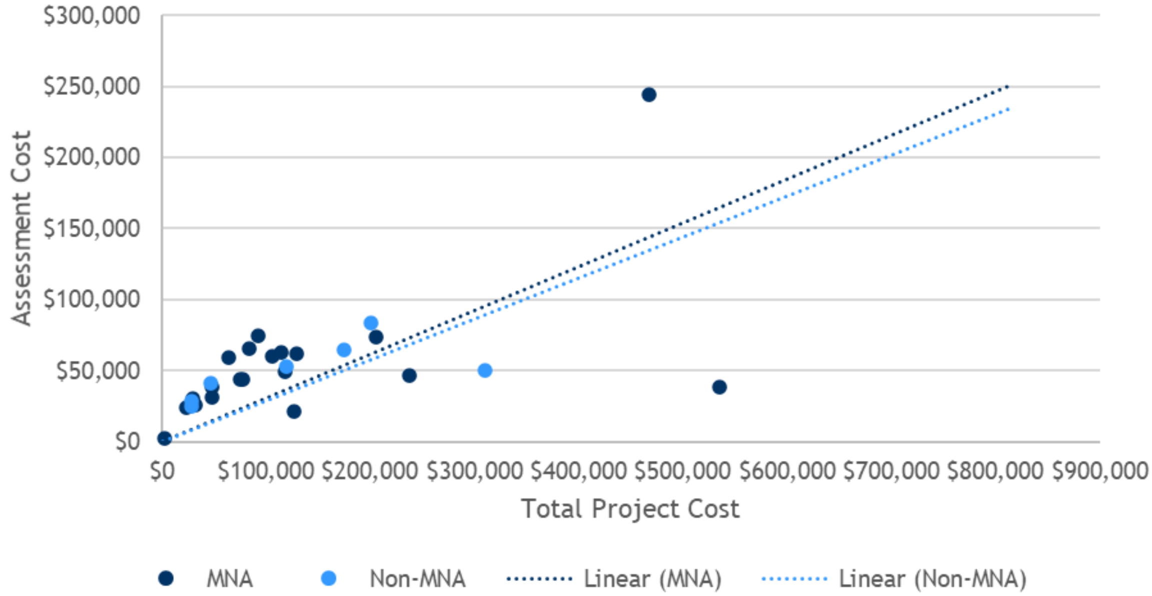


EXHIBIT 27. ASSESSMENT VS. TOTAL COSTS AT NON-REMEDIAL SITES (MNA VS. NON-MNA)



We used regression analysis to explore further whether increased assessment costs reduce overall site costs. On a raw dollar basis, this is assessed by regressing total site costs, as the dependent variable, on assessment costs as the independent variable. The resulting linear regression, after controlling for state, indicates that each $1.00 in assessment cost increases total site cost by approximately $1.46.[16] However, this conclusion is potentially distorted by the presence of complex sites, which have higher assessment costs *and* higher non-assessment costs. To address this, we consider assessment costs on a proportionate basis, and regress total site costs on the *proportion* of total costs that are assessment costs. In this regression, after controlling for state, a one percent increase in the *proportion* of total costs that are assessment costs suggests a $221 decrease in total site costs; this finding is highly statistically significant and robust to the inclusion of site closure status as a control variable, and the proportion of costs that are site assessment cost explains roughly one-fourth to one-third of the variation in other (non-assessment) site costs. This impact may be even greater at remedial action sites. When limiting the regression to just these projects, a one percent increase in the assessment proportion of total costs corresponds with a $296 decrease in total site costs, compared to just a $91 reduction at non-remedial action sites. Therefore, it is possible that more assessment reduces overall site expenditures, and that these effects are greater at remedial action sites.

[16] This finding is statistically significant at the one percent level, and the coefficient increases when only the subset of sites with non-zero assessment costs is examined.

CLEANUP COSTS BY TECHNOLOGY AND STATE

Costs by technology were difficult to determine due to both a lack of information available from the states and overlap (i.e., multiple technologies) within sites. Due to these challenges, it is important to note that the results presented in this section are meant to illustrate the range of costs that may be present at a site using a given technology, rather than as a predictor of what the costs will be per a given technology used.

