Institute of Water Research
MICHIGAN STATE UNIVERSITY

INSTITUTIONAL CONTROLS FOR GROUNDWATER MANAGEMENT:

LONG-TERM COSTS AND POLICY IMPACTS

Institute of Water Research
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FLOW
FOR LOVE OF WATER

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EXECUTIVE SUMMARY

Contaminated groundwater can represent a significant loss of a valuable public trust resource, pose public health and safety hazards, contaminate surface waters, damage aquatic habitat, degrade ecological function, decrease property values, and inhibit private and community development opportunities. Cleaning up large areas of contaminated groundwater can be expensive and require years to accomplish. In some cases, restoring a severely contaminated aquifer may not be feasible. Although not a substitute for aquifer restoration, land use restrictions that restrict property use with the goal of preventing further public exposure to hazards posed by groundwater contamination are a means of mitigating some of the negative effects of the contamination, primarily those associated with public health and safety under current regulations. Such restrictions, collectively referred to as institutional controls (ICs), can be in the form of restrictive covenants (deed restrictions), municipal ordinances, or other control mechanisms that in most cases legally and permanently restrict property use. This project sought to explore the long-term economic costs of relying on ICs as a protective measure in lieu of actively removing contamination from an aquifer.

A team of researchers and policy advisors from Michigan State University and FLOW (For Love of Water) received funding from the Office of the Great Lakes at Michigan's Department of Environment, Great Lakes, and Energy (EGLE) to estimate the costs of utilizing ICs at seven case study sites. The team conducted extensive background research at each site, reconstructing timelines and gathering relevant cost data. That research informed the subsequent economic analysis that sought to isolate costs related to IC implementation and extrapolate them into the future. The insights from that analysis informed the development of a decision framework spreadsheet tool to guide future evaluations of IC implementation, such as during an EGLE review of a Remedial Action Plan or No Further Action proposal under Part 201 of the Natural Resources and Environmental Protection Act.

The main limitations of the approach were the challenges inherent with relatively small sample sizes and the inability to capture the unmeasured broader societal, health, and environmental costs in the estimates. The seven locations varied by region, scope, contaminants, and data availability. The diversity of this sample helped identify the types of costs and issues that can arise when implementing ICs and enabled the team to generate a comprehensive list of recommendations for improving the use of ICs in the future. However, the small size of the sample made it difficult to generalize findings across sites or extrapolate them to other locations. The costs estimated in this analysis function as lower bound estimates for the potential economic impacts of relying on ICs as a groundwater response activity. The actual costs would be higher. The project team incorporated data regarding water access, monitoring, oversight, public health, and foregone opportunities into its estimates. However, the opportunity costs are conservative as their upper bounds were hard to delineate. Other hard to quantify costs, such as the erosion of public trust, degraded aesthetics, degraded ecological function, denied environmental justice, and the stigmatizing effects of pollution on a locale, were not included in the estimates.

Though the exclusion of these broader costs tended to make the estimates of long-term IC-related costs at the case study sites relatively low, they were higher than the costs anticipated for IC-driven approaches in prior evaluations. For several of the case study sites, contractors or government agencies evaluated the costs of various remediation strategies, including relying on ICs. The difference in these prior evaluations and the estimates from this project implies that the long-term costs of relying on ICs to address groundwater contamination are often underestimated, which the decision framework spreadsheet tool is designed to help mitigate. Despite this difference, this project's estimates of long-term IC costs still tended to be lower than active remediation efforts to restore the aquifer, such as pumping and treating or soil vapor extraction. Economically, it appeared more affordable for responsible parties to fall back on approaches that do not actively clean up contaminated aquifers. Choosing to let groundwater contaminants attenuate for decades (centuries in some cases) effectively writes off a public resource, results in orphan sites, and creates a burden to be borne by future generations. This project highlights the need for a market-based correction that imposes much more of the impacts associated with groundwater contamination to be captured in the cost of doing business by the contaminating entities.

BACKGROUND

Michigan's groundwater has been called the sixth Great Lake[1]. It supplies drinking water to 45% of the state's population, including two million through small private wells. On average per day, 260 million gallons are withdrawn for irrigation needs with another 64 million for industry. More than 40% of the water in the Great Lakes comes from groundwater. It feeds streams and rivers, helps regulate water temperatures for sensitive fish species, and sustains wetlands. It is an invaluable resource. However, Michigan has over 3,000 sites where groundwater contamination is so severe that State law requires an alternative source of drinking water.

The 30-Year Water Strategy for Michigan[2], developed in 2016 by the Michigan Office of the Great Lakes, called for "a comprehensive groundwater management strategy to better protect Michigan's valuable water resources." Implicit in that recommendation is the need to consider the state of Michigan's groundwater and the effectiveness of groundwater policies.

In a 2020 report submitted to Michigan's Department of Environment, Great Lakes, and Energy (EGLE), Beeler, Nasi, and Willig (2020) evaluated the use of institutional controls (ICs) in Michigan under Part 201 of the Natural Resources and Environmental Protection Act (NREPA). Through interviews with staff from EGLE and Michigan's Department of Health and Human Services (DHHS), protocol reviews, and GIS analyses, the authors developed recommendations for improved use and management of ICs in Michigan. The recommendations included improving data standards and accessibility for tracking groundwater contamination and strengthening enforcement mechanisms under Part 201. The authors also acknowledged a need to better understand the long-term costs of ICs.

EGLE and DHHS formed a working group to further explore the topic of IC use and issued a request for proposals (RFP) to assess the long-term economic cost of using ICs and other restrictive actions to manage risks associated with groundwater contamination compared with the cost of other potential management actions[3]. The use of ICs and other land or resource use restrictions is an outgrowth of amendments to Part 201 of the Natural Resources and Environmental Protection Act (NREPA), Act 451 of 1994, approved by the Governor and Legislature in 1995.

ICs and other land or resource use restrictions have been used widely in Michigan to manage risks associated with groundwater contamination. As of August 2023, the Department had recorded more than 4,000 ICs at over 3,500 sites across the state. EGLE believes the numbers of sites and controls are significantly higher.

Unanticipated developments have occurred at some sites where ICs were implemented. For example, one human health exposure associated with contaminated sites that was not well understood when many ICs were implemented is vapor intrusion. Vapor intrusion occurs when vapor-forming chemicals released into the environment migrate from a subsurface source into an overlying building. At a handful of sites, federal and state authorities had to evacuate businesses or residences until air contaminants were reduced to acceptable

[1] https://forloveofwater.org/sixth-great-lake/
[2] https://www.michigan.gov/egle/about/organization/office-of-the-great-lakes/strategy
[3] This project employed a broad definition of *institutional control*, which includes local ordinances, local health department policies, restrictive covenants, and state laws and regulations that restrict land use.

levels. A former department director estimated there may be as many as 4,000 such sites[4]. It is important to consider whether costs resulting from these and other unexpected developments are adequately considered in the use of ICs.

EGLE's RFP called for the use of economic case studies to evaluate the Department's process and criteria for determining when ICs are the appropriate response to a groundwater contamination event, the development of a decision-making framework for future instances of groundwater contamination based on a holistic prediction of long-term risk and cost, and incorporation of the risk of additional unexpected costs into this framework.

The project was led by the Institute of Water Research (IWR) at Michigan State University (MSU). Jeremiah Asher is the Assistant Director of IWR and was the main developer of the web interface for the State of Michigan's Water Withdrawal Assessment Tool. Dr. Glenn O'Neil is an Environmental Scientist for IWR and has led groundwater modeling efforts on multiple projects. Full-time Ph.D. researcher Steven R. Miller, specializing in regional economic modeling and analysis, led the work for MSU's Center for Economic Analysis (CEA).

IWR partnered with For Love of Water (FLOW) for policy analysis. FLOW is a (501)(c)(3) science, law and policy center founded in 2011. The FLOW team included Andrew W. Hogarth, a retired Michigan Department of Environmental Quality Senior Management Executive, Christine Flaga, FLOW Project Consultant, retired from the Remediation and Redevelopment Division of the EGLE in 2019 after 36 years working as a toxicologist for the DNR, DEQ, and EGLE. Also included on the FLOW team were Liz Kirkwood, Executive Director, Dave Dempsey, Senior Policy Advisor, and Skip Pruss, Advisor for FLOW and former Deputy Director of EGLE.

IWR and FLOW established an advisory board to provide guidance on the overall project design, and share legal, regulatory, policy, and scientific knowledge and experience necessary to guide the selection of case study sites, calculations of IC cost, and decision framework development. Among others, members included George Heartwell, the former mayor of Grand Rapids and member of multiple environmental advisory boards; Bill Rustem, former president of Public Sector Consultants and environmental advisor to former Michigan Governor William Milliken; Jon Allan, Senior Research Program Officer at the University of Michigan and former director of the Office of the Great Lakes at EGLE; Mitch Adelman, former Field Operations Manager for EGLE's Remediation and Redevelopment Division (RRD); and Bryan Lewis, Executive Director of EcoWorks, an environmental justice advocate with a passion for community sustainability and youth development. The project team also engaged with an interagency work group throughout the project which included representatives from multiple EGLE and DHHS divisions and programs to advance the recommendation in the Michigan Water Strategy. In particular, EGLE staff in RRD played a critical role in the project work, providing vital information and perspective on sites considered for the case studies.

IWR and FLOW proposed the following tasks in quantifying the long-term costs of implementing ICs as a groundwater contamination response in Michigan:

- Identify case study sites in which an IC for groundwater was used in Michigan.
- Calculate the cumulative cost of that choice at each site, including costs associated with monitoring, drinking water access, property value, public health, and recreational loss, among others, while engaging stakeholders to help identify relevant datasets, records, and cost considerations.

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[4] https://www.detroitnews.com/story/news/local/michigan/2017/02/16/mich-deq-chief-vapor-intrusion-poses-health-threat/98020512/

- Develop a framework to guide future decision-making for controlling exposures to groundwater contamination, supplementing existing RAP decision-making frameworks that are used by Michigan's remediation programs.

METHODS

As of August 2023, Michigan Environmental Mapper[5] (an online mapping tool for viewing the locations of ordinances, RCs, and other layers related to environmental protection), indicates that there are over 17,000 sites of environmental contamination regulated under Part 201, over 18,000 leaking underground storage tanks (LUSTs) regulated under Part 213, and that ICs have been utilized at over 3,500 of these sites. Calculating the economic costs of ICs across all sites was beyond the scope of this project. Instead, this project utilized a small sample case study approach, in which site histories were thoroughly researched, remedial responses and their rationales carefully analyzed, and timelines categorized into key phases. This effort allowed for a detailed economic analysis that yielded insights into the impacts of ICs and how the state can more effectively employ them. This section describes how the case study sites were selected, their histories researched, their costs analyzed, and the findings incorporated into a decision framework for IC cost evaluation and discusses the limitations of this approach.

Case Study Site Selection

Seven sites of contamination were selected for this project (Table 1, Appendix A). The project team collaborated with EGLE and DHHS in developing a list of about 30 candidate sites, and then narrowed it down to the final sample. Though seven sites out of 3,500 across the state are not enough to constitute a representative sample of IC use in Michigan, the project team and EGLE sought to capture some diversity within the seven selected sites along different criteria. Taken as a whole, the seven sites attempt to account for Michigan's geographic diversity, with locations scattered across the state and representing different landscapes. Lincoln Brass Works was situated in a dense, urban environment. The contamination at K&L Landfill, Charlevoix Municipal Well, and Ford Kingsford primarily affected suburban communities, whereas Wash King Laundry, Hitachi Magnetics, and the Wickes Manufacturing Trichloroethylene (TCE) Plume occurred in more rural areas. The case study sites also varied in scope and resulting exposures from their respective contaminants. Wickes Manufacturing TCE Plume and K&L Landfill are dealing with large and still expanding groundwater plumes, whereas Charlevoix Municipal Well and Lincoln Brass Works had toxic vapors emanating from contaminated groundwater and soils. Additionally, the sites varied in terms of their data availability. K&L Landfill, Wash King Laundry, and Charlevoix Municipal Well are EPA Superfund sites, which require regular reporting of progress and publicly shared data. The extent of the Wickes Manufacturing TCE Plume contamination necessitated EGLE taking over the coordination of the remedial response, and the development of a public paper trail like the EPA Superfund sites. However, the remaining sites required more extensive research and coordination with local staff and EGLE project managers, illustrating the difficulty of evaluating the economics of ICs at data poor contaminated sites.

[5] https://www.michigan.gov/egle/maps-data/environmental-mapper

Site	Location
Charlevoix Municipal Well	Charlevoix, Charlevoix County, MI
Ford Kingsford	Kingsford, Dickinson County, MI
Hitachi Magnetics	Edmore, Montcalm County, MI
K&L Avenue Landfill	Oshtemo TWP, Kalamazoo County, MI
Lincoln Brass Works	Detroit, Wayne County, MI
Wash King Laundry	Baldwin, Lake County, MI
Wickes Manufacturing TCE Plume	Mancelona & Bellaire, Antrim County, MI

Table 1: Case study sites.

One of the challenges of the analysis was isolating the impacts of ICs from other activities at the case study sites. Ideally, the sample population would include seven data-rich sites in which the use of ICs was the sole tool utilized to address groundwater contamination. In these ideal circumstances, it would be easy to attribute the subsequent long-term costs of not actively remediating the contamination to the choice to rely solely on ICs. However, to explore the potential worst-case scenarios that such an approach could yield, the sample had to include complex sites where contamination was significant in scope and severity. This complexity often meant that the case studies included IC utilization along with active remediation, such as the Charlevoix Municipal Well (air sparging, sub-slab depressurization), Lincoln Brass Works (soil excavation), and Hitachi Magnetics (groundwater pump and treat system). Wickes Manufacturing TCE Plume and K&L Landfill were closer to the idealized scenario of a mainly IC-driven response, with each evaluating but declining to adopt more expensive and active remediation efforts. These sites also employed source control strategies in addition to ICs. To the extent possible at each site, the project team identified the immediate and long-term costs to the ICs and distinguished them from other costs. While scenarios did not always present clear and distinct costs of the IC, the resulting estimates were developed to reflect the best cost estimate of not immediately controlling pollution sources through aggressive remediation of groundwater contaminants. Given the challenges to measuring the socio-economic costs of ICs discussed below, the resulting estimates of economic costs of instituting ICs are considered lower bounds of the true social and private costs the respective ICs impose.

Site Analysis

The team drafted a template for documenting the relevant information for each case study site (See Appendices D through J for examples). Each template included a background section describing the main events at the site, a timeline of those events, a list of ICs utilized, a list of other remedial measures taken, and an evaluation of the relevant exposure pathways. As stated above, some of the sites had detailed and accessible public reports due to their EPA Superfund status, or because of the significant scope of their contamination (e.g., Wickes Manufacturing TCE Plume). The density of these records posed their own challenges, but their availability made it easier to piece together the site history. At the other sites, the team worked closely with the respective EGLE project managers to track down past reports, monitoring data, and cost information, in some cases, searching open sources and submitting FOIA requests where necessary.

The team mined these records for cost data (e.g., number of municipal water extensions provided, the extent and duration of bottled water provisions, monitoring analysis, ordinance development, and oversight, among others). The site histories and cost data allowed the team to identify key moments in the timeline when choices were made to rely on ICs in lieu of active remediation, and attribute long-term costs to those decisions accordingly.

Economic Analysis

Environmental and ecological economists have devoted considerable effort to understanding the socio-economic implications of environmental damages since the passage of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. Interest was renewed with the passage of the Oil Pollution Act (OPA) of 1990, which established the basis for compensating affected parties of catastrophic chemical spills. Under these two acts, efforts were made to standardize Natural Resource Damage Assessment (NRDA) with the intent to establish accountability of the responsible party where viable. Quantifying the effects of groundwater contamination under an NRDA requires site-specific accounting for the natural resource services adversely affected (Dunford, 2000) and changes in household and community behaviors (Abdalla Charles W, 1990).

Groundwater contamination presents economic challenges to both the responsible parties (if viable) and third parties impacted by the contamination. These challenges entail direct transactional costs of controlling the contamination and human exposure, opportunity costs of forgone uses of affected resources and revenues arising from use restrictions of directly and indirectly impacted properties and spillover costs, including damages to third parties. Responsible parties can recompensate affected third parties for costs and lost value with direct payments or by compensatory restoration – the process of making third parties whole with regard to the contamination. In addition, the responsible party may be required to pay any rehabilitation or remediation costs of the site, or if the determined best option is monitoring with natural attenuation (MNA), may require indefinite compensation to impacted third parties (National Research Council, 2013, p. 202).

It is not unusual for site costs to change over time. Health-based cleanup standards for contamination of soils and groundwater evolve over time as science provides more complete understanding of adverse effects of chemicals. For example, EGLE (then known as the Department of Environmental Quality) lowered the Part 201 Generic Residential Drinking Water Criterion for 1,4-dioxane from 85 parts per billion (ppb) to 7.2 ppb in 2017, mandating that levels in groundwater once considered acceptable were now considered unacceptable (EPA, 2021). In a similar vein, additional contaminants at a site can be identified after the initial record of decision (ROD), expanding the treatment mandate (National Research Council, 2013, p. 203). Furthermore, continued monitoring of surrounding areas may reveal plume mobility or new plumes of contamination – subsequently adding to the geographic extent of the site. If there is a need to drill new and deeper wells to avoid a contaminated aquifer, such wells can incur much higher construction costs as additional measures, such as double casings, may be necessary to ensure that the drilling operation does not exacerbate the situation. Finally, projected and realized costs of managing a site may change because the initial site costs are generally not known from the outset, and it is difficult to generalize expected costs from other comparable sites. It is common for the costs of remediating a site of environmental contamination to be more than the measurable economic benefits gained by doing so (Easter and Konishi, 2006).

The primary approach to measuring the economic costs of groundwater contamination is called the avoidance cost method, or ACM. The ACM asserts that communities and individuals choose a set of options to avert the adverse effects of contamination that minimizes the costs of doing so (Easter and Konishi, 2006; Sarnat et al., 2017). ACM estimates generally account for transactional costs, or costs measured by total expenditures required to circumvent the adverse effects of exposure to contaminants. In nearly all cases, there are other relevant costs, including those not directly observable by the transfer of dollars. Such costs, however, can be difficult or impossible to measure but are relevant to the social costs incurred by a community due to a contamination source. Accordingly, ACM estimates of social and private costs of groundwater contamination are considered the lower bound of actual social costs (Abdalla Charles W., 1994). In short, this process can establish a “floor” for costs but does not address a potential “ceiling” of all relevant social costs. Appendix B provides a more in-depth discussion and literature review of ACM-based approaches.