Exhibit 28 shows the total average costs at sites where a given technology was used in the cleanup. To account for variation across the states, we grouped technologies into four prevalent categories. Projects in Kansas that used soil-vapor extraction (SVE) were slightly more expensive than air sparging and excavation projects, although there was a high degree of overlap where multiple technologies were present for a single project, which limits the overall cost differences that we could observe between sites. Monitored natural attenuation (MNA) projects in South Carolina had an average cost of $120,244 and a median cost of $94,250, which were substantially less expensive on average than SVE, air sparging, and excavation projects in the state. Fourteen of the MNA sites in South Carolina also included at least one additional technology. When excluding these sites, the average total project cost dropped to $113,875 with median costs of $89,578. The lone SVE project in South Carolina cost $310,770, nearly $100,000 more expensive than the average air sparging cost, the next highest-cost technology ($218,096). Across all states, SVE projects had average and median total costs of $305,966 and $271,355, respectively, the highest if any technology. We discuss these findings further in the Regression Analysis Results Section below. We received limited technology data in Virginia and were only able to classify costs at two sites into these broad categories. One project used both SVE and excavation and cost $23,809, while the other included excavation with total costs of $1 million.

EXHIBIT 28. AVERAGE COSTS BY TECHNOLOGY AND STATE

STATE	MNA - INCLUDING OTHER TECHS		MNA - ONLY		SVE		AIR SPARGING		EXCAVATION	
	N	AVG. $	N	AVG. $	N	AVG. $	N	AVG. $	N	AVG. $
Kansas	0	--	0	--	44	$312,269	39	$297,752	34	$290,728
South Carolina	164	$120,244	150	$113,875	1	$310,770	9	$218,096	9	$203,471
Virginia	0	--	0	--	1	$23,809	0	--	2	$511,905
All States	164	$120,244	150	$113,875	46	$305,966	48	$282,816	45	$283,107

Although data were limited on the specific methods for removing free product, Kansas provided data on the presence of free product at each site. Of the 53 sites in Kansas, free product was present at 13. These sites had substantially higher average total costs ($411,198) than the 40 sites with no free product present ($264,180), suggesting that the presence of free product, and the technologies needed to remove it, are another key driver of costs.

Exhibits 29 through 32 show the total project costs for all projects where a given technology was present (MNA, SVE, air sparging, and excavation). As descried above, there were overlapping technologies at many of these sites, so these results do not reflect the true cost of a technology at each site. The figures show a wide range of costs across all technologies, but costs for SVE projects tended to be higher across all projects and states compared to other technologies.

EXHIBIT 29. MNA TOTAL PROJECT COSTS BY STATE

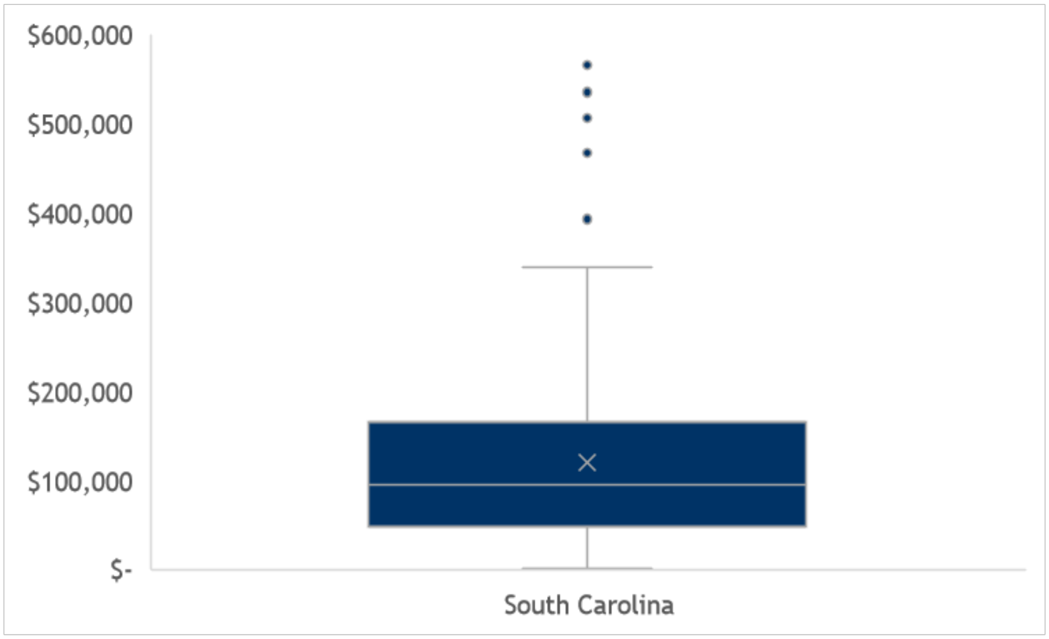


EXHIBIT 30. SVE TOTAL PROJECT COSTS BY STATE

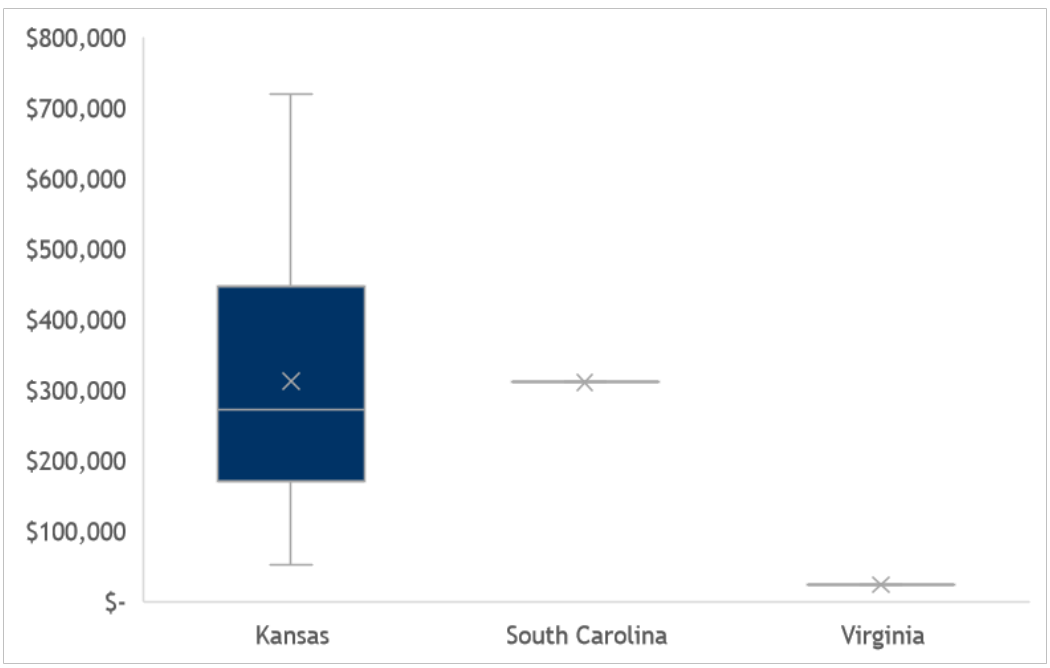


EXHIBIT 31. AIR SPARGING TOTAL PROJECT COSTS BY STATE

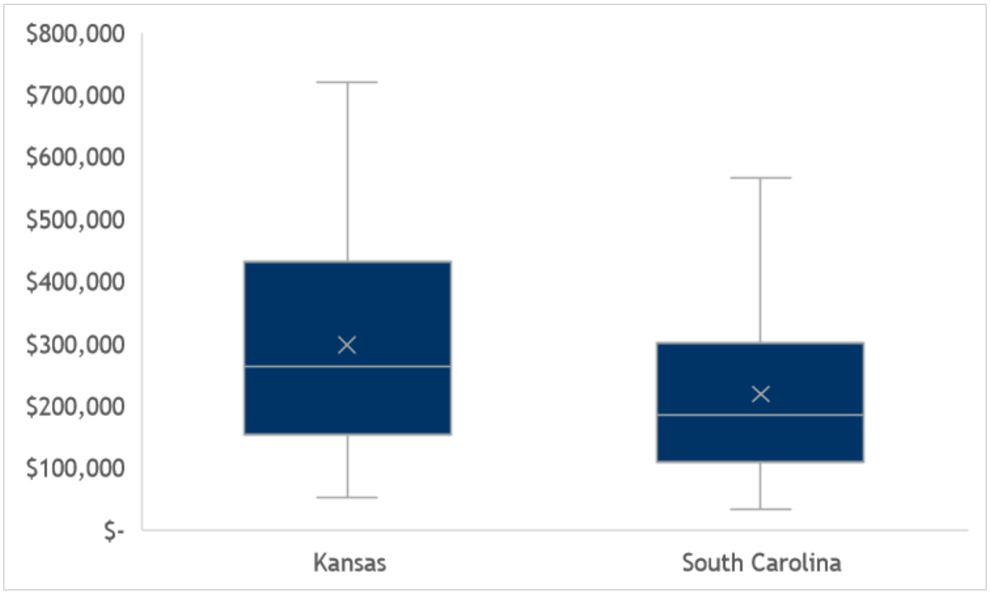
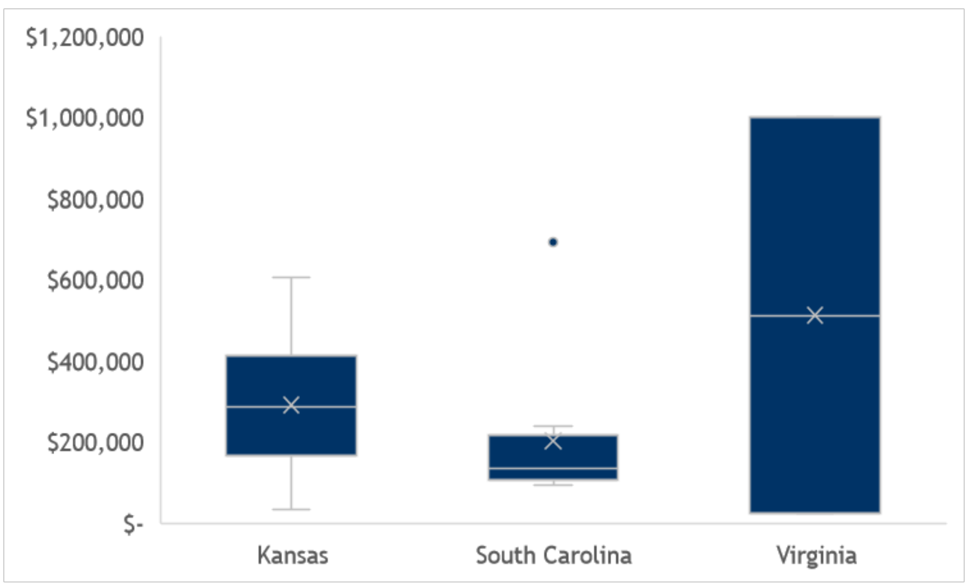