The MSU/FLOW research team leveraged these prior efforts and resources to develop an approach for estimating socio-economic costs of implementing IC controls in place of active and effective remediation at the seven case study sites. In deriving economic cost estimates, certain boundaries, or cost philosophies had to be established, including what should and should not be included in the site costs attributed to the respective IC. To be clear, measurable costs included were those that occurred once the IC was established and not prior to its establishment. Accordingly, the following three constructs are established in determining what is and is not a private or social cost of an IC in this analysis:

- The alternative to an IC is full and active contaminant removal, where implementing an IC is the purposeful deference of the immediate costs of remediating the groundwater contamination. Hence, along with direct costs of implementing and maintaining the IC, any future cost incurred because the impediment was not immediately removed is a valid cost of the IC.

- IC costs can only be realized after the IC is established. Specifically, this means the health impacts and costs of exposures prior to declaring or establishing an IC as a substitute for active remediation cannot be part of the cost of the IC. Additionally, any environmental or use-damage/restriction caused by the contaminant before the IC is established cannot be part of the cost of the IC.

- Mobile plumes for which an IC has already been established may subsequently require expanding the geographic bounds of the existing IC, and this expansion would likely not exist under the alternative case of full and active contaminant removal. Therefore, all prior realized costs of subsequently added acres to the contaminated site are subjective costs of the original IC and should be included.

These philosophical bases for inclusion and exclusion of costs are designed to be malleable to the diverse circumstances underlying IC sites across the state. They accommodate variations in geography, geology, and circumstances, and function as a standard framework for costing ICs, as a pre-defined template for estimating the social and private costs of ICs cannot be established that would conform to each site's unique characteristics. That is, each site requires a unique perspective and frame for establishing the expected social and private economic costs of the respective IC, for both the costs already incurred and those expected to be realized well into the future.

By categorizing IC costs, it is inevitable that some costs will transcend other cost categories, including realized costs, recurring costs, potential costs, and unmeasurable costs. Realized costs are those that have occurred and therefore are realized, whether the value of the cost is known or not. Recurring costs may persist indefinitely on a recuring basis. Generally, society places more concern on immediate costs than on those expected to occur well into the future. Accordingly, expected future costs are discounted to reflect the time-value-of-money. Alternatively, potential costs may be relevant societal costs but are often unmeasurable. An example is the chance that the plume will migrate to encompass residential properties not currently impacted by the contaminants of concern (COCs). Here, measuring the probability and scope of plume migration will be outside the scope of this project. Finally, unmeasurable costs are those that can only be described qualitatively in terms of unvalued disruptions or impediments to use. An example may be the loss of ecoservices derived from contaminated groundwater draining into fish spawning streams and rivers with the overall effect of degrading the ecological value of the stream and food web supported by that stream. Such consideration should include the potential loss of recreational fishing in a stream – especially in the case that the plume discharges at levels exceeding maximum regional screening levels (RSLs). Note that these different categories of costs, ranging from realized to unmeasurable costs, are framed within the methodology and strategy, i.e., identifying and measuring costs that occurred once the IC was established.

The overriding strategy for estimating social and private costs of ICs is to establish costs on a per-unit basis using fixed, or inflation-adjusted prices. This allows cost estimates at one site to be extrapolated to other sites and at other times where unit cost estimates are not available. It also provides for scalability – projecting costs should the plume expand over more units. By reviewing the seven site reports in the Appendices, it will become evident that more documentation was imposed on the K&L Avenue Landfill report than others. This is because the team viewed this site as a keystone for estimating activity costs of other sites. Further, the K&L Avenue Landfill site management was supportive in providing transparent estimates of the expenditures generated and the site had a wide breadth of cost types. While the K&L Avenue Landfill site cost estimates underly many of the activity-specific costs for other sites, in many cases, more than one set of cost estimates exists, giving some latitude in adopting per unit cost estimates that best align with the site in question. That is, the site-specific costs for each activity, for example drilling deeper wells, installing a sub-slab depressurization system, etc., were compiled across all such reporting sites to generate a profile of costs by activity that can be used for sites without a reported expenditure for that activity. However, secondary estimates from other sites were only applied when the site in question did not have a viable cost estimate for that cost component.

With these guidelines established, the team utilized the case study site background research (described above in the *Site Analysis* section) to estimate transactional costs for each site. The background research established the timeline of key events and actions taken at each site, allowing IC-related costs to be distinguished from costs not attributable to the IC. For some sites, the background research identified costs directly from EGLE/DNR, EPA and published and community presentations and communications. Some examples include fact sheets provided by EGLE for communities impacted or potentially impacted by the Wickes Manufacturing TCE Plume.[6] For the Charlevoix Municipal Well site, EPA's Five-Year-Review[7] reports for Superfund sites were instrumental in documenting records of decision, associated realized and projected activities, and in many cases the expected expenditures under those activities. The Army Corp of Engineers provided detailed budgets under multiple site management options useful in assigning expected and realized costs for the Charlevoix Municipal Well, while third-party technical consultants contributed to specific cost estimates at most sites, including Wickes Manufacturing TCE Plume, K&L Avenue Landfill and Hitachi Magnetics. Especially for the case of the K&L Landfill site, the managing party, the KLA Group, documented costs in response to the project team's requests. At sites where report availability was limited, such as Lincoln Brass Works and Ford Kingsford, costs had to be inferred from other sources, including observations from the other case study sites or from published literature. All the cost data was adjusted for inflation to 2020 values, including both past and anticipated future expenditures.

Though costs were estimated for each case study site, those estimates were developed to be scalable across multiple sites. This scaling fed the cost data sources that support the decision framework, and helped fill in gaps for sites where the background research was able to identify a relevant activity, but not the costs. Costs that accrue at the household level are measured at the rate per household; for example, the cost of connecting residential water to a municipal water main. Similarly, recuring costs are measured at the accrued rate per year. For water delivery, the average cost per household per year is established by sites with realized and reported costs per household. Many costs accrue per site, like administrative and research costs of reporting to regulators. Others may be on a unit basis, including the costs of drilling a monitoring well, for which the costs will be proportional to the number of monitoring wells required. In most cases, more than one

[6] https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Programs/RRD/Remediation/Wickes-Manufacturing/Wickes-Manufacturing-TCE-Plume-Fact-Sheets-January-2012.pdf?rev=85f15de9354b450cbcc15dc77589fa2c&hash=6B9ADDF25C6F6AC0D9DD8096923380ED
[7] https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.scs&id=0503013&doc=Y&colid=70237&region=05&type=SC

estimate is provided by multiple sites or multiple sources. These multiple estimates are used to create upper and lower bounds of the expected costs for that item. In aggregate, however, practical experience dictates that the costs identified in this study for each site be viewed as a cost floor.

Decision Framework

Though the analysis was limited to seven case study sites, the project sought to leverage the data and insights gained from that effort to provide guidance to EGLE staff when working with a responsible party considering an IC-driven approach to a groundwater contamination. That guidance is provided in the form of a spreadsheet-based decision framework. To develop the framework, the team first developed flow charts to identify the main categories of IC-driven costs (e.g., water access, monitoring, RCs, ordinances, oversight), define their contributing components (e.g., well abandonment, municipal water supply, bottled water delivery), and map those back to user-provided inputs for the spreadsheet (e.g., number of homes requiring bottled water, duration of delivery need). The flow charts were then used to construct the spreadsheet, with guided question and answer forms yielding cost estimates for each cost category and for an overall cost. The costs identified across the case study sites, and in searches of broader economic literature, were organized into a cost schedule for the main categories and incorporated into the spreadsheet to drive the framework's math. The tool was then tested internally among the project team for logic, function, design, and user-friendliness. That initial testing revealed a need to describe the tool's limitations more explicitly, especially the relevant outcomes it does not estimate. The subsequent revision added a form upfront that describes the potential impacts that not actively remediating contaminations can have on public trust, environmental justice, and natural aesthetics, in addition to the potential for creating regional stigmas that could depress tourism. It is not possible, however, to put unique dollar value estimates on all these types of impacts. An additional round of testing will be conducted with EGLE staff, and their feedback will inform further refinements of the tool. See the *Results* section below for a detailed description of the decision framework tool and its outputs.

Limitations of the Approach

There were three primary limitations to this project's effort to estimate the costs of relying on ICs for responding to groundwater contamination. The first was the small sample size, the second the inability to identify and quantify all relevant private and social costs (e.g., health, aesthetics, public trust), and the third the limited data availability at some of the case study sites.

There is a need to better understand the cumulative costs of relying on ICs throughout Michigan. Given the variety of costs and settings among the seven case study sites, the small sample proved insufficient for extrapolating costs state-wide. Though the team strove to capture as much diversity in its sample as was feasible, the relatively small size made it difficult to generalize the findings for various conditions. For example, Lincoln Brass Works was an important case study site to include because it was the only site situated in a densely urban area, but it does not ensure that the project's findings are representative of other urban areas in Michigan. Nor does the impact of IC failure at Hitachi Magnetics imply that similar failures would yield comparable outcomes at rural sites. The small sample size also excluded other potentially relevant situations. For example, the sample population did not include a gas station (i.e., a leaking underground storage tank site governed by Part 213), one of the most prevalent sources of contamination in Michigan, though efforts were made to include one (Appendix K). The small sample size may have also skewed the analysis towards larger, more complex, and problematic sites, at the expense of smaller, simpler sites. There is value in studying these sites because they often have rich data histories to mine and documenting the worst-case-scenario outcomes is important when providing guidance on the consequences of not actively remediating contamination. But doing so potentially excludes sites where the use of IC-focused approaches may have been effective and appropriate.

While undertaking this analysis, it seemed evident that the presence of the option to implement an IC creates a disincentive to implement an active remediation approach. The option to implement and general recognition that ICs tend to generate lower management costs than active remediation was shown to be a source of delaying any form of containment effort in the K&L Avenue Landfill site and may have attributed to decision delays for the Hitachi Magnetics plume, among others. Accordingly, this blurs the distinction of when costs associated with an IC are accrued. If the option of implementing an IC delays the adoption of any viable active remediation or control of spread, one can argue that the option of the IC assures the costs of active remediation will be too high to implement any degree of containment. The project team derived no effective way for accounting such effects.

As discussed in other sections of this report, quantifying the economic costs associated with ICs was fraught with challenges. As the approach used to generate these cost estimates entailed adding up all the documentable costs, it is evident that not all socio-economic costs will be included in the final estimates. That is, the universe of potential sources of economic costs is both extensive and unbounded and cannot be accounted for, even at the most thoroughly documented sites. Two primary reasons limit measuring the extent of economic costs: 1) there is no accounting for expenses by all injured parties; and 2) there are numerous, difficult to measure costs. The failure to account for all expenses arises from the inability to coordinate all affected parties. That is, different degrees of reporting may be expected from different parties. Even though government agencies may have traceable expenditure lines for managing the IC site, they will also have overhead costs that will be difficult to allocate to the IC. For example, the IC will likely add costs to local units of government, like the local health and public safety departments, but it would be difficult to allocate personnel and shared resource costs to the IC. In addition, third-party residents may take precautionary and unreported measures other than those authorized or mandated by the IC and responsible parties. Such may entail out of pocket expenses, like those for improved water filtration systems or improved HVAC systems in excess of those authorized or paid for by responsible parties. It may also have psychological effects on one's perception of well-being and associated changes in behaviors and purchases. Thus, the economic results of this study are framed as lower bounds of cost estimates)

One cost that may be of particular interest is how ICs impact property values. In this regard, we considered an IC to be a continuation of the plume and all associated restrictions to land use (primarily well water and potential for vapor intrusion) to influence the underlying value of properties. To understand this source of effect, the research team turned to academic literature and peer-reviewed studies of property value impacts of standing groundwater pollution (See Appendix B). The literature shows that for residential properties, an announcement of the plume and restrictive covenants is sufficient to reduce the market values of affected properties. However, such impacts are temporary, as the residential property values eventually return to parity with comparable properties not affected by the plume. Commercial property values, especially those of industrial properties, however, may remain suppressed indefinitely. The precise nature of such value effects is difficult to generalize due to the nature of industrial property valuations, but the primary reason commercial property values may be inversely impacted appears to be associated with businesses seeking to remove themselves from future liabilities tied to the land.

The inclusion of large, complex sites also introduced challenges for isolating IC-related costs. While sites like Hitachi Magnetics and Charlevoix Municipal Well relied heavily on ICs as part of the long-term remediation plan, they also included active remedial actions. Hitachi Magnetics installed a pump and treat system for several years, and an air sparging system and multiple sub-slab depressurization systems were implemented in

Charlevoix. It is not unusual for active remediation methods to accompany ICs as part of a plan to prevent exposure, but when they do it can muddy efforts to attribute costs and impacts to the reliance on ICs. In such circumstances the team tried to isolate the IC-related costs by carefully evaluating a site's timeline of events to identify moments when decisions were made to rely on ICs as the primary response. Should an IC implemented in lieu of a holistic remediation led to a subsequent active remediation effort requirement, then such active remediation costs should be part of the overall cost of the IC.

Leaving pollutants in the environment can have societal impacts that go beyond site-specific costs. The decision framework acknowledges this through its *Context* tab and its discussion of matters of public trust, environmental justice, and natural aesthetics. These impacts carry economic costs that are difficult or impossible to quantify and were not estimated in this project. The small-sample, case-study approach does not lend itself to extrapolating these broader societal costs, but this project's analyses provide a springboard for such an effort. A policy question beyond the scope of this study is the cumulative impact of ICs (at more than 3,500 locations to date) on future generations. A common response to the contamination of a potable aquifer has been to extend municipal water supplies from a separate and uncontaminated aquifer. But as more aquifers are contaminated and not actively remediated via the use of ICs, future generations may not have clean water sources to rely on.

A final limitation of this project's approach was the paucity of available records at all case study sites. From a policy perspective, this may have profound effects. The research team anticipates that many contaminated sites in Michigan share in this lack of effective documentation of private and public investment in managing groundwater pollution sites and suffer from limited paper trails for evaluating outcomes. The implications are that effective policy choices are hampered by a lack of objective and actionable data. Though the experience of studying data-poor sites was informative on a broader scale, it added uncertainty to the cost estimates generated for this project. For example, there were relatively few records documenting the Lincoln Brass Works contamination, as this site was wholly managed by private responsible parties with no mandate for public reporting of activities and costs of any or all efforts to control exposure pathways. Though the EGLE project manager was helpful in providing earlier consultant reports and a recent No Further Action proposal, the team was unable to gather enough data to adequately estimate the potential cost to public health caused by the vapor intrusion, or fully document the costs of any remedial or controlling effort. A FOIA request to the City of Detroit's health department for records and communications related to the exposure of Head Start students in the affected building was denied, forcing the team to have to make coarse estimates about the number of affected children and the health complications they may have faced.

Despite these limitations, this project provided an important initial step at exploring the economic impacts of ICs, and the decision framework provides a mechanism that can aid in extending that exploration to additional locations in Michigan. The cost bases collected across the seven sites reviewed were compiled and applied to a decision support tool and made generalizable to the extent possible. Such parameters require user discretion, recognizing the limitations of the approach and selected case sites described in this report.

RESULTS

This section summarizes the results of the cost analysis and the development of the decision framework. For a more detailed description of how the costs were calculated for each case study site, see the respective section in appendices D through J.

Costs of Institutional Controls

There exists little overlap across the seven case-study sites in the overall structure of total site costs attributable to an IC. Perhaps the most attributed cost category is providing access to potable water, which may take the form of providing subscription services to bottled water, as experienced with K&L Avenue Landfill. In rural settings, providing extensions to municipal water systems is common, as found at Hitachi Magnetics and Wickes. The Wickes Manufacturing TCE plume is expansive and required significant investment in extending existing municipal water mains through its “Well First” program. Alternatively, contaminated groundwater in urban settings was easily addressed and exposures prevented by the existing municipal water system. However, for Charlevoix, the contaminant threatened the municipal water wells and required changing the source of water from a groundwater source to a surface water source.

Table 2 below summarizes the economic cost findings, breaking costs down into realized costs up to 2020 and the expected future costs for those sites with anticipated future expenses and recurring expenses. Expected future costs are discounted to 2020 values and represent best assessments of the future social costs, both private and public, in maintaining the IC, including required monitoring, continued water access and vapor intrusion mitigation costs, and where records of decisions call for, the costs of future active mitigation for restricting pathways to exposure. The reader can interpret the overall cost estimate of the ICs below as the sum of the past realized costs and the present value (PV) estimates of future costs. The figures in the table may provide a false assurance that the realized and future costs estimated are inclusive of all costs, but for the reasons described in this report, represent lower bounds of the true socio-economic costs.

Contaminated groundwater at two of the reviewed sites was deemed to be expansive and mobile, generating the highest overall social costs. K&L Avenue Landfill and Wickes Manufacturing generated groundwater plumes which remain largely rural. This required expensive extensions to municipal water systems and may have disruptive effects on economic development initiatives, as connecting to the nearest municipal water main will add to the development costs. While not expansive, the Charlevoix Municipal Well site commanded significant intervention due partially to high population density over the plume. Accordingly, this is an interesting case study on the ongoing costs of an IC in an urban setting. Future costs include intensive monitoring and support of VOC containment, including expected active remediation efforts to contain future exposure to VOCs. Alternatively, the Lincoln Brass Works site has since been remediated and has zero expected future costs. To an extent, this may be overly optimistic in that there is the potential prospect of future health-related costs for those exposed to TCE contaminants, especially relevant to the operations of the Head Start preschool classroom on this site. As detailed in the site report in Appendix H, the present value of those expected costs is positive but insignificant. All other future IC costs of the Lincoln Brass Works site were negated when Ford Motor Company acquired the facility.

As discussed above, the estimated private and social costs of these seven sites provide lower bounds of the socio-economic costs of institutional controls, limited by the extent to which verifiable accounts of expenditures and activities exist. In most cases, the realized, or past costs make up the largest component of the estimated IC costs. However, expansive sites with mobile plumes appear to have higher future costs than sites with stable plumes. In most cases, future costs are derived from past costs that are expected to recur year over year. However, in the case of Charlevoix Municipal Well, future costs also entail expected mitigation efforts under the US Army Corps of Engineers (USACE) projected costs by option. For this site, the analysis assumes the projected future costs under the USACE alternative site management plans are the most appropriate projected IC costs, even though they entail some degree of mitigation like soil excavation. Alternatively, Wickes Manufacturing produced no similar type of projected cost report on the most likely future site plans, and options outlined by third-party consultants did not establish the most likely minimum required mitigation plans for containing the plume under the existing IC. Accordingly, the projected future costs are forward projections of the annual recurring costs and omit consideration of likely minimal active mitigation efforts that may be realized as minimum required effort for mitigating exposure pathways.

IC Site	Key Feature	ICs Utilized	Super-fund	IC Year	Realized Cost	PV Expected Future Costs
K&L Avenue Landfill	Expansive; migratory; landfill	RCs, ordinance	Yes	1994	$5.27mil	$10.44mil
Hitachi Magnetics	Migratory; breach of IC	RCs, ordinance	No	1997	$3.87mil	$0.86mil
Wickes Manufacturing	Expansive; migratory; orphaned; threat to surface waters	RCs, ordinance	No	2005	$66.9mil	$6.06mil
Lincoln Brass Works	Municipal; Health effects; IC failure	RC	No	1996	$8.94mil	$0
Charlevoix Municipal Well	Multiple sources; Orphaned; Municipal Setting	Ordinance, sanitary code	Yes	1985	$24.7mil	$12.6-$15.5mil
Ford Kingsford	Municipal; home explosion; recreation center	RCs, ordinance	No	2005	$27.6mil	$30.7mil
Wash King	Dry cleaners	RC (called for but not implemented)	Yes	1984	$18.0mil	$1.47mil

Table 2: Costs of ICs at the study sites. All cost estimates in 2020 dollars and the PV Expected Future Costs are discounted to present values as of 2020.

One of the clear takeaways when reflecting on the present value of costs above is that the costs of ICs are generally underestimated. As an example, the technical analysis of the K&L Avenue Landfill site provided by Golder and Associates (2020) estimated that the 2020 public investment costs of implementing a passive IC-reliant approach would be $6.4 million, while this project estimated that cost to be $10.4 million. As discussed above, this project's cost estimates must be recognized as the lower bound of the expected private and social costs imposed by ICs, yet it exceeds those provided by the technical consultants. Furthermore, Golder and Associates estimated that a minimal remediation effort of ongoing pumping and treating the groundwater under the K&L Avenue Landfill would require a social investment of $61.5 million, or ten times their estimate of the costs of an IC solution. The results suggest that while the social costs of ICs are largely underestimated, our best projected costs of ICs are decidedly lower than the least costly remediation approach, resulting in excessive emphasis on ICs when the best cost estimates of ICs necessarily are limited to lower bound estimates.

The failure to be able to fully account for the actual social costs of an IC constitutes a potential market failure. Market failures are characterized as having unaccounted for costs or benefits to society called externalities. The externality these findings suggest is the failure to account for the true social cost of implementing an IC against other alternatives and may lead to less optimal social outcomes than if a true comparison can be made between implementing an IC or pursuing an active remediation plan. Additionally, underestimating the true social cost of an IC option may implicitly encourage entities to pollute, should the expected economic profits of groundwater polluting activities exceed the expected required costs, should the firm be allowed to implement an IC to control exposure pathways.

Similar findings arose with other sites reviewed in this report. MACTEC (2008) estimates for the implementation of a pump and treat system for the Wickes Manufacturing TCE Plume was $17.7 to $37.7 million, versus $2.6 to $5.6 million for an IC-driven response. This project's expected costs of indefinitely retaining the current IC are higher, at $6.1 million. Once again, the more aggressive IC cost estimates, though constituting a lower bound, are not high enough to advance the pump and treat option on economic cost grounds. For the Charlevoix Municipal Well, the cost differences were not as dramatic. The USACE Feasibility Study (2019) estimated the cost of an aggressive remediation plan to be $15.6 million, versus an IC-driven approach at $3.3 million (over 525 years). This project's lower-bound estimate of IC-related costs of $12.6 to $15.5 million makes the choice between simply preventing exposure as opposed to cleaning up a contamination less obvious from an economic perspective. Regardless, the relatively low-cost estimates for ICs at these case study sites highlight the challenge in motivating responsible parties to select active remediation options. If society is not comfortable with groundwater cleanup plans that take one-half of a millennium to complete, then it must make those options more expensive either through fees or other market-correcting measures. The *Recommendations* section below explores several such approaches.

An alternative to the transactional approach of measuring economic costs of groundwater contamination may be to establish a value on the underlying aquifer itself and ascertain how much society gains from that water. In this context, the cost of polluting that aquifer would be the loss of use of the water making up the aquifer. One such measure the team explored was to assess the value that the water subject to pollution at the Wickes Manufacturing TCE plume at the marginal contributions that water would generate if available for agricultural irrigation, where irrigated acres generate higher yields per acre than rain-fed acres. Using yield and irrigation data from MSU Extension (2014) and crop prices for corn and soybean from the Chicago Mercantile Exchange (CME Group 2024), the team estimated a range of crop value added at $1.88 to $3.59 per 1,000 gallons from groundwater (Table 3). In this context, the value of the 13 trillion gallons of water contaminated in the Wickes Manufacturing TCE plume ranges from $29 billion to $39 billion, eclipsing the realized cost for the site ($66.1 million) by multiple orders of magnitude. Despite the absence of irrigated farmland in this region, the approach establishes a thought experiment on the magnitude of the potential socio-economic value subject to loss through negligent groundwater management. A similar thought experiment could take the value of a gallon of water at the grocery store and extrapolate the potential opportunity cost. At $2 for a gallon jug, the cost of the Wickes Manufacturing TCE plume would explode to $26 trillion.

	Value (low-end)	Value (high-end)	Data source
Michigan Irrigation			
Corn yield (rain-fed) (bu./ac.)	120	130	MSU Extension (2014)
Corn yield (irrigated) (bu./ac.)	230	260	MSU Extension (2014)
Soybean yield (rain-fed) (bu./ac.)	35	45	MSU Extension (2014)
Soybean yield (irrigated) (bu./ac.)	65	75	MSU Extension (2014)
Groundwater use (gal./ac.)	135,771	162,926	MSU Extension (2014), based upon estimate of 5-6 inches of average annual irrigation depth
Inferred Value of Michigan Groundwater			
Historical corn price ($/bu.)	$8.50	$13.50	CME Group (2024)
Historical soybean price ($/bu.)	$3.25	$4.50	CME Group (2024)
Value added for corn ($/1,000 gallons)	$2.63	$3.59	(irrigated corn yield – rain-fed corn yield) * corn price * (1,000 / groundwater use)
Value added for soybean ($/1,000 gallons)	$1.88	$2.49	(irrigated soybean yield – rain-fed soybean yield) * soybean price * (1,000 / groundwater use)

Table 3: Inferred value of Michigan groundwater by analyzing irrigation yields.

While the economic cost estimates outlined in this report highlight the difficulty in determining the true economic costs of institutional controls, accounting for the transactional costs alone provides cost estimates that are subject to omission of relevant cost considerations. The thought experiments may provide more inclusive economic cost estimates, though along more abstract grounds. In total, there are unmeasured opportunity costs that could yield similarly elevated social cost estimates, such as water use for manufacturing, commercial opportunities, and residential development which can be anticipated but cannot lead to verifiable costs of the IC. For instance, contaminated groundwater can have negative effects on the environment with impacts on recreation and fisheries as well as on land and other aquatic organisms. Limiting socio-economic cost considerations to observable, transactional data may provide cost floors of ICs but affords a higher level of reliability on final estimates.

Decision Framework

The decision framework spreadsheet tool (see Appendix C for screenshots) is an effort to encapsulate the results and insights described above into a guide that could inform future evaluations of IC use in Michigan. The spreadsheet is structured in a question-and-answer format, walking users through the various components of costs related to responding to a groundwater contamination with an IC-driven approach, and estimates the long-term cost of relying on ICs in lieu of active remediation. Its intended audience is EGLE staff designing or providing input on groundwater remediation plans, perhaps as feedback on proposed remedial action or No Further Action plans under Part 201, though it could also be utilized by responsible parties evaluating response options. If those plans rely heavily on the use of ICs, the tool will allow EGLE to more thoroughly evaluate the long-term costs of such an approach than was done at the project's case study sites.

The user is initially presented with a pop-up window explaining the tool's purpose, followed by an *Introduction* tab that explains how to navigate the spreadsheet. The user then works through each of the spreadsheet's tabs (one for each cost category and others for results) by answering questions about the site to evaluate. The *Context* tab addresses the tool's limitations at the start, acknowledging that there are costs for not actively remediating pollution that are hard to quantify. The questions explore impacts to public trust, aesthetics, public health, and lost development opportunities. The *Background* and *Properties* tabs capture information about the scope of contamination, in terms of area, population, and time. *Water Access* gathers inputs on needs for bottled water delivery, municipal water connections, well abandonment, and new well drilling. *Monitoring* collects information about sampling all the pathways potentially affected by groundwater contamination, including drinking water, soil vapors, and surface waters. The *Institutional Controls* tab asks users to specify how many RCs and ordinances may be necessary to prevent exposures, while *Oversight* gathers information about staffing and reporting requirements. The *Surface Water* tab collects information about potential lost recreational opportunities.

The *Results* tab presents estimated categorical and total costs, a range of costs for various active remediation activities, along with a listing of warnings and notifications based upon the user's responses. For example, if the user specified on the *Context* tab that the affected area has a history of inadequate environmental management, then the *Results* tab includes an alert that the public would likely be skeptical of an IC-driven approach. That warning would be presented directly alongside the cost estimates, to ensure that such harder-to-quantify outcomes are not overlooked when considering the long-term costs of not actively remediating groundwater contamination. The *Charts* tab provides visual representations of some of the costs.

The *Cost Data Sources* tab lists the range of costs for each component utilized in spreadsheet's calculations and their associated sources (some from the case study sites, others from literature). Users can edit the values in this tab if better or more precise cost information for their study area is available. Updating the values on this tab will subsequently update the cost estimates and charts throughout the rest of the spreadsheet.

RECOMMENDATIONS

In reviewing the histories of these case study sites, evaluating the key decisions made regarding their remediation plans, and exploring their long-term costs, the project team drafted recommendations to address challenges associated with IC reliance. Those recommendations are listed below, organized by category, and include their respective rationales and relevant case study sites.

Primary Recommendation Category: *General*

1. To the maximum extent possible, stress to lawmakers, policy makers, and stakeholders that failing to remediate contamination transfers the responsibility and costs to future generations.

   Rationale: Not actively removing contaminants from groundwater carries long-term economic, social, and environmental costs. Preventing exposure should be the primary concern when responding to contamination, and ICs are an essential tool to do so. However, relying on them as the sole method of remediation creates opportunities for contaminants to migrate, causing a greater number of exposures and more natural resources impacted, and persist for decades if not hundreds of years, multiplying the costs across generations.

   Other Relevant Categories: Outreach

   Relevant Case Study Sites: All

2. Reinstitute annual site ranking for determining priority sites for remedial action.

   Rationale: EGLE's predecessor agencies established a system to prioritize agency action at sites of environmental contamination based primarily on the hazard the sites presented to human health and the environment. The ranking system under Act 307, established criteria informing the site evaluation process. Given that site remediation resources will not be sufficient to address the estimated 24,000 sites of contamination in Michigan, establishing a process to determine which sites should receive prioritized remedial actions should be considered. This process should be made public to increase the transparency of the department's decision-making process.

   Other Relevant Categories: Law/policy Changes

   Relevant Case Study Sites: All

3. Develop an aquifer ranking for prioritizing remedial actions for groundwater contamination.

Rationale: Though EGLE should promote the protection of groundwater throughout the state, there may be aquifers of greater significance as a source of drinking water perhaps as measured by the local population or characteristics of the aquifer. An aquifer's contribution to nearby wetlands and lakes and streams including sensitive species should also be considered. For such high-valued aquifers, IC-only responses to groundwater contamination could be prohibited, and active contaminant removal mandated.

Other Relevant Categories: Law/policy changes

Relevant Case Study Sites: All

Primary Recommendation Category: *Fees*

4. Consider establishing a user fee that would be required of any responsible party establishing any IC as part of a remedy. The fee could help defray the state costs associated with creating and maintaining the IC records in Environmental Mapper.

   Rationale: The suggested programmatic and data systems recommendations, if implemented, will require additional staff resources, technology and information system upgrades, and enhanced interaction with the public and local governments. Many existing ICs are not yet included in Environmental Mapper. The parties responsible for releasing hazardous substances as well as those who assume due care responsibilities should support EGLE's programmatic needs.

   Other Relevant Categories:

   Relevant Case Study Sites: All

5. Consider a natural resource damage assessment payment to the state for any responsible party that utilizes an IC on groundwater as a part of its remedy. This fee could be a function of the extent to which the responsible party implements remedial actions to remove source materials, reduce concentrations of the contamination in the aquifer, and restrict expansion of the plume.

   Rationale: Natural Resource Damage Assessments would enable more thorough and complete evaluations of the impacts to natural resources associated with a release of hazardous substances including the nature and scope of the impacts, the feasibility of recovery and restoration, and compensation for past and future natural resources damages that cannot be fully restored.

   Other Relevant Categories:

   Relevant Case Study Sites: All

Primary Recommendation Category: *Thoroughness*

6. Any party responsible for a site of environmental contamination should evaluate all exposure pathways to the best extent possible and address sources. Acknowledge uncertainties and potential costs regarding future identification of new contaminants, new exposure pathways, new toxicity information, etc.

   Rationale: At the Lincoln Brass Works and Charlevoix Municipal Well case study sites, vapor intrusion was not initially considered an exposure threat (Dames and Moore, 1996, Appendix D; Michigan Department of Natural Resources, 1993), though it proved to be one at both. At Ford Kingsford, the presence of the vapor threat was not realized until a home exploded. At the K&L Landfill, changes to 1,4 dioxane exposure criteria significantly expanded the plume footprint. For the case study sites in which evaluations of proposed remedial action plans were available, the potential for such outcomes were (in hindsight) not sufficiently considered. Future evaluations should more directly address the potential for these exacerbating contingencies some of which may be unknown toxicity, exposures, or contaminants.

   Other Relevant Categories:

   Relevant Case Study Sites: Charlevoix, K&L Landfill

7. Prioritize the investigation and identification of all source areas and removing or preventing those source areas from continuing to contaminate and migrate. Eliminate or change the current Part 201 definition of "source" or change it to reflect the following: to include locations where high concentrations of hazardous substances exist such as dense nonaqueous phase liquid (DNAPL), light nonaqueous phase liquids (LNAPL), or where other high soil concentrations of hazardous substances can continue to pollute groundwater.

   Rationale: Removal of a source area of contamination is the most cost-effective measure that can be undertaken. Removal of the source material reduces the potential for increasing groundwater contaminant concentrations and plume expansion. It also reduces the likelihood of transferring cleanup costs to the State, taxpayers, and future generations. The current Part 201 definition of "source" is "any storage, handling, distribution, or processing equipment from which the release originates and first enters the environment." Sources should not be limited *to containers and equipment* but must include areas where the contaminants have been released to the environment.

   Other Relevant Categories:

   Relevant Case Study Sites: Charlevoix, Ford/Kingsford, K&L Landfill, Wash King Laundry, Wickes

8. To identify all possible contaminant sources, the state should consider exercising enforcement discretion for identifying the locations of previously unidentified underground storage tanks or other sources. This offer could be limited to insolvent potentially responsible parties.

Rationale: For the Charlevoix Municipal Well case study site, underground storage tanks leaking PCE continued to be discovered after the sources were thought to have been contained. Knowing the location of all contaminant sources is essential for developing an effective remediation plan. The state could offer leniency regarding potential fines to responsible parties in exchange for disclosing the location of a previously unreported LUST. However, to avoid granting amnesty to large polluters or companies with adequate resources to pay fines and remediate the LUST, the state could limit such an offer of leniency to smaller-scale or insolvent companies.

Other Relevant Categories:

Relevant Case Study Sites: Charlevoix

9. During remedy selection processes EGLE should consider the possible future generation of hazardous conditions, such as explosive vapors (e.g., methane) from the biodegradation of organic materials (wood, charcoal, landfill content) in groundwater. Potentially affected properties should be eligible for free groundwater and soil vapor testing.

Rationale: For the first time, free well water testing was recently made available for Michigan residents who have private wells; however, as of September 14, 2023, the program is no longer accepting new requests for free testing. EPA rules that protect public drinking water systems do not apply to private household drinking water wells. EPA recommends the periodic testing of private wells for biological and chemical contaminants and identifies certain water quality indicators (WQIs), nitrates, and volatile organic compounds that are of concern[8].

Other Relevant Categories:

Relevant Case Study Sites: Ford Kingsford

10. The main body of the RC should clearly identify uses, activities and populations that are not allowed on the property (e.g., day cares and schools are not permitted). The updated RC forms have been significantly improved but could still be clearer in the restrictions. e.g., "The types of activities and uses NOT allowed include but are not limited to the following: daycares and schools for young children…"

Rationale: The RC registered for Lincoln Brass Works did not explicitly restrict activities that involve caring for children. Though the operators of the Head Start program said that they were unaware of the site's history of contamination or any restrictions on the property's use, had they been presented with the registered RC they still could have concluded that they were clear to start the program.

Other Relevant Categories: Transparency

8 https://www.cdc.gov/healthywater/drinking/private/wells/testing.html#:~:text=When%20to%20have%20your%20well,test%20for%20those%20as%20well

Relevant Case Study Sites: Lincoln Brass Works

11. If property owners are/would be unable to develop their property because clean drinking water is not available, this opportunity cost should be included when considering alternatives for remedial activities.

Rationale: For the evaluations of proposed remedial actions at both the K&L Landfill (Golder Associates Inc., 2020) and Wickes Manufacturing TCE Plume (MACTEC, 2008) sites, neither estimated the foregone development opportunities that could result under the option to primarily rely on ICs. Though such costs are hard to calculate because of the range of potential development scenarios (e.g., new residential, commercial, agricultural), they should be acknowledged and factored into the evaluation of remedial options.