EXHIBIT 32. EXCAVATION TOTAL PROJECT COSTS BY STATE



REGRESSION ANALYSIS RESULTS

To further support our findings, we used regression analysis to control for various observed and unobserved factors driving costs on a site-by-site basis, and to examine the data for statistically significant drivers of costs. This analysis supported our findings reported above. Specifically, we found statistically significant differences in costs between states, and confirmed that projects involving remedial action were more expensive than non-remedial action projects, even when controlling for other factors. Increased project duration was also a significant driver of higher total costs. The regression analysis also found closed sites, and those using MNA as opposed to a different technology, to be less expensive than other projects in the dataset, at statistically significant levels. We present these regression results in detail in **Appendix B** below.

APPENDIX A: STATE SPECIFIC RESULTS

This section shows average and median costs for technologies and phases as provided directly by the states (i.e., prior to our reclassification into broad categories that could be compared across all three states).

KANSAS

Kansas provided specific costs for activities from bid sheets for remedial action sites. As noted in the main body of the report, Kansas provided only remedial action cost and total cost data, but monitoring and closure costs were contained in remedial costs. We used these to group into the cost by phase data presented in the main body of the report. **Exhibit A-1** shows average and median costs from the bid sheets for all activities as defined in Kansas' data. Excavation/ Trenching, Soil Placement and Backfilling was the highest cost activity with an average cost of $67,798. Free Product Recovery Trench, Rock and Soil Placement, and Backfilling ($57,700) and Remedial System Installations ($54,859) were the second and third most expensive, respectively, although remedial system installation was present at nearly all sites (49 of 53) compared to Free Product Recovery Trench, Rock and Soil Placement, and Backfilling costs being listed for only one project.

EXHIBIT A-1. COSTS BY CLEANUP ACTIVITY - KANSAS

SPECIFIC COST	N	AVERAGE	MEDIAN
Remedial Implementation	53	$844	$790
Remove Tank/ Distribution System/ Pump Island/ Canopy Footings	1	$4,950	$4,950
Free Product Recovery Trench, Rock and Soil Placement, and Backfilling	1	$57,700	$57,700
Large Diameter Boring (LDB), Sand Placement, and Backfilling	1	$25,348	$25,348
Locate Landfarm	7	$1,134	$1,340
Excavation/ Trenching, Soil Placement and Backfilling	22	$67,798	$54,190
Landfarming Activities	23	$8,341	$6,650
Landfarm Field Screening	23	$1,041	$836
Landfarm Confirmatory Soil Sampling	23	$1,429	$980
Landfarm Restoration	23	$2,850	$1,500
Drilling Activities - Direct Push	1	$7,232	$7,232
Drilling Activities	49	$22,585	$18,377
Sampling and Analytical (Post Excavation & Backfill)	1	$2,140	$2,140
Property Restoration	1	$3,240	$3,240
Remedial System Installations	49	$54,859	$58,359
Remedial System Installation (Miscellaneous)	49	$19,503	$17,570
SVE & AS Pilot Tests	1	$1,500	$1,500
Waste Handling and Treatment	39	$1,195	$450
Soil Sampling	1	$3,520	$3,520
System Start-Up	49	$5,236	$4,879
Remedial System Performance Review	7	$923	$860
Final Remedial Report and Permits	52	$5,116	$3,275
Monthly Maintenance and Monitoring (Total)	48	$11,308	$10,940
Quarterly Operation & Maintenance/Monitoring (Total)	51	$18,946	$18,612