Other Relevant Categories:

Relevant Case Study Sites: K&L Landfill, Wickes

12. ICs should be periodically reevaluated and if necessary, updated and/or revised to reflect the latest toxicological science, geological conditions, and migration of contaminants.

Rationale: The toxicological characteristics and potential health impacts of hazardous substances released into the environment may change over time. Similarly, new information regarding exposure pathways and the characteristics of migrating plumes may change based upon new sampling data and information regarding hydrogeological conditions.

Other Relevant Categories:

Relevant Case Study Sites: All

Primary Recommendation Category: *Documentation/Transparency*

13. More strongly enforce the Sellers Disclosure Act, Act 92 of 1993. Require landowners with knowledge of existing contamination, institutional controls, or restrictive covenants to notify EGLE, local government, and prospective new purchasers/lessees of the contamination/RCs/ICs. Include such information in title searches for mortgages.

Rationale: It is sometimes difficult to determine if there is an IC associated with a property. Information regarding ICs should be more accessible to realtors, title companies, prospective property purchasers, local officials, and the public. For the Lincoln Brass Works case study site there is evidence that the existence of the RC for the property and its use restrictions was not made clear during the property's transfers of ownership (Meeting Minutes of Project Update for EGLE staff, 2022). The operator of the Head Start program and the property owner in 2016 were unaware of the prior contamination and the use restrictions for the property, resulting in the exposure of children to TCE vapors.

Other Relevant Categories: Law/policy changes

Relevant Case Study Sites: Lincoln Brass Works

14. Require all ICs and RCs be submitted to the department and made available to the public in Environmental Mapper.

Rationale: Environmental Mapper is the primary resource available to the public to identify the locations of sites of environmental contamination along with their ICs and use restrictions. For individuals to make informed decisions about local risks, it is essential that the information in Environmental Mapper is accurate, complete, and up to date. For example, the documentation and boundaries of the groundwater ordinances for the Ford Kingsford site are not available in Environmental Mapper.

Other Relevant Categories:

Relevant Case Study Sites: Ford Kingsford

15. For each site, a standard form that concisely documents which exposure pathways have criteria exceedances and how those pathways are to be addressed, should be part of the administrative record. This form should be updated as needed when new information becomes available, or when clean-up criteria changes. Such a form would help ensure quality control in decision making and establish a clearer administrative record.

Rationale: Templates for exposure pathway evaluations exist[9,10], but in the review of records for this project's case study sites, no completed versions were found. A standard and consistently utilized form would help ensure quality control in decision making and establish a clearer administrative record.

Other Relevant Categories: Outreach

Relevant Case Study Sites: All

[9] Land Use Based Response Activity Approval and Tracking Form (revision 1/2023)
[10] https://www.michigan.gov/egle/-/media/Project/Websites/egle/Documents/Forms/RRD/EQP4469-Leaking-Underground-Storage-Tank-Site-Classification-Form.pdf?rev=db326edce71645a1adb4709d88bec95c&hash=65D752B6EB53801731517BD0B96DD74E

16. EGLE should receive copies of all RCs and ICs recorded under Part 201 and Part 213. Additionally, EGLE should have more staffing dedicated to tracking the status of pending RCs and ICs.

    Rationale: Part 201 requires EGLE to be notified within 30 days of the recording of an RC but does not require a copy of the RC. This limits EGLE's ability to upload RCs and other restrictions into Environmental Mapper, which makes it harder for the public to know the history of use restrictions for properties. Part 213 only requires that the RC be recorded within 30 days of the final assessment (does not require notice of the RC or a copy of it be sent to EGLE).

    Other Relevant Categories: Staffin

    Relevant Case Study Sites: All

17. Parties wishing to conduct self-implemented remedies should be required to submit a report to EGLE detailing the proposed response activity, providing EGLE with time to evaluate and comment on the plan. If those response activities include an RC, that RC should be provided to the department.

    Rationale: At the Wickes Manufacturing TCE Plume site, the owner of the property demolished the plant in 2011 without EGLE oversight because the statute allows parties to conduct voluntary work. Given the scope of that plume and EGLE's role in coordinating the response, EGLE should have a role in reviewing and advising activities that could affect the contamination.

    Other Relevant Categories: Law/policy Changes

    Relevant Case Study Sites: Wickes

18. There is a need for statewide requirements for how groundwater data are collected and formatted so that it can easily be used in building the Michigan Hydrologic Framework.

    Rationale: A standardized and accessible groundwater database will make it easier to monitor groundwater quality across contaminated sites, and better evaluate land for sale, development, and conservation. However, such a tool will only be useful if the data stored in it is gathered and submitted in a consistent manner.

    Other Relevant Categories:

    Relevant Case Study Sites: All

19. EGLE should require appropriate terminology in submitted reports, such as "relevant pathway" and "applicable criteria." The department needs to hold consultants to the same language and terminology to which they hold staff; otherwise, confusion can result when analyzing the administrative record.

Rationale: Some consulting firms tend to refer to a pathway as not being "complete" if there is no current opportunity for exposure via that pathway. For example, groundwater may exceed the residential criteria for drinking water, but there are no drinking water wells on the property, so they might say it is an incomplete exposure pathway. The problem is that the terminology can be misleading and imply nothing needs to be done about it. However, since the criteria are exceeded, then the pathway needs to be considered as relevant, terminology that triggers an assessment of what type of response activity is necessary to ensure exposures do not occur in the future as property uses may change, potentially just a use restriction. Just because a pathway is not currently "complete" does not mean it will continue to be incomplete unless some action is taken. When complex sites involving multiple locations and exposure pathways are being considered it is important to be precise in the use of terms to avoid overlooking potential problems.

Other Relevant Categories: Outreach

Relevant Case Study Sites: Lincoln Brass Works

<u>Primary Recommendation Category: *Expediency*</u>

20. Decisions regarding remedial actions for the leading edge of a plume should be approached with a sense of urgency. Plume expansion should be avoided whenever possible.

Rationale: For the K&L Landfill, eleven years transpired between the discovery of the contamination and EPA's issuing of the initial record of decision (1990). EPA was aware the plume was expanding in 1990 (US EPA, 1990).

Other Relevant Categories:

Relevant Case Study Sites: K&L Landfill

21. To prevent contaminant exposures resulting from delayed implementation of RCs or groundwater ordinances, the state should explore means for expediting the implementation of such ICs.

Rationale: At the Ford Kingsford site ten years passed between the home explosion and the registration of the first RCs for the source properties, and sixteen years for the township ordinances. At Wash King Laundry RCs were called for but never implemented. Though exposure pathways may not be complete (e.g., municipal water already prevents drinking water exposure, or hydrogeologic conditions prevent vapor intrusion) implementing measures to prevent the disturbances of contaminated media that could threaten those pathways should not be delayed.

Other Relevant Categories: Law/policy changes

Relevant Case Study Sites: Ford Kingsford, Wash King

22. Do not wait for the transfer of ownership to implement an RC for a contaminated property. Either grant EGLE the authority to record RCs on contaminated properties or amend the statute to require non-responsible property owners to record RCs on their property as part of their due-care obligations.

Rationale: Both the Hitachi Magnetics and Wickes Manufacturing TCE Plume sites contain properties that likely should have RCs on them but do not. For Wickes, the contaminant source areas do not have RCs, neither do farm fields to which the Hitachi Magnetics plume has expanded or will likely expand. The EGLE project manager for Hitachi Magnetics has indicated that an RC is needed for those unrestricted properties (Wierzbicki, 2022). The lack of such restrictions increases the likelihood of exposure.

Other Relevant Categories: Law/policy Changes

Relevant Case Study Sites: Hitachi Magnetics, Wickes

Primary Recommendation Category: *Outreach*

23. A one-call system like Michigan's 811 program (MISS Dig) should be developed to include all sites with use restrictions due to soil or groundwater contamination.

Rationale: The MISS DIG model is a highly effective and user friendly statewide underground utility safety notification system operating as a free service. Determine whether EGLE's IT Modernization capabilities could create a low-cost, efficient, accessible system. Some states have created similar environmental contamination one-call systems.

Other Relevant Categories: Transparency

Relevant Case Study Sites: Hitachi Magnetics

24. Advance groundwater awareness of the public at large through innovative information and visualization tools to incorporate conservation and environmental protection into personal, business, school, and institutional practices. Actively promote Environmental Mapper to the broader public.

Rationale: Approximately 44 percent of Michigan's population is dependent upon groundwater for its water supply, yet comparatively few members of the public are aware of the extent of groundwater use, the vulnerability of groundwater to biological and chemical contaminants, and the importance of environmental stewardship. An educational campaign should be considered to fill this informational gap.

Other Relevant Categories:

Relevant Case Study Sites: All

25. Enhance the capabilities of Environmental Mapper and RIDE to discern the extent to which low income, tribal, and communities of color are disproportionately affected by proximity to sites of environmental contamination and the potential for increased exposure to environmental hazards.

Rationale: Advancing environmental justice is a high priority for states and the federal government. EPA has committed to enhance its mapping capabilities to identify communities having higher risks of unacceptable exposure to hazardous substances and prioritize remedial actions enforcement efforts to mitigate risks to human health[11].

Other Relevant Categories:

Relevant Case Study Sites: Lincoln Brass Works

Primary Recommendation Category: *New Technology*

26. Green energy, such as solar, should routinely be included as a power source when long-term remedial alternatives are considered.

Rationale: Consistent with the MI Healthy Climate Plan and state and national efforts to accelerate the transition to clean energy resources, opportunities to use renewable energy to power remedial actions should be taken advantage of. Operation of groundwater cleanup systems can require long term energy consumption. Such energy demands have been cited as a reason not to pursue aggressive cleanup. Use of green energy may make such choices more feasible.

Other Relevant Categories:

Relevant Case Study Sites: All

27. Consider integrating the Michigan Environmental Mapper and RIDE systems as part of the Modern IT Strategy and expand the resources available to help ensure that information regarding known sites of groundwater contamination is more readily available and existing ICs used to prevent unacceptable exposures are maintained.

Rationale: Multiple benefits can be derived from data system integration efforts including addressing compartmentalized data and eliminating data silos, improving access to data, identifying, and removing erroneous and redundant data, and generally improving the quality and integrity of EGLE's program data.

[11] https://www.epa.gov/system/files/documents/2021-07/strengtheningenvirjustice-cleanupenfaction070121.pdf

Other Relevant Categories: Documentation and Transparency

Relevant Case Study Sites: All

Primary Recommendation Category: *Law/policy Changes*

28. The definitions of the terms “owner” and “operator” should be amended to state:
   a. "Owner" means a person who presently owns a facility or owned the facility at the time the release of a hazardous substance occurred.
   b. "Operator" means a person who is in control of or responsible for the operation of a facility or operated the facility at the time the release of a hazardous substance occurred.

Rationale: The current definitions of "Owner" means a person who owns a facility, and the definition of "Operator" means a person who is in control of or responsible for the operation of a facility. The current definitions conflict with MCL 324.20126(1) as they do not include persons who were past owners or operators at the time that a release of hazardous substances occurred. On information, EGLE has been confronted with situations where responsible owners or operators transferred the properties and maintained they were no longer responsible for the release because they were no longer owners or operators.

Other Relevant Categories:

Relevant Case Study Sites: All

CONCLUSIONS / NEXT STEPS

This project sought to explore the consequences of employing land use restrictions to control human exposures to groundwater contaminated with hazardous substances in lieu of aggressive groundwater restoration. To do so, the project team from MSU and FLOW studied seven case study sites in Michigan and evaluated the economic costs of relying on ICs in response to groundwater contamination. The seven sites were a diverse sample, varying in region, exposure pathways, data availability, contaminants, presence of a viable responsible party, and scope. The sample was too small to reflect all the conditions and nuances across the more than 3,500 sites in Michigan in which ICs have been utilized. However, it still provided a rich opportunity to start exploring what can happen when groundwater contamination is not actively remediated.

The effort to account for all socio-economic costs of the seven selected sights was extensive, but incomplete in the final assessment. The extent of costs unaccounted for in the estimates is unknowable. However, we believe the measures of economic costs are objective in their estimates and represent most past and future costs that can be attributed to the choice of relying on the IC as the primary approach for mitigating pathways of exposure for these seven sites. The experience of generating these estimates highlights a myriad of challenges to making such estimates that included lack of consistency of cost types across sites, different degrees of recording site costs by affected and responsible parties, and lack of clearly established rules for what costs should and should not be attributed to the IC. One cost category was consistently absent from each of the sites reviewed: the costs for undertaking technical assessments, often by third-party consultants, were rarely recorded in site documents. Where site-specific costs were not available, cost estimates from other sites or sources were imputed based on the level of activity, resulting in a more robust cost estimate for the IC than would be available using site documentation alone. Other sources used for estimating costs included those reported at other IC sites in the study, other EPA/EGLE/USACE site documents, and through other published materials.

While the socio-economic cost estimates generated in this report provide sound, yet conservative, baselines for the expected cost of these ICs, they fail to be generalizable in the aggregate across other ICs in the state. This is because each site reviewed was unique enough in detail to not be representative of all other IC sites in the state. However, the unit cost estimates for common costs of managing a plume under an IC are generalizable and useful in the development of a decision support system discussed below.

Though the project's small sample size precluded the development of a generalizable formula for long-term IC costs, the team utilized the insights gained in studying costs at the case study sites to develop a framework for evaluating those costs at other sites. The decision framework spreadsheet tool is an accessible, user-friendly tool that helps users estimate long-term costs on IC reliance, drawing on costs observed at the case study sites and drawn from literature. It also helps users consider the hard-to-quantify costs and impacts of not cleaning up contamination, such as damage to public trust, environmental justice, and impacts to wildlife.

The in-depth analysis of the case study sites also helped the team identify areas where operations and policies could be improved to avoid some of the issues and complications that arose over the course of the response to each contamination. ICs are still an important component in protecting Michiganders from contamination, but the list of recommendations included in this report provide a starting point for strategizing how the use of ICs in Michigan could be improved. That list includes recommendations to improve public awareness of the existence of ICs, how user fees could offset some of the costs inherent to a more robust state program for monitoring and oversight, and how evaluations of proposed remedial actions can better account for potential long-term costs.

There are several avenues that should be considered in continuation of this project's effort. The first is a broadening of the case study site sample to include additional locations and scenarios in which ICs were utilized. This study's sample included only one site from Michigan's Upper Peninsula, and only one from Michigan's large cities. A subsequent study should further explore the experience of IC reliance in rural and urban settings. This study's sample did not include a gas station with a LUST, where ICs have been frequently used on the thousands of LUST sites in Michigan. Further evaluations of long-term costs of IC usage should include multiple LUST sites and explore how well the policies of Part 213 functioned in protecting the public from exposure. Furthermore, because this project tended to focus on exploring large, complex, and problematic sites of contamination, subsequent studies should evaluate more sites that are smaller in scope, and sites where ICs functioned as expected with little complication.

In addition to broadening the sample size and allowing for a better representation of typical IC-related sites in Michigan, future efforts should build upon the localized costs calculated in this project by incorporating ecological economics and political science into the analysis. Insights from these fields could allow for better estimates of the broader societal costs incurred by ceding large portions of groundwater to decades-long courses of natural attenuation. How do decisions to utilize ICs in lieu of active remediation affect ecological function? What is the economic value of that function to society, to the environment, now and into the future? What is the effect of the erosion of public trust within a community when members feel that the government and the market are not adequately protecting their shared natural resources? What is the cumulative effect of that erosion state-wide? Evaluating the costs and policies around the use of ICs is just one component of addressing these broader questions.

One of the reasons for the widespread contamination of groundwater is that its intrinsic values and economic importance to future generations are not easily quantifiable yet are significant and must be considered. Indeed, as water scarcity elsewhere worsens and as the country's population grows, groundwater will be in ever greater demand. To the extent that ICs foreclose the use of groundwater resources for decades, or even centuries, they impose a meaningful economic burden on Michigan for generations to come. This study, then, should not be interpreted as the definitive answer to the question of the cost of ICs. Rather, as economic methods become more sophisticated and capture the true cost of restricting groundwater use, the cost estimates presented herein will increase significantly.

References in Appendix L

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APPENDIX A: CASE STUDY SITE MAP

APPENDIX B: ECONOMIC ANALYSIS METHODS LITERATURE REVIEW

ACM establishes several channels of groundwater contamination damage entail both transactional and non-transactional costs, including (Abdalla Charles W., 1994; Easter and Konishi, 2006):

1. **Avoidance cost**: groundwater contamination leads to public and private avoidance costs, where expenditures are made for monitoring, filtering, and otherwise circumventing groundwater exposure, including municipal water hookups.
2. **Property value loss:** losses in property value can also be categorized as avoidance costs, as current and potential buyers use the bidding process to vacate or acquire land subject to institutional control. If ICs make properties less desirable, this will be reflected in a reduction in the market value of the property.
3. **Ecological damage and loss of recreational use**: realized damages to the environment are often limited to contaminants' imposition on human use or enjoyment of the natural resources damaged, including loss of recreational value. But other benefits like productive capacity for agriculture and forestry, effective water cycling, and extractive resource production can also be hindered by groundwater contamination.
4. **Human health costs:** prolonged exposure to contaminants can result in chronic illnesses and result in morbidity losses, including healthcare costs.
5. **Impairment of nonuse values**: all natural resources have inherent value rather used or not. Such value entails future option values and bequests value.

Exposure Avoidance Costs

Household avoidance costs may include connecting to municipal water systems, use of bottled water, or application of local or household water filters, to name a few. One 1990 estimate at a Pennsylvania community with contaminated water supply put household avoidance costs between $318 and $652 in today's dollars (Abdalla Charles W, 1990; Abdalla Charles W., 1994; Abdalla Charles W. et al., 1992). Using a contingent valuation approach to determine willingness to pay, (Powell, 1991) showed that awareness of groundwater contamination increased willingness to pay for avoidance by less than $100 (2022 prices) per year. However, being contingence estimates, the willingness to pay estimates are derived based on hypothetical occurrence of groundwater contamination rather than reveal by actual avoidance expenditures. A more thorough review of empirical estimates of cost avoidance indicated that household avoidance costs range from $323 to $853 (2020 prices) per year (Abdalla Charles W., 1994).

Households can also avoid contaminated well water by re-drilling their well, usually to a greater depth, if the contamination can be restrained at higher-elevated aquafers. This incurs two costs: the costs of abandoning the current well and the cost of drilling a new deeper well, where the prior entails securing the prior well and capping it. Home and DIY advice web pages suggest that the costs of drilling a new well ranges between $1,500 and $15,300, with a median of $8,500 (HomeAdvisor, 2022; HomeGuide, 2022). These estimates may be on the conservative side as they do not represent the expected costs of drilling deeper wells that may be necessary in the presence of a plume. Alternatively, the expected costs of capping and abandoning an existing well is $1,150 (City of Madison, 2022).

Municipal water treatment systems from well water also engage in cost avoidance in the presence of groundwater contamination. Municipal systems may select the cost-minimizing alternative between sourcing new water sources or investing in the capital and operational capacity to filter the contaminants (Abdalla Charles W., 1994). Where municipal water systems depend on contaminated sources of water, additional treatment is required. Nielson and Lee estimated the cost of removing pesticides from municipal water sources, indicating that the per household cost span from $861 (2020 prices) for small municipal systems serving 5,000 households to $173 for systems serving 500,000 households (Nielsen and Lee, 1987).

It is common for properties with contaminated well-water to be connected to municipal systems, at the government's or the responsible party's expense. This is an avoidance effort. Connection to municipal water systems requires significant initial investment costs but reduces the annual operating costs relative to providing bottled water and may be comparable to installing and maintaining whole-house water filtration systems. In 1987 the City of Barton, WI connected 41 houses with contaminated well-water to municipal water at an average cost of $21,800 in 2022 prices (Page and Rabinowitz, 1993).

Property Value Losses

When 41 homes in Barton, WI required connection to the local municipal water system at the government's expense, there was no discernable impact on the property values (Page and Rabinowitz, 1993). Assessing eleven groundwater contamination sites in Wisconsin, Rabinowitz and Page (1995) show that groundwater restrictions due to contamination has little to no impact on property values for residential uses. However, others show that an IC will reduce developer interest in developing virgin or agricultural property into residential housing (Mercer and Morgan, 1982). It also has significant bearing on property values for non-residential uses, as commercial and industrial buyers fear the transference of liability from the original property owner to the new (Page and Rabinowitz, 1993). A study across five communities in Minnesota determined that losses in commercial property values and commercial property development due to groundwater contamination resulted in a loss of $20.7 million (2022 prices) in property tax revenues (Freshwater Foundation, 1989; Page and Rabinowitz, 1993). In addition to properties directly impacted by the groundwater contamination, periphery properties may also experience property value losses due to stigma effects from proximity to an environmental toxic site (McCluskey and Rausser, 2003; Messer et al., 2006).

The findings favor that residential property values are not impacted by the presence of groundwater contamination (Dotzour, 1997; Guignet, 2013; Malone and Barrows, 1990; Page and Rabinowitz, 1993). However, more recent studies employing more sophisticated estimation techniques have shown some evidence of a negative impact on residential housing values. Case et al. (2006) tracked properties over multiple sales to determine that groundwater contamination initially reduces the selling prices of residential condominiums by 4.7 percent. Recognizing that public memory is limited, time may reverse any negative consequences of the initial public announcement of contamination. Boyle et al. (2010) shows that groundwater contamination may negatively affect the price of residential real estate, but that effect fades over time (Kiel, 1995). Others show no effect even before and after site remediation (Guignet, 2013). That is, when the contaminant is made public, potential buyers and sellers will bid down the property value, but as memory of that contaminant fades, the price will return to parity with equitable properties. In the long-run, property values are not impacted.

It seems relevant that there are limitations to the findings of no long-run residential property value impacts. Most importantly, access to water is a minimum requirement for a property to be in residential use. If a groundwater plume contaminates a property's groundwater and it is not feasible to drill a deeper well and/or connect to a municipal water system, then that property will likely cease being viable for residential use. Accordingly, the residential value of that property would approach zero. We have not seen such cases play out, though the case is plausible. Another limitation is that the current literature has focused on the impact of groundwater pollution on property values in the aggregate, while there may be two categories of routes of exposure, through use of groundwater and through vapor intrusion, should vapor intrusion be of concern. Hence, separating the effects is not possible and because vapor intrusion does not exist for all groundwater contamination sites, and because research reports do not note the presence or absence of vapor intrusion, it is that existing estimates do not consider vapor intrusion impacts. Accordingly, there is not enough research to assign the impact on residential property values of groundwater-sourced vapor intrusion.

Unrealized loss of value: farmland not developed. Where plumes occur near urban centers, extension of a municipal water system can be relatively cost effective to allow development for residential uses.

Ecological Damages and Loss of Recreational Use
A new branch of economics for valuing environmental resources, called ecological economics, views natural resources as a chain of ecological benefits affording value to human consumption. In this view, value is still attributed to direct or indirect human consumption of the environmental amenities or resources, but it does recognize the chain of benefits which gives rise to values humans receive. That is, there is a non-use value to uncontaminated natural resources that often goes unmeasured in the absence of a transaction by which the benefits can be measured. For example, the source of ecological benefits may be cool freshwater streams, which support fish hatchlings and food web support that can be linked to human benefit through recreational and commercial fishing.

Non-use benefits of uncontaminated groundwater may not be realized until well into the future. The eventual degradation of the food web may erode wildlife habitat in ways that are difficult to predict. This may have adverse effects on amenities in the surrounding region, should the ecological damage impact natural resource amenities in the area. Natural resource amenities contribute to regional economic development and growth (Green, 2001), and any obstruction of those amenities can have long-term consequences that are difficult to account for.

Cost-benefit analysis often leads to an under-estimation of non-use benefits of groundwater. While objective measures of non-use benefits of groundwater are rare, case-studies indicate that the overall value attributed to protecting groundwater is highly dependent on the value attributed to non-uses (Görlach and Interwies, 2003).

Human Health Costs
Cost of illness approach accounts for the transactional health-related costs, such as treatment, and lost employment, and morbidity, but often fails to account for non-transactional costs like degradation of quality-of-life measures from exposure to harmful contaminants (Smith and Desvousges, 1986). Therefore, cost of illness approaches underestimates the true health associated costs.

Impairment of Non-use Values
A final source of economic loss is more abstract than those above but represents real losses in economic value. Impairment of nonuse values entails the loss of social value attributed to the existence of a natural state if such values are precluded by the presence of contaminants. Nonuse values, sometimes called bequest and existence values, are difficult to measure because the value the property's natural state of existence bestows is not clearly discernable to stakeholders (Dunford, 2000; Lazo et al., 1992). Studies attempting to quantify nonuse values of natural resources are limited to resources with pervasive human regard, like the Colorado River in light of the amenities it has generated over millennia (Dunford, 2000), or the non-use value placed on America's bald eagle, of which collective conscious of value may be attributed to well-ingrained national price (Boyle and Bishop, 1987). Economic measures of groundwater contamination of nonuse values remain elusive (Mendelsohn and Olmstead, 2009).

APPENDIX C: DECISION FRAMEWORK SPREADSHEET TOOL SCREENSHOTS

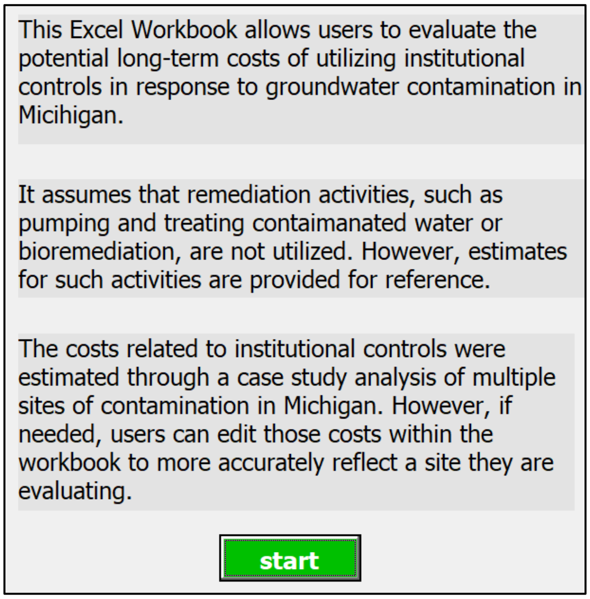

Figure 1: The starting pop-up screen presented to the user.

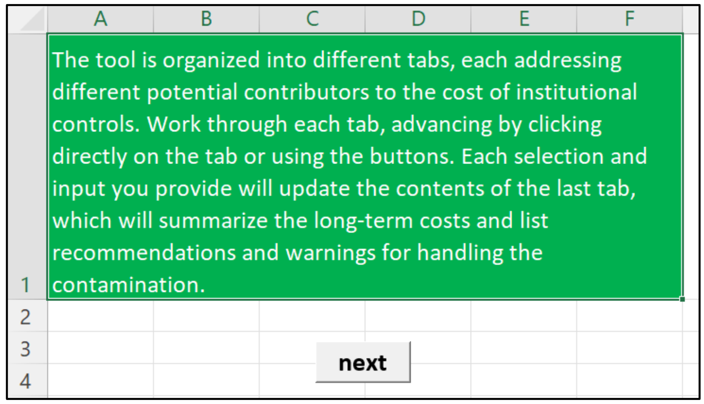

Figure 2: Initial guidance on how to navigate the tool.

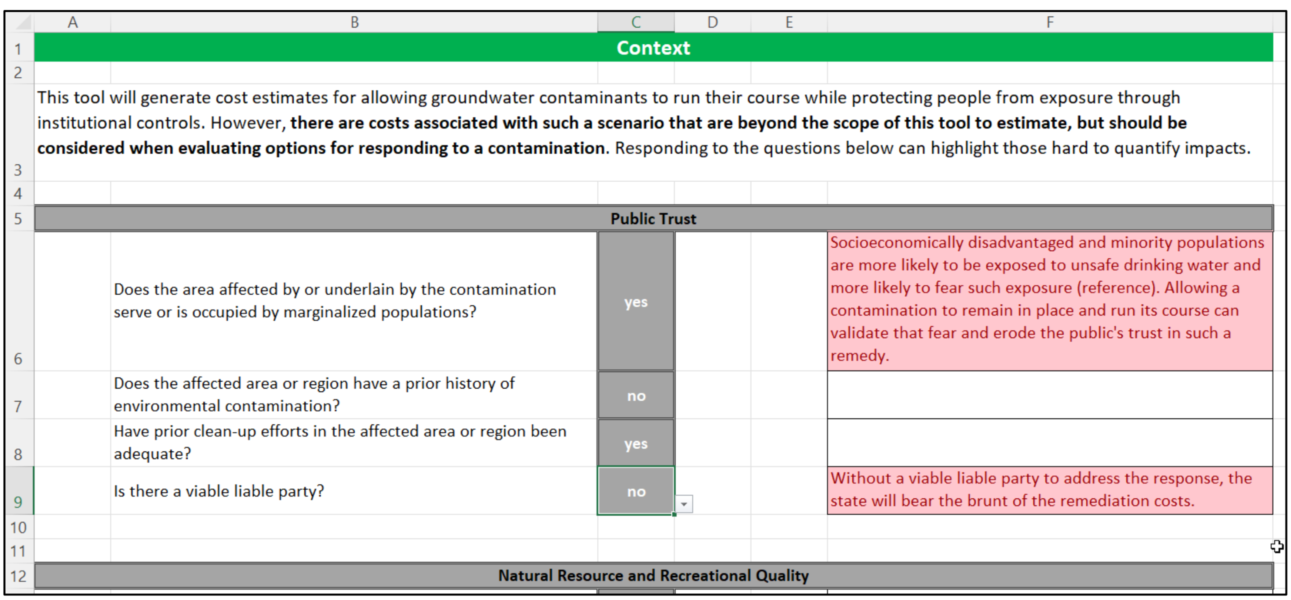

Figure **3**: The Context tab explores costs that cannot be easily quantified but should be considered.

#	Background: Inputs			Notes
1	How large is the affected area?	5	*square miles*	
2	Is the contaminant source contained?	yes		
3	How would you characterize the dominant geologic class of the affected aquifer?	sand and gravel		Sand and gravel are highly conductive media for groundwater. Plumes can migrate quickly through such an aquifer, and warrant close monitoring and a timely remedial response.
4	Could the concentration of the contaminant in the aquifer increase in the future?	yes		An increase in the concentration of the contaminant may cause additional exposure pathways (e.g. vapor instrusion, soil direct contact, groundwater-surface water interface) to exceed safe thresholds.
5	Do you anticipate the contaminant plume expanding into the future?	yes		An expansion of the plume may cause additional exposure pathways (e.g. vapor instrusion, soil direct contact, groundwater-surface water interface) to exceed safe thresholds. To explore the costs of an expanded plume adjust your inputs of area, properties, population, and time horizon accordingly.
6	What is the time horizon for this analysis?	30	*years*	
		next		

Figure **4**: The Background tab gathers information about the size of the affected area and duration of the contamination.

#	Properties: Inputs		Notes	
1	How many residential properties are currently affected?	150		
2	How many commercial properties are currently affected?	10	*160*	total properties
3	How many acres of undeveloped land may be affected?	25		
4	How many acres of public land / parks may be affected?	10		
5	What is the population of the affected area?	900		
	next			

Figure **5**: The Properties tab captures information about affected homes and population.

#	Water Access: Inputs			Notes	Total Costs	
1	What percentage of currently affected properties require well abandonment?	50	%		min	**$2,357,928**
					expected	**$4,271,244**
2	What percentage of currently affected properties require bottled water delivery?	50	%		max	**$6,743,641**
3	For how long?	6	*months*			
4	What percentage of currently affected properties require new connections to municipal water supply?	75	%		jump to results	
5a	Are new water mains needed?	yes				
5b	If yes, estimate a total length of the new mains	2,000	*feet*			
	next					

Figure **6**: The Water Access tab is one of several that starts to tabulate the estimated total cost.

Warnings

Socioeconomically disadvantaged and minority populations are more likely to be exposed to unsafe drinking water and more likely to fear such exposure (reference). Allowing a contamination to remain in place and run its course can validate that fear and erode the public's trust in such a remedy.

Without a viable liable party to address the response, the state will bear the brunt of the remediation costs.

Costs

item	min	expected	max			
Water Access						
Well abandonment	$61,128	$101,244	$305,641			
Bottled water	$9,600	$16,800	$16,800	*over*	*6*	*mo*
Municipal water connections	$1,440,000	$2,091,000	$2,460,000			
New water bills	$403,200	$1,618,200	$3,517,200			
Water main installations	$444,000	$444,000	$444,000	*over*	*2,000*	*line*
water access totals	**$2,357,928**	**$4,271,244**	**$6,743,641**			
Monitoring						
Monitoring well installation	$416,600	$2,285,000	$3,786,550			

Figure **7**: The Results tab presents cost breakdowns for each category, presented alongside the outputs from the Context tab.

TOTAL COSTS	**$9,841,718**	**$14,848,485**	**$19,891,819**			
Other Remedial Activities						
Pump and treat	$10,375,822	$36,691,528	$55,087,405	*over*	*30*	*years*
Permeable Reactive Barrier	$643,009	$993,741	$1,461,383			
Hydraulic control	$2,132,462	$6,921,890	$11,711,317			
In-situ chemical oxidation	$12,166,922	$12,166,922	$12,166,922			
In-situ thermal remediation	$17,206,689	$17,206,689	$17,206,689			

Figure **8**: Total Costs for the IC-driven response are presented with estimates for other remedial activities.

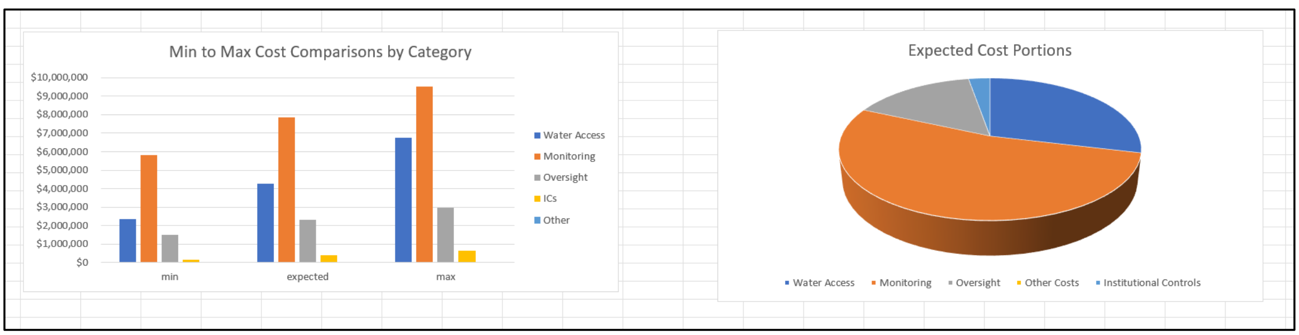

Figure **9**: Cost comparisons are also presented in chart format.