SOUTH CAROLINA

South Carolina provided phase data that aligned with the broad phase categories included in the body of this report. In addition to these phase data, South Carolina provided some additional technology specific costs that went beyond the major technologies that we identified across states. **Exhibit A-2** shows the average total costs for projects associated with each of these technologies. Note that we reclassified and cleaned some of these data, so these do not align directly with the technology costs shown in the main body of the report. Despite this, these results show that average total project costs across a high number of MNA projects ($116,711) were substantially lower than those for vapor/fluid recovery projects (AVFR; $171,027), the second most prevalent technology.

EXHIBIT A-2. COSTS BY TECHNOLOGY - SOUTH CAROLINA

TECHNOLOGY	AVERAGE COST	N
AVFR	$171,027	95
Bio	$213,389	14
Chemical Treat	$212,320	8
Enhanced Fluid Recovery	$183,081	5
GW AS	$218,992	7
GW VE	$239,340	6
Pump and Treat	$291,337	1
Product Recovery (Not AVFR)	$310,770	1
MNA	$116,711	142
Soil Excavation	$99,216	1
Source Removal	$99,216	1
Standard treatment, Bio or Chemical	$126,695	2

VIRGINIA

Virginia provided several data fields that were not present (or were very limited) in other states, including project lead (state or RP), and reopened projects in addition to closed and active sites. As discussed in the body of the report, we needed to drop a large number of sites in Virginia from our analysis due to a lack of cost data, or costs not being split out by phase. **Exhibit A-3** shows average and median project costs for all sites in Virginia split out by project lead and status when including all sites that were provided in the data. Unsurprisingly, average and median costs were lower when including all sites as compared to the projects shown throughout the body of the report, as many of the dropped sites had no listed costs or costs that were small and not associated with a specific phase. This table also shows that state-lead sites tended to have substantially higher average and median costs than RP-led sites. One exception to this trend was across closed sites when excluding sites with no cost listed (blank or $0) totals. In these cases, RP-led costs were higher on average ($50,482) than state-led projects ($31,767).

EXHIBIT A-3. VIRGINIA AVERAGE AND MEDIAN CLEANUP COSTS BY SITE LEAD AND STATUS

SITE LEAD	STATUS	ALL INCLUDED			EXCLUDING NO COST LISTED (BLANK OR $0) TOTALS			REMEDIAL ACTION ONLY		
		N	AVG $	MEDIAN $	N	AVG $	MEDIAN $	N	AVG $	MEDIAN $
State Lead	Active	6	$388,745	$226,315	6	$388,745	$226,315	4	$561,898	$288,074
	Closed	14	$29,498	$13,870	13	$31,767	$15,225	N/A	N/A	N/A
	Total	20	$137,272	$19,419	19	$144,497	$20,662	4	$561,898	$288,074
RP Lead	Active	210	$67,412	$0	92	$153,876	$92,742	31	$212,783	$157,238
	Closed	1,765	$11,269	$0	394	$50,482	$20,851	13	$392,389	$468,967
	Reopened	6	$37,352	$26,284	4	$56,029	$54,419	N/A	N/A	N/A
	Total	1,981	$17,300	$0	490	$69,940	$25,589	44	$265,849	$177,343
Total	Active	216	$76,338	$0	98	$168,256	$93,202	35	$252,682	$172,042
	Closed	1,779	$11,412	$0	407	$49,884	$20,662	13	$392,389	$468,967
	Reopened	6	$37,352	$26,284	4	$56,029	$54,419	N/A	N/A	N/A
	Total	2,001	$18,499	$0	509	$72,723	$25,165	48	$290,519	$186,985

Exhibit A-4 shows average and median phase cost data as provided by Virginia (prior to our reclassifying) at all sites and remedial action only sites. Post Site Characterization Report Monitoring was the most common phase listed in the dataset (236 sites), ahead of Corrective Action Plan Implementation (181) and site characterization (147). Corrective Action Plan Implementation had the highest average phase costs ($81,517), although the median was slightly lower than that of Interim CAP development ($43,692 compared to $48,398), suggesting a higher level of variation across Corrective Action Plan Implementation costs.