APPENDIX D: CHARLEVOIX MUNICIPAL WELL SITE SUMMARY

Location	Lakeshore Dr, Charlevoix, MI, 49720
EGLE district / contact	Nicolas Dawson: dawsonn1@michigan.gov; 517-897-0912
EGLE site summary? (link)	Not on the web.
EPA Superfund? (link)	https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0503013
EPA contact	Matthew Ohl : 312-886-4442
Contaminants	Primarily tetrachloroethylene and trichloroethylene in groundwater, soil vapor, and soil.
Exposure pathways	Primarily drinking water early on and vapor intrusion more recently.
Background	-In 1981, the City of Charlevoix was notified by the MI Dept. of Public Health that its groundwater was contaminated with high concentrations of TCE that were impacting the municipal water supply. The city installed 4 new monitoring wells near the municipal well and discovered that a portion of an adjacent PCE plume was overlapping the TCE plume. EPA began its RI in 1983. The 1984 interim ROD selected a remedy to address the TCE plume which was a new water intake into Lake MI and a new filtration water treatment plant. In 1985, EPA constructed the system (the selected remedy). A new water intake structure was constructed in 1992 due to capacity issues. -A final ROD in 1985 selected a remedy which focused on minimizing the risk of exposure to contaminated groundwater. It consisted of the following components: allowing the plumes to discharge naturally into Lake MI (a 50-year estimate for the groundwater to purge); long term monitoring of the plumes; and restrictions on the installation of private wells in the contaminated groundwater enforced by local health officials through an existing permitting program. -January 1986, the PCE plume was identified as the Charlevoix Municipal Well Field (**PCE**) state site. The State completed an RI report August 1989 identifying 3 source areas. -EPA delisted the TCE Charlevoix site from the NPL in December 1993. -Beginning in 1994, state funds were used to install and operate soil vapor extraction (**SVE**) (at Arts Drycleaners, Impac Tool Co., & Hooker's Drycleaners) and air sparge (**AS**) systems (at Hooker's Drycleaners & Impac Tool Co.) at 3 PCE sites. Two systems operated for one year and one system operated for 6 years. All systems were decommissioned, and annual groundwater (**GW**) monitoring has occurred since 1996. The purpose of AS and SVE was to reduce contaminant levels in GW, so they were no longer a threat to surface water resources (per EGLE site summary). -In 2006, while reviewing the site for potential designation as "ready for use", EPA became aware that the site had GW concentrations higher than those considered safe for unrestricted use and determined that another FYR should be conducted. The Third FYR was signed in 2011 and

	determined that PCE GW and soil contamination could pose a vapor intrusion risk and that further investigation is warranted. -Vapor studies were conducted by EPA in 2012 and 2013. Sample concentrations from the sub-slab and soil gas points indicated exceedances above indoor air risks. Additional sampling was planned for indoor air and sub-slab points at the 3 source areas and was completed in March 2014. Results showed immediate risk to human health and the environment. Further investigations resulted in the installation of sub-slab depressurization systems at two residences. The investigation continued through early 2015. -EPA ERB continued their vapor intrusion (VI) investigation through September 2015. 16 sub-slab depressurization systems were installed at buildings where contaminant levels exceeded VI screening levels in 2014-15. EPA & EGLE continued the VI investigations until Spring 2016. -Three orphaned underground storage tanks (USTs) were discovered in November 2013 near Art's Dry Cleaners. . One near Arts Dry Cleaners had high levels of drycleaning constituents. -Another round of groundwater sampling was conducted in Fall 2012 by EGLE: results indicated that the TCE GW plume had discharged to Lake MI and no longer exceeded drinking water standards (DWS). PCE groundwater levels still exceeded DWS and further monitoring is necessary. -September 2014, EPA approved a time critical removal action to mitigate the threat of VI into residential and commercial structures: additional sampling to identify the extent of waste and contaminated soil for removal and off-site disposal, delineation of soil gas impacts, and VI assessment activities in buildings. -In November 2014, three more USTs were discovered at the former Art's drycleaning facility. Tanks had high levels of drycleaning constituents; the tanks were cleaned out and filled. No contamination was detected in soil below the tanks. -EPA signed the Fourth FYR in April 2016. Another round of GW sampling in 2016 confirmed earlier GW sampling. TCE below DWS but PCE is not, and further monitoring is necessary. -EPA completed RI/FS field activities in October 2017: no increase in TCE or PCE GW concentrations with continued monitoring again deemed necessary. -A VI investigation of downtown Charlevoix was completed April 2018. Detections were reported but not elevated and warrant further investigation. Groundwater sampling completed in October 2018 showed no increase in concentrations for either PCE or TCE. The same was shown in October of 2019. -In April 2020, EPA signed the interim ROD (related to the 2014 time-critical removal action noted above) which addressed soil, soil vapor, and groundwater contamination. The following elements are addressed in the ROD: soil excavation to address contaminated soil; ICs to prevent exposure to contaminated GW; vapor mitigation for all structures exceeding preliminary remediation goals; in situ treatment of PCE in GW > 15 ppb in the shallow zone; and air sparge/soil vapor extraction of saturated soil and GW (to start end of summer of 2021). EGLE concurred with EPA.

	-From the Fifth FYR (2021): the site consists of 3 OUs. OU1 = the city's municipal water supply contamination. The remedy is protective at OU1. OU2 = groundwater contamination. The remedy at OU2 is not protective because COC levels in groundwater present a vapor intrusion risk. OU3 = contamination in source areas and soil gas related to vapor intrusion (not addressed in Fifth FYR because the remedial action has not yet begun). A human health risk assessment performed during the 2019 RI identified PCE and TCE as COCs for the site in soil, soil vapor, groundwater, and indoor vapors. Exposure pathways are GW via ingestion, inhalation, and dermal contact; surface soils via ingestion and inhalation; sub-slab vapor exposures via volatilization to indoor air (see page 5 of the Fifth FYR). The Charlevoix Municipal Well Site GW was evaluated for trends in PCE concentrations. Out of 8 monitoring wells sampled, a trend was in only one monitoring well (MW-209) located in the northern extent of the plume; the trend was decreasing.
Status	Open (Superfund)
Formal ICs used	District health department and city ordinances (2008) banning installation of wells in groundwater affected by department sanitary code well permitting program (i.e., incorporated more areas of contaminated groundwater and restricted all groundwater use). ICs were called for in the 1985 ROD. EPA's 3rd Five-year Report (p. 19) says that the 1985 ROD stated that an adequate IC was already in place, that being the Charlevoix County's Sanitary Code authorizing health officials to reject new well applications. Northwest Michigan Community Health Agency did not permit any new wells in the affected area.
Alternative ICs used	
IC failures	The vapor intrusion pathway was not an identified exposure pathway when the original IC was acknowledged in the 1980s (Charlevoix County's Sanitary Code), so not a true failure.
Other remedial activities	**1985**: EPA funds new water intake from Lake Michigan **1992**: Update to the water intake. **10/94 – 11/95**: SVE at Art's Dry Cleaners **12/97 – 9/02**: AS and SVE at former Impac Tools **8/01 – 9/02**: AS and SVE at Hooker's dry cleaners **2015-2016**: 18 sub-slab depressurization systems were installed
Expanding plume	No, according to EPA and the EGLE project manager.
Timeline	**1982** – MI-Department of Health found that city water contained TCE levels that exceeded EPA criteria. Confirmed by the installation of 4 monitoring wells (Superfund web page – Cleanup Activities) **1982** – City installation of temporary aeration system only partially effective. Additional monitoring found TCE and PCE in groundwater, but PCE not found in city water. (Superfund web page – Cleanup Activities) **1983** – EPA begins investigation after high concentrations of PCE and TCE found in groundwater moving toward municipal well field. **1984** – Initial interim ROD focused on remedying OU1 (the contaminated municipal water wells) through construction of a Lake Michigan water intake. **1985** – EPA focused feasibility study determines deterioration of municipal well presents unacceptable health risk. Highest concentrations were found near middle school. EPA also determines only health risk is consumption of contaminated water; exposure through surface water, exposure of biota, and exposure to toxic or carcinogenic vapors is slight because monitoring did not find high concentrations. (See 2019 health risk assessment below for update). **1985** – Final ROD calls for construction of a Lake Michigan water intake to replace municipal well, monitoring of plume discharge to Lake Michigan, institutional restrictions on installation of new

	wells in the contaminated aquifer. ROD estimates aquifer will return to usable in 50 years. The State of Michigan had objected to the decision not to remediate plume. ROD also calls for allowing discharging of groundwater plumes to Lake Michigan under natural flow conditions. **1986** – State of Michigan scores and ranks the site based on the PCE plume (state site is identified as Charlevoix Municipal Well Field (PCE) site, the EPA lead site is Charlevoix Municipal Well Field Superfund site.) The state identifies three sources for PCE: two former dry cleaners and a former manufacturing site. Interim response actions include state-funded groundwater sparge and soil vapor extraction. PCE remains in soil and groundwater. Goal: "to reduce the contaminant source areas in soil and groundwater so that concentrations in the groundwater were no longer a threat to surface water resources." All state-funded remediation was completed by 2002. **1987** – Charlevoix begins operating the new water intake (3/31/87). **1989** – Lake Michigan water intake and treatment plant completed. **1993** – After initially balking, Charlevoix City Council approves DNR requested monitoring wells for PCE; DNR staff person says some of the contaminant appears to be moving toward Lake Michigan. **December 1993** – EPA removes Charlevoix from NPL. **1994** – State of Michigan operates an SVE system at Art's dry cleaners (10/94 – 11/95) **1997** – State of Michigan operates an SVE and air sparge (AS) system at former Impact Tools, Hoskins Manufacturing, and drycleaning sites (12/97 – 9/02). **2001** – EPA's 2nd FYR deems the remedial measures taken (new water supply, allowing plume to discharge to Lake Michigan, long-term monitoring, and ICs) remain protective of human health. Goes on to state that both EPA and State of Michigan believe no additional FYRs are necessary. **2001** – State of Michigan operates an AS/SVE system at Hooker's Dry Cleaning (8/01 – 9/02). **2011** – PCE vapor intrusion detected in 16 buildings. **2011** – EPA's 3rd FYR acknowledges that PCE in soils and groundwater at OU2 could pose vapor intrusion risks. States that the assumption in the 1985 ROD that the TCE source no longer exists has been proven correct and that almost all the TCE plume has discharged to Lake Michigan. But EPA acknowledges that the assumption that the source of the PCE plume no longer exists was incorrect. States that the State of Michigan's SVE and air sparging system from 1997-2003 reduced PCE contamination, but that it remains at levels that will make it a "continuing source for the groundwater contaminant plume." **2013** – After monitoring, EPA concludes TCE plume has discharged to Lake Michigan and concentrations do not exceed drinking water standards. However, the majority of sampling wells have PCE concentrations above drinking water standards. **Also 2013** – EPA detects two additional PCE source areas, 2 orphan underground tanks with high levels of dry-cleaning constituents. **2014** – EPA approves time critical removal action to mitigate the risk of vapor intrusion into residential and commercial structures, removing three storage tanks, installing sub-slab depressurization systems at 16 buildings where contaminant concentrations exceeded VI screening levels. The removal included additional sampling to determine the nature and extent of waste and contaminated soil for removal and off-site disposal, the delineation of soil gas impacts and VI assessment in buildings. **2016** – since FY 2016 EGLE has monitored groundwater annually. **2019** – EPA determines that PCE and TCE in soil, soil vapor, groundwater and indoor vapor contribute to unacceptable health risk: • Groundwater exposures to residents and construction workers via ingestion, inhalation, and dermal contact. • Surface soil exposures to commercial workers via incidental ingestion and inhalation.

	• Soil exposures to residents via incidental ingestion and inhalation of volatiles and particulates. • Outdoor soil vapor exposures to construction workers via inhalation. • Sub-slab soil vapor exposures via vapor intrusion for residents and commercial workers via inhalation. **February 2020** – Charlevoix newspaper reports DNR treated PCE plume as a separate site/source from TCE and assured residents that treatment of TCE would bring contamination under control. EPA has found a pool of PCE 16 feet beneath a home. They want to tear down the building, compensate owner for its value, remove all contaminated soil and give owner back a vacant lot. **April 2020** – EPA approves interim ROD for operable units 2 and 3 (not implemented as of 2021) • Determined necessary because if unattended: • COCs in OU 2 would remain above safe levels for hundreds of years longer than 1985 ROD predicted; and • There would be unacceptable vapor intrusion exposure to building occupants and other potential receptors via inhalation of soil gas and direct exposure to PCE-contaminated soils in OU 3 • Actions determined: soil excavation to address soil contamination; institutional controls to prevent exposure to groundwater; vapor mitigation for all structures containing sub-slab vapor concentrations exceeding remediation goals; in-situ treatment of areas containing higher than 15 ug/L of PCE in the shallow groundwater; air sparge and soil extraction treatment of saturated soil and groundwater. EGLE concurs. **2022** – EPA says final remedial actions will take place in 2023 and it will be an estimated 35 years before groundwater contamination reaches background levels. **January 2022** – EPA announces it will use $1B from infrastructure bill to finish cleanup at 4 Michigan Superfund sites, including Charlevoix.
Public health cases	None on the record
Impacted recreation	None on the record
Impacted property value	None on the record

Exposure Pathway Evaluations (prior to implementation)

Note: EPA's Superfund page states that human exposure is not under control:
https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.Healthenv&id=0503013

CH2MHill remediation feasibility study from 1985 listed the only significant threat to human exposure was direct consumption of contaminated water, not vapors (p. 34 of the PDF)

This (newspaper article) shows a map with the locations of source facilities in Charlevoix.
https://www.petoskeynews.com/story/news/local/charlevoix/2020/05/28/plan-for-charlevoixs-pollution-clean-up/115826862/

Drinking water

Were criteria exceeded?	Yes (but not EGLE criteria specifically because they did not exist). Per the 1984 ROD, concentrations of TCE in the city's water supply was 13-30 ppb in September 1981. In December 1982, the concentration of TCE was up to 100 ppb. PCE was not detected in the water supply, but concentrations of TCE and PCE were both high throughout parts of the aquifer being monitored. Long-term health advisories are reported in the ROD: 80 ppb for TCE and 20 ppb for PCE. Criteria standard from 3rd FYR Table 3: TCE 5 ug/L, PCE 5 ug/L

Remedial responses

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?
Prohibit groundwater use until MCLs no longer exceeded	IC	1985 2008	Yes	City ordinance (2008) Health Department District of NW Michigan sanitary code (2007). Initial restrictions required by the 1985 ROD were enforced by local health officials through an existing permitting program i.e., the NWMHD District Sanitary Code.
Installation of Lake Michigan DW source to prevent exposure to contaminated wells	RA	1984	Yes	No exposure to contaminated groundwater. Yes.

Were soil criteria to protect drinking water exceeded?	2019 USACE RI used the Drinking Water Protection Criteria as a screening level for soil (see section 5). Criteria were exceeded in Areas A, B, and C (but not Area D). Source soils are addressed in the 2020 Interim ROD. (Remedial responses could start summer 2023.) Status of the selected remedies (soil excavation, ICs, vapor mitigation, in-situ treatment of PCE in shallow groundwater, AS/SVE of saturated soil and groundwater) unknown

Remedial responses

Name	Type	Year	Anticipated to prevent leaching?	How

Groundwater surface water interface (GSI)

Were criteria exceeded?	Unsure. 1985 ROD stated that expected concentrations of PCE and TCE in near shore surface waters of Lake MI were significantly less than federal criteria to

<table>
<tr><td></td><td>protect freshwater aquatic life from acute effects. Also, the expected concentration of PCE is significantly less than the chronic value for the protection of aquatic life. No such value existed for TCE. The first FYR states that PCE and TCE levels in Lake MI were non-detect yet the EGLE summary says that AS and SVE were initiated to reduce risks to surface water resources. The 2019 RI/RA indicates surface water samples taken from 3 locations and none exceeded detection levels. I have not found information indicating EGLE's GSI criteria were exceeded.
Criteria standard from 3rd FYR Table 3: TCE 200 ug/L, PCE 45 ug/L</td></tr>
<tr><td>Remedial responses</td><td>
<table>
<tr><th>Name</th><th>Type</th><th>Year</th><th>Anticipated to prevent venting to surface?</th><th>How</th></tr>
<tr><td>Monitoring of discharge of TCE plume</td><td></td><td>1985</td><td>No</td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>AS & SVE</td><td></td><td>1994 - 2002</td><td>Maybe</td><td>Reduce concentrations in soil and groundwater</td></tr>
</table>
</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Were soil criteria to protect GSI exceeded?</td><td>Not evaluated.</td></tr>
<tr><td>Remedial responses</td><td>
<table>
<tr><th>Name</th><th>Type</th><th>Year</th><th>Anticipated to prevent leaching?</th><th>How</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
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</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2"><h2>Soil Direct Contact</h2></td></tr>
<tr><td>Were criteria exceeded?</td><td>Yes. 1985 ROD indicates some soil sampling around the middle school, but contamination not detected and criteria not available. The 2019 HHRA states that except for areas around ST-001 in Area A (former dry cleaner, Impac Tool, and former Hoskins Manuf.) direct contact does not present an unacceptable risk. The Interim ROD for Vapor Intrusion, Source Areas, and Groundwater (EPA, April 2020): PCE soil concentrations 0.73-1.3E+7 ppb; TCE soil concentrations 0.22-34,000 ppb. TCE concentrations < SDCC [1.1E+5 ppb (DD)]; PCE concentrations > SDCC [2E+5 ppb (C)]. TCE < SDCC; PCE > SDCC.
Criteria standard from 3rd FYR Table 3: TCE 4,000 ug/kg, PCE 900 ug/kg</td></tr>
<tr><td>Remedial responses (None yet for the purpose of addressing soil direct contact. The Interim ROD will address direct contact exposures via Alternative 6: Soil Excavation, Groundwater Chemical Treatment, Air Sparging/Soil</td><td>
<table>
<tr><th>Name</th><th>Type</th><th>Year</th><th>Anticipated to prevent exposure?</th><th>How</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
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<table>
<tr><td>Vapor Extraction, Institutional Controls, and Vapor Mitigation)</td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Volatilization to indoor air</td></tr>
<tr><td>Were groundwater volatilization to indoor air criteria or screening levels exceeded?</td><td>Yes: may not have been these criteria specifically but the vapor investigations conducted from 2012 to 2015 indicated indoor air risks and VI screening levels were exceeded.</td></tr>
<tr><td>Remedial responses</td><td>
<table>
<tr><th>Name</th><th>Type</th><th>Year</th><th>Anticipated to prevent exposure</th><th>How</th></tr>
<tr><td>18 sub-slab depressurization systems</td><td></td><td>2014-15</td><td>yes</td><td>Contaminated sub-slab vapors are discharged outdoors not indoor air space</td></tr>
<tr><td>Vapor Studies</td><td></td><td>2012-16
2018</td><td>no</td><td>...but would indicate where SSDS were needed</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
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</td></tr>
<tr><td></td><td></td></tr>
<tr><td>Were soil volatilization to indoor air criteria or screening levels exceeded?</td><td>Yes: may not have been these criteria specifically but the vapor investigations conducted from 2012 to 2015 indicated indoor air risks and VI screening levels were exceeded.</td></tr>
<tr><td>Remedial responses</td><td>
<table>
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<tr><td>18 sub-slab depressurization systems</td><td></td><td>2014-15</td><td>Yes</td><td>Contaminated sub-slab vapors are discharged to the outdoors not to the indoor air space</td></tr>
<tr><td>Vapor studies</td><td></td><td>2012-16
2018</td><td>No</td><td>...but would indicate where SSDS were needed</td></tr>
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<tr><td></td><td></td></tr>
<tr><td colspan="2">Ambient air</td></tr>
<tr><td>Were criteria exceeded?</td><td>The RI Report (2019) by the US Army Corps of Engineers does identify “inhalation of volatiles from soil” (not VI) as an exposure pathway for residents and workers however, it is not identified as presenting unacceptable risks to the receptors.</td></tr>
<tr><td>Remedial responses</td><td>None</td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Source materials</td></tr>
<tr><td>Any present?</td><td>Yes. The USACE RI did not specifically conduct a source investigation but did identify where soil and groundwater contamination present an unacceptable risk primarily for the vapor intrusion pathway. Contaminated soils, groundwater and soil gas pose an unacceptable risk in parts of Areas A, B, C and D. Details are in the</td></tr>
</table>

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<tr><td></td><td>USACE RI (section 7). Source areas are addressed in the Interim ROD and remedies were supposed to start summer of 2023. Status unknown.</td></tr>
<tr><td>Remedial responses
(None yet for the purpose of addressing source areas. The Interim ROD will address source areas via Alternative 6: Soil Excavation, Groundwater Chemical Treatment, Air Sparging/Soil Vapor Extraction, and Vapor Mitigation)</td><td><table>
<tr><th>Name</th><th>Type</th><th>Year</th><th>Addresses source materials</th><th>How</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
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Charlevoix Municipal Well Site IC Cost Breakdown

Past costs

Two primary remediation efforts were discovered. The first was the establishment of a new and extended municipal water intake from Lake Michigan to bypass municipal well water source, subject to exposure to the TCE and PCE plumes. This effort targeted circumventing the municipal and household water channels of exposure to TCE and PCE for residents and businesses. The intake of Lake Michigan water for municipal source of water was established in 1987. The final reported costs totaled $3,105,833 in 1989. Adjusted to 2020 prices, this entails $7,470,480. Because the plume was expected to migrate to Lake Michigan, and for other foreseen issues with the intake extension into Lake Michigan, the municipal water intake was extended farther into the lake. This extension was completed in 1992 at a reported cost of $408,298, or $852,193 in 2020 prices.

The capital investment expenditures in municipal water systems were fully documented in the five-year review and through other sources. Since this impacted the source of the municipal water and not the distribution of the municipal water system, only the costs of installing the Lake Michigan-sourced system are documented here. We conjecture that the operational costs of the municipal water system were not impacted by this change. The estimates also assert that no new residential connection was created in response to the IC. As the plume is encased in the municipal boundary, this is a valid assumption.

With the municipal water channel contained, the next channel to affect is through air intake, especially in enclosed spaces. At the individual structure-level, vapor mitigation systems installed in the basement or crawlspace of the structure are used to pull up and vent vapors from the soils underneath the structure. Alternatively, soil vapor extraction involves removing contaminated vapors from soils using a vacuum attached to designed wells over a small region and transporting the vapors to a treatment system that contains and destroys the contaminants. Air sparging uses a blower to force the transport of contaminants from contaminated groundwater. Contaminants are vaporized and pumped out of the soil to a treatment facility for containing and destroying the contaminants.

In total, 18 sub-slab vapor mitigation systems were installed in area structures between 2015 and 2016 and have been operating since. In addition, three soil vapor extraction (SVE) systems were installed and operated at Art's Dry Cleaners (10-94-11/95), Impac Tools (12/97-9/02) and Hooker's Dry Cleaner (8/01-9/02) facilities, while air sparging (AS) systems were installed and operated at Impac Tools (12/97-9/02) and Hooker's Dry Cleaners (8/01-9/02). Each of these three systems generated both installation and annual operating costs and are considered a result of the IC.

The 18 sub-slab depressurization systems have expected installation and annual operating costs of $11,632 and 164, respectively, in 2020 prices. Over the 1985-2020 period this amounts to $224.113. The SVE system costs are based on monthly costs of operating a medium-sized mobile unit with a 250 scfm blower and a thermal oxidizer for treatment of $24,400 over 83 months for a total of $1,992,000. The AS system costs are comparably assessed based on a medium-scale, mobile system over 70 months for a total cost of $1,980,000.

A total of six monitoring wells were installed before the 1985 ROD. Since then, about 30 monitoring wells have been documented, suggesting 24 new wells installed since the IC. Existing estimates of the costs of drilling and installing monitoring wells and the annual operating costs of monitoring wells were used, including testing and all maintenance costs to derive the total cost of monitoring well activities between 1985 and 2020. EGLE reported that O&M costs of the monitoring wells from 1985 to 2011 were $17,000 and that the same from 2011 forward was $20,000 per year. Adjusting to 2020 prices, this suggests that average annual O&M costs in the first 26 years were $28,870, while those of the next nine years were $23,012. Aggregating O&M costs of monitoring wells were just under $978,000. The installation costs of the 24 monitoring wells in 2020 prices were estimated to total $1,096,800 in 2020 values.

A total of five underground storage tanks were identified for removal in 2013 and 2014. Cost assigned to each removal was $22,411 in 2020 values, resulting in total costs $112,055 over all five tanks.

Under the 1985 ROD, annual operating and maintenance costs of the site were expected to be $118,000. Adjusted to 2020 prices, the annual operating costs from 1989 to 2020 were estimated at $283,826 per year. In addition to these annual operating costs is the cost of drafting and passing a municipal ordinance that codifies the IC for $37,021, five EPA five-year reviews with average assigned cost of $73,627 each and $32,000 annual professional staffing for managing the site. In total, the site overhead costs totaled $10,323,768 between 1985 to 2020, measured in 2020 dollars.

Collectively, we estimate the social costs realized between 1985 and 2020 to be around $24.7 million.

Recurring Costs (Into Future)

Costs are expected to continue into the foreseeable future. In the case of the Charlevoix plume, the US Army Corp of Engineers (USACE) has established a schedule of expected future site costs, which are followed here. Accordingly, six potential courses of action have been enumerated for expected future costs. The fifth and sixth options are the ones we conjecture for future cost estimates here. The fifth option is described as "Soil Excavation, Air Sparge & Soil Vapor Extraction, Institutional Controls, and Vapor Mitigation," and the sixth option is described as "Soil Excavation, Groundwater Chemical Treatment, Air Sparge & Soil Vapor Extraction, Institutional Controls, and Vapor Mitigation." Both entail a significant portion of past approaches but add elements of soil extraction and chemical treatments. The USACE provides total costs and present value discounted costs for each of these options. Rather than derive our own, we adopt these costs in our estimates. Accordingly, the expected total future costs under each of these alternatives are comparable, but because Alternative 6 has relatively more up-front costs relative to alternative 5, Alternative 6 has a higher present value relative to alternative 5.

	Total Cost	Present Value
Alternative 5	$21,500,074	$12,642,801
Alternative 6	$21,819,522	$15,447,373

Table D-1: USACE Projected Future Costs
Discount rate applied is 7%

The USACE cost future cost estimates for the six alternatives include the option "Do Nothing." This alternative is unrealistic and renders and expected social cost of zero, which equally unrealistic. The implicit assumption in the ability to have zero social costs under the do-nothing scenario is that society bears no cost due to the plume, but only realizes a cost if action is taken to control the plume. However, as this study of the Charlevoix plume has not identified unrealized costs – like costs to future development, future health-related costs, etc. this assumption of no costs in the do-nothing scenario does not entirely contradict those historical costs estimated here. While we should not ignore costs that are not directly observed, the absence of such costs in estimates does not imply such costs do not exist.

Unmeasured costs

This site has unmeasured sources of social costs. The first is the plume's potential effect on future economic development. While no longer on the EPA National Priorities List, the community's exposure to groundwater contamination has implications to short- and long-term economic development opportunities. Though difficult to quantify the effects, future development opportunities and business recruitment may be hampered by both real and stigmatizing effects to future growth.

The citizens of Charlevoix have been exposed to various levels of TCE and PCE since the establishment of this IC. While mostly monitored and controlled, the mere presence of health threats poses an economic cost on citizens that may take the form of added stress and risks to future health outcomes, both of which are difficult to quantify.

Finally, the IC provides for attenuation of the plume and the eventual discharge into Lake Michigan at levels determined by the EPA to be safe for surface waters. Regardless, it would be myopic to assume that there are no costs to the ecology for the underground plume, the discharge into Lake Michigan and the volatilization into the air in confined and open spaces.

Summary

The review of this site indicates the presence of significant direct and observable costs associated with the multiple operating units (OUs). However, few non-observable points of costs were measurable in this analysis, which gives the false impression that such costs are not material. Of the observed costs, $24.7 million has been realized between 1985 and 2020. The USACE expects these costs to continue, totaling an additional $21 million. Discounted, the future costs are expected to impose $12.6 to $15.4 million in social costs, once discounted to current present values.

Charlevoix Municipal Well Site Recommendations

1. Evaluate all exposure pathways to the best extent possible and acknowledge uncertainties regarding future identification of additional contaminants, new exposure pathways, and new toxicity information, etc.

2. Prioritize identification of all source areas and removing or preventing those source areas from continuing to contaminate and migrate.

3. To identify all possible contaminant sources, the state should consider exercising enforcement discretion for identifying the locations of previously unidentified underground storage tanks or other sources. This offer could be limited to insolvent potentially responsible parties.

APPENDIX E: FORD KINGSFORD SITE SUMMARY

Location	**Kingsford, City of & Breitung Township (Dickinson County), Kingsford, MI, 49802**
EGLE district / contact	Marquette District Office Christopher Austin; austinc@michigan.gov; 906-235-8039
EPA Superfund? (link)	No.
EPA contact	--
Contaminants	The hazardous substances identified include numerous organic and inorganic contaminants. Degradation of the organic contaminants present in the groundwater has resulted in the generation of methane gas which led to the explosion of the Kingsford residence in 1995. To date, over 50 hazardous substances have been identified at concentrations that exceed many of the Part 201 Cleanup Criteria.
Exposure pathways	Fire and/or Explosion Hazards, Drinking Water Ingestion, Direct Contact, Volatilization to Indoor Air and Groundwater Surface Water Interface (the Menominee River).
Background	The Site consists of a former automotive plant and wood carbonization plant along with a series of abandoned, unlicensed industrial waste pits, and industrial dumps owned and operated by the Ford Motor Company and Kingsford Chemical Company. The Facility is spread out over approximately 1.5 square miles within the City of Kingsford, Sections 1, 2, 11, and 12 of Township 39 North, Range 31 West. The Ford Motor Company owned and operated a plant that made wooden automobile parts (1921-1951). To utilize the scrap wood (400 tons/day), a wood carbonization and distillation plant was put into operation. The wood carbonization plant produced charcoal and briquettes, while the distillation plant produced several commercial chemical products. The plant was sold to Kingsford Product Company's (KPC) predecessor, Kingsford Chemical, in 1951. Kingsford Chemical continued operation of the wood carbonization/distillation plant until 1961. Lodal, Inc. purchased the major remaining portions of the land and buildings that were formerly the Ford-Kingsford Product Facilities operations. Lodal, Inc. manufactures garbage handling truck units, truck loaders, and equipment for handling containerized garbage. The land adjacent to the former waste disposal areas (where a significant amount of the solid waste materials remains) was divided into several parcels and developed for various land uses including residential, recreational, and commercial businesses. Waste products were disposed of in at least three areas - the Riverside Disposal Area (RDA), the Southwest Pit (SW Pit) and the Northeast Pit (NE Pit). These areas were unlined and lacked measures to contain the contaminants that could leach from the waste. Near these former disposal areas, much of the underlying soils have been contaminated with hazardous substances that exceed most of the Part 201 Soil Cleanup Criteria. The primary source of the organic constituents in groundwater was historical process wastewater discharged into the former Northeast Pit (prior to 1961). Historical liquid releases from this pit entered the groundwater system which is comprised of glacially derived unconsolidated deposits consisting of clay, silt, sand, and gravel that overlie bedrock and having lateral and vertical spatial variability.

	In July of 1995, an explosion at a Kingsford residence occurred due to accumulations of methane gas in the basement. The explosion lifted the house off its foundation and severely injured the occupant, leaving him with third degree burns over 60 percent of his body. The Kingsford Fire Department suspected that the explosion occurred when the owner was removing laundry from a clothes dryer, igniting a large volume of methane gas which had migrated into and accumulated in his home. Following the explosion, investigations were conducted by City of Kingsford, EPA, USGS, and DEQ (EGLE) to determine the source and the extent of the methane contamination. The extent of the groundwater contamination is approximately 1.5 square miles within the commercial and residential area of Kingsford. EPA issued an action memorandum on Jan. 2, 1996, requesting approval to spend $542,500 to mitigate public health threats from the presence of high methane gas levels around five homes in the Easton Estates Subdivision in Kingsford. The monies were used to identify the source of the methane and to install SVE systems to remove methane from the ground around the remaining four most threatened homes on Breen Ave. Between 1990 and 2001, several active SVE and passive venting systems were constructed to remove methane gas from the subsurface. Since 1998, methane venting and control activities have been implemented. Eight areas, where concentrations of methane are above 1.25 percent by volume have been identified. Active or passive venting is being implemented to remove the gas from these areas. Interim response actions have also been implemented across the site for current and/or future residential and commercial buildings. (Details provided in the 2012 RAP.) October 2004: Consent judgement (CJ) between the DEQ, Ford Motor, and Kingsford Products to conduct a remedial investigation, perform interim response activities, and prepare and implement a Remedial Action Plan. The following interim response actions took place between 2001-2003: waste material within the Riverside Disposal Area was relocated and consolidated and a 30-inch soil cover cap was constructed. Interim response actions in 2003-2004: increased the existing soil cover to over 30 inches at the SW disposal pit and maintained the existing SVE system. Interim response actions in 2004-2005: an engineered cap was placed over the wastes of the NE Disposal Pit along with a SVE system (neither addresses GW contamination); several groundwater extraction wells were installed along the edge of the Menominee River and a water treatment plant was constructed to address the acutely toxic groundwater discharging to the river. As a presumptive remedy per the CJ, response activities for residential and nonresidential structures consisting of residential methane programs and commercial methane programs that included Vapor Control System (VCS) installation, sealing of floor slabs or foundations, structure inspections, and methane detector or soil vapor probe installation (where applicable) and monitoring, have been implemented across the site since 2004. Since inception of this program, no gas-phase methane associated with the site has been detected within any structure, and there have been no site-related methane detector alarms sounding. In addition, thousands of sub-slab locations have been monitored and have continued to supplement the existing database indicating that gas-phase methane is not present in shallow soils.

	In December 2005, full scale operation of a groundwater extraction and treatment system was achieved. Forty-eight groundwater extraction wells were installed to capture groundwater at the Menominee River. In 2007, the Former Plant Site Interim Response Action Plan and Construction Documentation Report was submitted to the department. This report only addressed direct contact hazards at the FPS. In February 2012, the Remedial Action Plan was submitted to the department. Both documents were written by Arcadis. This RAP included information from the 2007 report and addressed methane and groundwater contamination across the site. The RAP addressed six areas of the site which all have Operation and Maintenance (O&M) Plans: • The Smith Castings property is approximately 4 acres in size and owned by Smith Castings Inc. and lies in an area zoned for industrial use. It includes portions of Smith Steel, Smith Castings, Zams Automotive, and City of Kingsford areas sufficient to include the troughs connecting the former carbonization building to the distillation and powerhouse buildings. The property encompasses the former distillation building of the Former Plant Site and contains waste and tar material. The RC was recorded in January 2012 which amends and restates the RC of September 2007 amended 2008. See below for details. • The Delta Do-It/East Area consists of the former Delta Do-It Center property and all other portions of the FPS not included in the Smith Castings area. It contains no waste or tar material. The RC was recorded September 2005 (see below). • The former Northeast Pit (NE Pit) portion of the Ford-Kingsford facility. The NE Pit is approximately 35-feet deep and three acres in size, located in the City of Kingsford. An IRAP was developed to address impacts to the soil and groundwater at the NE Pit, which resulted in the selection of the cover system as a response action. The NE Pit cover system consists of consolidated waste material covered by impacted and non-impacted soil, two high-density polyethylene liners and a geo-composite drainage layer. A protective soil layer is above the geo-composite drainage larger, followed by an asphalt layer at surface level. The cover system is approximately five acres in size. Another component of the cover system is a passive venting system to route methane that may otherwise accumulate below the cover to the atmosphere. The primary focus of the response action is to prevent direct contact with impacted soil/waste material, and to minimize groundwater infiltration to prevent potential leaching of waste constituents. The RC was recorded January 2012 and amends the September 2005 RC (see below). • The Carter Drive Right-of-Way is a stretch of roadway approximately 500 feet in length, is owned by the City of Kingsford and is in an area zoned for industrial use. During the implementation of response actions, a small quantity of waste material was left in place north of the former NE Pit beneath Carter Drive due to inaccessibility. The roadway serves as a cover/barrier for the waste material left in place beneath Carter Drive. The RC was recorded January 2012 (see below). • The former Southwest (SW) Pit (center point) is located approximately 1,100 feet north of Breitung Avenue and approximately 1,500 feet west of Balsam Street in the central portion of the City of Kingsford. Waste materials remain in place and response actions include the cover system and implementation of ICs. The RC was recorded in October 2011 (see below). • The former River Disposal Area (RDA) is located approximately 600 feet south of the western end of Pyle Drive and approximately 1,400 feet west of Westwood Avenue in the City of Kingsford. The RDA is contained within property owned by the city of Kingsford, is zoned for nonresidential use, and is currently zoned for recreational use. The soil cover system was constructed to accomplish the Remedial Objective of protection of human health and the environment from direct contact with waste materials remaining in place. The completed surface of the cover

	system was designed as a youth soccer field. The RDA cover system is comprised of soil fill (18 inches) and topsoil (12 inches) and covered by a vegetative layer. The area outside the soccer field playing surface is covered by a minimum of 24 inches of fill and six inches of topsoil. The RC for this area was recorded in December 2009 (see below). Per the Master Data Summary, in 2013 and 2015, EGLE contracted collection of groundwater samples to better understand the groundwater conditions. The results of the groundwater sampling showed that a large volume of contamination still resided in the groundwater system near the former disposal areas. Also, as the groundwater migrated towards the Menominee River, some of the chemical constituents underwent some degree of biological degradation. However, the rate of this degradation did not appear to be sufficient to allow the discharge to meet Rule 323.1057 for Final Acute Values (FAV for aquatic life) and aquatic toxicity. The summary seemed to end with the planned collection of GW samples in 2015. However, RRD receives annual progress reports from Arcadis which includes groundwater monitoring and sampling as well as maintenance and monitoring of response actions (like cover systems at disposal areas), methane extraction and control, the methane program, etc. The project manager (PM) sent the last one dated March 2022 which reports for 2021. Residents and businesses in Kingsford do not rely primarily on groundwater from aquifers in glacial deposits. The City of Kingsford provides potable drinking water from a source that is upgradient and outside of the source area. The supply wells have not and will not be impacted by the site contaminated groundwater. Per the PM, municipal water has been provided to Kingsford residents since the early 1980s. Risks to the Menominee River also present unique considerations and costs to evaluate. There is a pump and treat system in place to reduce toxicity to the Menominee River, but it is not an attempt to remediate the contaminated groundwater. It is a system to protect the Menominee River from receiving highly toxic contaminated groundwater. The venting groundwater is captured and treated before it is discharged to the river. In 2016, The First Modification to the Consent Judgment was signed and implemented. 9/28/2017 news article: A $60,000 DEQ brownfield redevelopment grant was awarded to the City of Kingsford to investigate environmental contamination at the Lodal Inc. property on Breitung Road. The investigation must be conducted before the underutilized manufacturing plant can be sold to a new owner who will increase production and create new jobs. The brownfield grant will help the city assess the current levels of environmental contamination at the site, which was previously owned by Ford Motor Company and Kingsford Chemical Company. The PM sent the 2018 Conceptual Site Model Summary Report dated September 2018, which is based on the 2010 RI Report. It presents information about the geology, hydrogeology, and the groundwater plume (distribution and movement, biological degradation, methane production, methane solubility and dissolved phase methane distribution and movement). The PM also sent Progress Report #55 (March 2023) January-December 2022: reports on all response activities; methane extraction and control; the residential and commercial methane program; GW extraction and treatment system; GW monitoring/sampling. Topics of focus and on-going evaluation: dissolved-phase methane assessment; evaluation of COD in GW adjacent to the Menominee River; source life cycle assessment.
Status	Active/open