EXHIBIT A-4. COSTS BY CLEANUP ACTIVITY - VIRGINIA

PHASE	N (SITES WITH INFO)	AVERAGE COST	MEDIAN COST	MEAN COST - REMEDIAL-ONLY SITES	MEDIAN COST - REMEDIAL-ONLY SITES
Corrective Action Plan Addendum	3	$20,616	$19,661	$20,616	$19,661
Corrective Action Plan Development	20	$22,852	$21,996	$22,852	$21,996
Corrective Action Plan Implementation	181	$81,517	$43,692	$119,803	$58,029
Emergency	5	$30,456	$14,466	$1,433	$1,433
Initial Abatement	28	$18,828	$16,585	$19,371	$21,220
Initial Abatement - Part 2	1	$3,098	$3,098	N/A	N/A
Interim CAP Development	5	$50,247	$48,398	$50,247	$48,398
Post Site Characterization Report Monitoring	236	$18,781	$9,867	$27,422	$22,462
Release Investigation	17	$11,539	$10,770	$17,298	$19,264
Site Characterization	147	$20,863	$13,758	$30,792	$27,885
Site Characterization Addendum	69	$38,256	$2,799	$89,528	$93,310
Site Closure	69	$3,782	$2,036	$16,406	$15,869

APPENDIX B: DETAILED REGRESSION ANALYSIS RESULTS

This section presents a series of results associated with regression analyses performed on the site data provided by states. Broadly, these regressions support the conclusions elsewhere in this analysis; the ability of regression analysis to supply multivariate analyses that examine the effects of one site characteristic while holding others constant generally did not yield new insights beyond the univariate analyses presented above. Rather, the results below reinforce many of the conclusions drawn earlier in this report. As described earlier in this document, the array of site data varied across states. Therefore, the regression results in this section leverage available data comparable across at least two states to draw conclusions. For the sake of completeness, the tables below show the results of multiple regressions using different costs by phase available for at least two states (remedial action costs, monitoring costs, closure costs, and total site costs) with the relevant independent variables. The R^2, or "goodness of fit" – the extent to which variation in costs is explained by variation in the chosen independent variables – is expressed in the bottom row of each table.

Exhibits B-1 and B-2 indicate a relationship between state site costs consistent with that elsewhere in the report: Costs for Kansas exceed those for South Carolina and Virginia. Overall site costs in the latter two states are not statistically differentiated once site closure status is controlled for. However, the combination of state and closure status does not yield much explanatory power for site-to-site variations in cost.

EXHIBIT B-1. REGRESSION ANALYSIS: SITE COSTS BY STATE

INDEPENDENT VARIABLE	ASSESSMENT COST	REMEDIAL ACTION COST	MONITORING COST	CLOSURE COST	TOTAL COST
Kansas (relative to South Carolina)	n/a	101,016***	-21,981***	6,317***	164,605***
Virginia (relative to South Carolina)	-32,704***	-25,703***	-32,863***	920**	-43,659***
N	527	524	530	529	530
R^2	0.16	0.18	0.16	0.14	0.12

Gray shading indicates a coefficient that is not statistically significant at the ten percent level.
* Statistically significant at the ten percent level, but not the five percent level.
** Statistically significant at the five percent level, but not the one percent level.
*** Statistically significant at the one percent level.

EXHIBIT B-2. REGRESSION ANALYSIS: SITE COSTS BY STATE AND CLOSURE STATUS

INDEPENDENT VARIABLE	ASSESSMENT COST	REMEDIAL ACTION COST	MONITORING COST	CLOSURE COST	TOTAL COST
Kansas (relative to South Carolina)	n/a	102,942***	-21,285***	6,133***	169,292***
Virginia (relative to South Carolina)	-27,426***	-17,070**	-29,825***	115	-23,217
Site Closed	-11,792***	-19,563***	-6,831*	1,802***	-45,958***
N	527	524	530	529	530
R^2	0.17	0.19	0.17	0.17	0.14
Gray shading indicates a coefficient that is not statistically significant at the ten percent level. * Statistically significant at the ten percent level, but not the five percent level. ** Statistically significant at the five percent level, but not the one percent level. *** Statistically significant at the one percent level.					

Consistent with findings from other cleanup programs, currently closed sites feature costs that, on average and after controlling for state, are approximately $46,000 lower than costs incurred at currently open sites. This is intuitive: Less complex sites with lower total costs are more likely to have already closed, while ongoing sites are more likely to feature additional complexity and expanded remediation timescales with a higher volume of costs.

The addition of site duration adds substantial explanatory power to the regression; site-to-site variation in total costs, as well as remediation and monitoring costs, is driven substantially by site duration, as shown in **Exhibit B-3**.[17] This pattern also holds when site closure status is included, per **Exhibit B-4**, which indicates that even after controlling for site closure status, the daily "burn rate" for a site appears to be approximately $119.

EXHIBIT B-3. REGRESSION ANALYSIS: SITE COSTS BY STATE AND DURATION (IN DAYS)

INDEPENDENT VARIABLE	ASSESSMENT COST	REMEDIAL ACTION COST	MONITORING COST	CLOSURE COST	TOTAL COST
Kansas (relative to Virginia)	-10,822***	121,951***	13,457***	2,977*	90,802***
Site Duration (in days)	-1	12***	1*	1*	116***
N	200	201	201	201	201
R^2	0.11	0.70	0.47	0.10	0.57
Gray shading indicates a coefficient that is not statistically significant at the ten percent level. * Statistically significant at the ten percent level, but not the five percent level. ** Statistically significant at the five percent level, but not the one percent level. *** Statistically significant at the one percent level.					

[17] South Carolina is not included in the regressions reflected in **Exhibits 24 and 25**, as duration data was not available for sites in the state.

EXHIBIT B-4. REGRESSION ANALYSIS: SITE COSTS BY STATE, DURATION (IN DAYS), AND CLOSURE STATUS

INDEPENDENT VARIABLE	ASSESSMENT COST	REMEDIAL ACTION COST	MONITORING COST	CLOSURE COST	TOTAL COST
Kansas (relative to Virginia)	-10,507**	105,255***	7,309***	8,852***	32,029
Site Duration (in days)	-1	13***	1**	1*	119***
Site Closed	389	-20,615	-7,591***	7,254***	-72,566*
N	200	201	201	201	201
R^2	0.11	0.70	0.49	0.14	0.58
Gray shading indicates a coefficient that is not statistically significant at the ten percent level. * Statistically significant at the ten percent level, but not the five percent level. ** Statistically significant at the five percent level, but not the one percent level. *** Statistically significant at the one percent level.					

In addition, we note two findings of interest from these regressions. First, while site costs by category and overall differ at a statistically significant level between Virginia and Kansas, even when controlling for site duration, the inclusion of site closure status removes this statistically significant distinction. This may be an artifact of the small sample of open and closed sites in Kansas. Second, the regression where total cost serves as the dependent variable indicates a “burn rate” of approximately $119 per day. However, the “burn rate” for the regression where remedial action cost is the dependent variable is only $13 per day. It is not self-evident where the remaining $100-plus rests; this may be an artifact of the ways in which these states apportion costs across phase relative to their tabulations of total cost.

While the data provided by Kansas, South Carolina, and Virginia included some remedial technology information, this information was for the most part highly specific. Including these data, as-is, into a regression results in substantial sample size and degrees of freedom challenges. Consequently, this report identified a subset of remedial approaches and technologies, including air sparging, excavation, monitored natural attenuation (MNA), and soil vapor extraction (SVE) for regression analysis, as shown in **Exhibit B-5**.[18] Note that the regression considers whether the technology in question was used at the site, and does not include interaction effects or otherwise distinguish between cases where more than one of the technologies in question was present.

[18] Dual-phase extraction was another technology considered for this subset; however, the array of sites with available technology and cost data did not include any using dual-phase extraction.

EXHIBIT B-5. REGRESSION ANALYSIS: SITE COSTS BY STATE AND TECHNOLOGY

INDEPENDENT VARIABLE	ASSESSMENT COST	REMEDIAL ACTION COST	MONITORING COST	CLOSURE COST	TOTAL COST
Kansas (relative to South Carolina)	n/a	37,479	-34,206**	2,917	39,071
Virginia (relative to South Carolina)	-61,873	-70,333	-53,115	-2,661	-204,968*
Air Sparging	-4,477	60,573**	-17,138	-719	3,662
Excavation	1,669	11,987	10,009	2,873**	16,888
Monitored Natural Attenuation (MNA)	-13,830*	-61,650***	10,817	-27	-63,600***
Soil Vapor Extraction (SVE)	1,985	-38,587	31,849*	2,610	78,479
N	272	266	272	272	272
R^2	0.15	0.22	0.06	0.21	0.18

Gray shading indicates a coefficient that is not statistically significant at the ten percent level.
* Statistically significant at the ten percent level, but not the five percent level.
** Statistically significant at the five percent level, but not the one percent level.
*** Statistically significant at the one percent level.

Exhibit B-5 indicates that even this analysis of a subset of technologies does not yield effective differentiation of site costs by remedial technology used. The exception is MNA, which is highly statistically significant and indicates a reduction in cost of over $63,000 relative to a site where this approach is not present. This is intuitive, as it generally suggests a more passive approach to site remediation compared to other frameworks.

Given the findings of **Exhibit B-5**, **Exhibit B-6** attempts to examine this group of technologies only for South Carolina, in an attempt to avoid nomenclature or technology identification issues that may arise from attempting to combine multiple datasets. However, the conclusions within **Exhibit B-6** are similar to those in **Exhibit B-5**: Even within a single state, MNA is the only statistically significant differentiator of total cost across this subset of technologies, though air sparing appears to be associated with a higher remedial action cost in South Carolina, while SVE is associated with a higher monitoring cost.

EXHIBIT B-6. REGRESSION ANALYSIS: SITE COSTS BY STATE AND TECHNOLOGY (SOUTH CAROLINA ONLY)

INDEPENDENT VARIABLE	ASSESSMENT COST	REMEDIAL ACTION COST	MONITORING COST	TOTAL COST
Air Sparging	-7,16	112,072***	-25,121	77,429
Excavation	4,172	50,806	26,096	76,181
Monitored Natural Attenuation (MNA)	-13,772	-61,991***	9,944	-64,514***
Soil Vapor Extraction (SVE)	-7,258	-39,628	168,369***	120,387
N	217	211	217	217
R^2	0.02	0.12	0.06	0.06

Gray shading indicates a coefficient that is not statistically significant at the ten percent level.
* Statistically significant at the ten percent level, but not the five percent level.
** Statistically significant at the five percent level, but not the one percent level.
*** Statistically significant at the one percent level.

APPENDIX C: DATA REQUEST LETTER TO ASTSWMO MEMBER STATES

The text below was sent in an email from OUST to ASTSMO LUST Members requesting the information that was ultimately used in this report:

ASTSWMO LUST Members:

The U.S. EPA's Office of Underground Storage Tanks (OUST) is launching a project to assist states in **calculating the lifecycle cost of different LUST cleanup technologies** and approaches with the **goal of making better, more cost-effective cleanup decisions**. ASTSWMO Task Forces participated in a call this week with EPA to discuss the project, and their feedback is reflected in the attachment. The purpose of this message is to provide further information about the project and invite you to participate.

What is this project about?
At its most basic level, this project seeks to answer the question: Which technology is the most cost effective? For example, is it better to employ a technology that has larger upfront costs and a greater potential of attaining cleanup goals quickly or a seemingly less expensive longer term technology that may involve more O&M costs over time? The project will involve trying to quantify the full cost of completing LUST cleanups using various cleanup technologies and then assessing their cost effectiveness. A state cleanup manager gave one relatively simple example when discussing her needs: Is it better to use a mobile cleanup system (e.g., a vacuum truck to periodically treat a site) vs. a fixed system? These two approaches will have different types of costs and may take different amounts of time to reach the desired endpoint. For example, there are repeated mobilization costs for multiple vac truck events while a fixed remediation system may have greater installation costs and higher utility costs.

The project will involve identifying key elements of cost for various cleanup technologies/approaches and require one or more states with robust remediation cost data. Please see the attached scoping document with more information about the project and the types of data being requested.

What are you asking me to do?
Participation in this project is completely voluntary. We are looking for states who are willing and able to provide easily obtainable remediation cost data.

Please let us know if you have:

- Interest in participating in the study;
- Comments and edits on the attached scoping document;
- Data that is available for one or more example sites;
- Standard cost guidelines/cost-reimbursement schedules for your state – both for the State Fund reimbursement sites and the state lead contracts; and/or
- Contacts in other states that you think might be interested

Who should I contact if I am interested or have questions about the study?
Please contact Tom Schruben at OUST: Schruben.Thomas@epa.gov

Please let Tom and me know by **Tuesday, March 9th** if you are interested in participating.