Formal ICs used	A **groundwater ordinance**[12] (no copies in our files) was enacted by the City of Kingsford (Ordinance No. 272/9-5-2011) and Breitung Township (Ordinance I of 2011/12-28-2011) and recorded with the Dickinson County Register of Deeds. They both prevent the installation, use and maintenance of water wells and ingestion of or contact with the groundwater. January 2012 restrictive covenant (amends the September **2005 RC for the NE pit**): The RC is for the property often referred to as the former Northeast Pit area which is 13.6 acres in size. For the whole NE Pit property, the RC prohibits the use or removal of groundwater for any purpose; all excavation and digging activities must be conducted in accordance with the waste management and health and safety plan; and activities shall not damage monitoring wells or vapor probes. There are prohibited activities near the cover system and in areas not a part of the cover system. September **2005 RC for the Deta Do-It Center** (the part of the FPS that does not contain waste material) which prohibits use of the groundwater, prohibits activities that would damage response activities, requires management of contaminated media, and requires all structures to have a Vapor Control System (VCS). December 4, **2009, RC for the RDA** (soccer field in place) with an affidavit to the RC with a revised O&M Plan recorded on January 31, 2012. RC: Restricts land use to be recreational or industrial/commercial; maintains the current cover system; prohibits excavation or penetration of the cover; prohibits the use of GW. Includes an O&M Plan for the cover system, a soil/waste management plan, a health, and safety plan, and requires a notice of intent to transfer the property to EGLE and Ford/Kingsford. Does not require VCS installed for new commercial/industrial buildings. September 19, **2007, RC amended in 2008 for the Smith Castings Area (the FPS)**: prohibits uses not compatible with industrial/commercial uses; protects the cover system; prohibits all uses of groundwater; new commercial/industrial buildings must have VCS installed; prohibits excavation and has a waste management plan, a health and safety plan, and O&M plan for the barrier system. October 13, **2011, RC for the SW Pit**: limits the property to recreational or nonresidential, protects the cover system, prohibits the use of the groundwater, requires VCS for new buildings, requires notice of intent to transfer property to DEQ and Ford/Kingsford. Includes both an IRAP waste management plan and a health and safety plan.
Alternative ICs used	In October of **2004, EGLE, FORD and KPC reached an agreement on a Consent Judgement** (CJ) to ensure the work continues in a timely and comprehensive manner. The CJ requires Ford and Kingsford to conduct an RI; perform interim response activities to mitigate unacceptable risk through direct contact, eliminate migration toward the Menominee River at the boundary of GW above applicable acute and chronic GSI criteria, mitigate potential explosive hazards, vent areas where methane levels > acceptable levels in soils gas, and any other interim response activity determined appropriate. Develop and submit an approvable RAP that complies with Part 201. Perform the approved RAP. Reimburse the State for response activity costs (as described in the CJ).
IC failures	None reported.

[12] https://library.municode.com/mi/kingsford/codes/code_of_ordinances?nodeId=COOR_CH16EN_ARTVREREWE

Other remedial activities	Noted above in the background section.
Expanding plume	The plume is stable per Christopher Austin, RRD PM
Timeline	**1921-1951**: Ford Motor Company made wooden auto parts **1924**: A wood carbonization and distillation plant was put into operation. **1951**: The plant was sold to Kingsford Chemical. **1961**: Kingsford Chemical closed its operations. Lodal, Inc. purchased portions of the former Ford-Kingsford Product Facilities operations. **July 1995**: Explosion at a Kingsford residence. EPA and EGLE investigations discover groundwater and soil contamination. **January 2, 1996**: EPA Action Memo to Abate Methane Risks **1990 and 2001**: several active SVE and passive venting systems were constructed to remove methane from the groundwater and soil. **2001-2005**: several interim response actions took place primarily in the disposal areas **October 2004**: EGLE, FORD and KPC reached an agreement on a Consent Judgement. **September 2005**: RC for the Delta Do-It Center which is a portion of the Ford/Kingsford FPS **December 2005**: Full scale operation of a groundwater extraction and treatment system. **2007**: the Former Plant Site Interim Response Action Plan and Construction Documentation Report was submitted to the department. September 2007, amended 2008, & amended/restated January 2012 RC for Smith Castings (FPS). **December 2009**: RC for the RDA with an affidavit in 2012. **October 2011**: RC for the SW Pit which is also called Lodal Park. **September 2011**: ordinance for the City of Kingsford **December 2011**: ordinance for Breitung Township **January 2012**: RC for the Carter Drive right of way (contamination under road near FPS) **January 2012**: RC for the NE Pit (amends the September 2005 RC for the NE pit) **February 2012**: Remedial Action Plan completed by Arcadis **2013 and 2015**: EGLE contracted collection of groundwater samples **September 2017**: DEQ Brownfield redevelopment grant awarded to the City of Kingsford to investigate environmental contamination at the Lodal property. **September 2018**: Conceptual Site Model Report **March 2023**: Last progress report (#55 for 2022)
Public health cases	Injuries to the resident resulting from the 1995 explosion of his home as well as destruction of his house.
Impacted recreation	None reported
Impacted property value	None reported

Exposure Pathway Evaluations (prior to implementation)

Drinking water

Were criteria exceeded?	Yes, per the RAP, page 52 and the EGLE Master Data Table. Sixty-two constituents in groundwater exceeded the generic DWC. (No one in Kingsford is drinking contaminated groundwater. Municipal water comes from another uncontaminated, upgradient source/aquifer.)

Remedial responses implemented

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?
GW Ordinance for City of Kingsford and Breitung Township		2011	Yes	They both prevent the installation, use and maintenance of water wells and ingestion of and contact with the groundwater. Yes.
RC for the NE Pit area (drinking water pathway is an issue for this area)		2012	Yes	Prevents the use of the groundwater at the site for any purpose. Yes.
RC for the RDA per the RAP		2009 & Amended in 2012	Yes	Prohibits the use of the groundwater at the site for any purpose. Yes.
SW Pit: RAP says an RC was recorded 2011 & 2012 but does not clearly indicate impacts to groundwater for drinking water pathway		2011	Yes	Prohibits any use of the groundwater for any purpose. Yes.
FPS not identified as having exceedances of DWC. 1/2012 RC for the Smith Castings portion of the FPS 9/2005 RC for the Delta Do It portion of the FPS (RAP states an RC was recorded 2007 with amendments in 2008 and 2012.)		2005 2012	Yes	Both RCs prohibit any use of the groundwater. Yes.

Were soil criteria to protect drinking water exceeded?	Yes, in vicinity of the former disposal areas, much of the underlying soils have been contaminated with hazardous substances that exceed the Part 201 Soil Drinking Water Protection Criteria. Per the 2012 RAP and the Master Data Table.
Remedial responses implemented	see table below

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?
RDA: waste material consolidated and cover constructed		2001-2003	Yes	Reduced leaching of soil contaminants in the waste material to the GW
SW Disposal Pit: increased the existing cover system		2003-2004	Yes	Reduced leaching of soil contaminants in the waste material to the GW
NE Disposal Pit: excavation of waste materials in mid 80s and 2004; engineered cap over the waste material was constructed in 2005 and 2008		mid 80s; 2004, 2005, 2008	Yes	Reduced leaching of soil contaminants in the waste material to the GW
Former Plant Site: Smith Castings portion		2012		A barrier system is in place and must be maintained. Yes, to some extent.

Groundwater surface water interface (GSI)

Were criteria exceeded?	Yes, per the 2012 RAP: Forty-two constituents exceeded the generic GSI criteria. Nineteen exceeded the Final Acute Value for aquatic organisms (FAV). Thirty-four exceeded the Final Chronic Value (FCV). Also, yes per the Master Data Table.
Remedial responses implemented	see table below

Name	Type	Year	Anticipated to prevent venting to surface?	How? Successful?
Groundwater extraction and treatment system		Oct 2005	Yes, specifically the GW concentrations exceeding the site-specific mixing zone based GSI criteria	Yes, through venting methane (and other contaminants?) and treating the groundwater

Were soil criteria to protect GSI exceeded?	Yes, per the Master Data Table and the 2012 RAP: In vicinity of the former disposal areas, much of the underlying soils have been contaminated with hazardous substances that exceed the Part 201 Soil GSI Protection Criteria.

Remedial responses implemented

Name	Type	Year	Anticipated to prevent leaching?	How? Successful?
RDA: waste material consolidated and cover constructed		2001-2003	Yes	Reduced leaching of soil contaminants in the waste material to the GW
SW Disposal Pit: increased the existing cover system		2003-2004	Yes	Reduced leaching of soil contaminants in the waste material to the GW
NE Disposal Pit: engineered cap over the waste material was constructed		Mid-80's 2004-2005, 2008	Yes	Reduced leaching of soil contaminants in the waste material to the GW
Former Plant Site: Smith Castings portion		2012		A barrier system is in place and must be maintained. Yes, to some extent.

Were the FESL exceeded?	Yes. Dissolved phase methane was detected at concentrations above the FESL per the 2012 RAP (page 52).

Remedial responses implemented

Name	Type	Year	Anticipated to prevent FESL exceedances?	How? Successful?
The selected interim response actions were chosen to minimize vapor intrusion of methane and eliminate the flammability and explosivity pathway. Implemented activities include: active SVE systems; passive venting systems; monitoring; a methane program including residential detectors and commercial property soil vapor probe		1998-current	Yes	Removal of some of the methane from the soil and groundwater and indoor air Since 2004 (methane program) no gas-phase methane detected within any structure and no detector soundings for methane.

	installation and monitoring; sealing of cracks/seams; and installation of VCSs.				
	A soil and groundwater vapor extraction system were installed at the NE Disposal Pit. There are 7 other sub-areas where gas phase methane is present below the water table or within the vadose zone		2004-2005	Yes	Removal of some of the methane from the soil and groundwater Since 2004 (methane program) no gas-phase methane detected within any structure and no detector soundings for methane. Monitoring has shown gas-phase methane not present in shallow soils.

Soil direct contact

Were criteria exceeded?	Yes, per the 2012 RAP and the Master Data Table in the vicinity of the former disposal areas.

Remedial responses implemented

Name	Type	Year	Anticipated to prevent direct contact with soil?	How? Successful?
RDA: waste material consolidated and cover constructed		2001-2003	Yes	Contaminated soil covered and restrictions put into place
SW Disposal Pit: increased the existing cover system		2003-2004	Yes	Contaminated soil covered and restrictions put into place
NE Disposal Pit: engineered cap over the waste material was constructed		2004-2005	Yes	Contaminated soil covered and restrictions put into place
Former Plant Site: all known waste material present within the		2002-2005	Yes	Waste and troughs removed and a barrier left over the

	FPS, except for a portion of the northern concrete trough present beneath the Smith Castings building, was removed. (see 2012 RAP for details). The concrete trough that passes beneath the Smith Castings building was left in place so as not to damage the building or interrupt business. The concrete floor of the Smith Castings building is utilized as a barrier to direct contact with any materials that may remain within the section of trough left in place.				portion of one trough left in place.

Volatilization to indoor air

Were groundwater volatilization to indoor air criteria or screening levels exceeded?	Yes, the RAP (pg. 82) states that only anthracene exceeded the GVIAC (estimated) and dissolved methane above the Flammability and Explosivity Screening Level (FESL).

	Name	Type	Year	Anticipated to prevent exposure	How? Successful?
Remedial responses implemented	Implemented interim response actions: active SVE systems; passive venting systems; monitoring; a methane program incl res detectors & com soil vapor probe installation & monitoring; sealing		1998 - current	Yes	Removal of some of the methane from soil and groundwater and indoor air. Since 2004 (methane program) no gas-phase methane detected within

	cracks; installation of VCS				any structure and no detector soundings for methane.
	A soil and groundwater vapor extraction system was installed at the NE Disposal Pit.		2004 – 2005		Removal of some of the methane from soil and groundwater
Were soil volatilization to indoor air criteria or screening levels exceeded?	Yes, areas of the site where methane gas present is in soil vapor above 1.25% have been addressed with soil vapor extraction (SVE) or passive venting in accordance with the Standard Contingent Venting Procedures. A Methane Program is in place.				
Remedial responses implemented ...wherever levels exceed 1.25% methane in soil gas throughout the site	**Name**	**Type**	**Year**	**Anticipated to prevent exposure?**	**How? Successful?**
	Implemented interim response actions: active SVE systems; passive venting systems; monitoring; a methane program incl res detectors & com soil vapor probe installation & monitoring; sealing cracks; install of VCS		1998 - current	Yes	Removal of methane from soil and groundwater and indoor air
	A soil and groundwater vapor extraction system was installed at the NE Disposal Pit		2004 - 2005	Yes	Removal of methane from soil and groundwater

Ambient air

Were criteria exceeded?	Yes, in certain areas				
Remedial responses implemented	**Name**	**Type**	**Year**	**Anticipated to prevent venting / leaching?**	**How? Successful?**
	SVE and passive venting for VSIC			Yes	
	Cover systems at the disposal areas address PSIC			Yes	

Source materials					
Any present?	Yes				
Remedial responses implemented	**Name**	**Type**	**Year**	**Addresses source materials?**	**How? Successful?**
	RDA	Buried waste	2001-2003	Yes	Contaminated soil covered and restrictions put into place
	SW Disposal Pit: increased the existing cover system	Buried waste	2003-2004	Yes	Contaminated soil covered
	NE Disposal Pit: engineered cap over the waste material was constructed	Buried waste	2004-2005	Yes	Contaminated soil covered and restrictions put into place
	Former Plant Site: all known waste material present within the FPS, except for a portion of the northern concrete trough present beneath the Smith Castings building, was removed. (see 2012 RAP for details & DC pathway above).		2002-2005	Yes	Waste and troughs removed, and a barrier left over the portion of one trough left in place.

Additional Notes

Master Data Table has not been updated in a while.

All restrictive covenants and ordinances are not available in Environmental Mapper.

This is a site that has both Institutional Controls and remedial response actions.

Suggestion was made in team discussions that reporting costs related to the explosion and all follow-up methane venting and flaring and monitoring, etc. are relevant. These are not costs related to an IC, but are instead related to not cleaning up the groundwater and could provide useful information to EGLE when dealing with sites contaminated with methane.

Ford Kingsford Site IC Cost Breakdown

Cost Findings

The largest overall cost component is for treatment, including a pump and treat system designed to manage the risk of runoff into the Menominee River and the system of Soil Vapor Extraction (SVE) to manage the ambient air pathways of methane exposure (ARCADIS 2007, ARCADIS 2020, ARCADIS 2023a). While there have been around 12 SVE systems installed, around eight units are in operation at any given time. Lutes, Stewart et al. (2022) provide a breakdown of the installation and operating costs of SVE systems, where netting out the fixed installation costs, the expected annual costs of operating an active SVE system is around $45,000. This will vary depending on the volume of vapor flow pursued. The initial up-front costs are estimated to be $58,000 per unit. Additionally, the cost of running a pump and treat system entails annual operating costs and the costs of disposing of groundwater sludge in a landfill. Annual wet sludge generated is estimated to be 284.8 short tons. With an average tipping fee of $54 per ton over 15 years, suggest handling charges of around $231,430. Annual operating costs of the Ford-Kingsford site are estimated at $1,148,375 in 2012. Adjusted for 2020 prices, we estimate the 15-year total costs for operating the pump and treat system total to exceed $18,575,000. Collectively, about $24,902,644 has been invested in maintaining active mitigation in support of the IC.

Methane monitoring is a significant component of the costs of the Ford-Kingsford IC (ARCADIS 2007, ARCADIS 2020). Monitoring entails a combination of soil, ambient air, and sub-slab censors. Some sensors, like sub-slab monitors are continuously measuring for the presence of methane in homes, alerting when methane is detected. Others derive results from laboratory tests on samples. We estimate about 80 such sites for laboratory tests are active, including monitoring wells. Laboratory sites are sampled monthly, annually, bi-annually, and occasionally, depending on the site. About 390 laboratory tests are completed each year, where each laboratory test has a social cost of around $200. Over the 15 years since 2005, total laboratory costs were estimated at over $1,259,000. Soil vapor probes are analyzed yearly at $650 per deployment, or $1,019,039 over 15 years of the IC. Finally, approximately 1,000 (947 best count) sub-slab methane monitors are in place with approximately 5% annual fail rate. New sub slab monitors were put into place before the declaration of an IC in 2005 and therefore the costs of those are not included in the estimated costs of the IC. However, replacements persist annually, and new structures are outfitted with monitors. In total, we estimate that 50 new sub-slab methane monitors are placed per year at $100 for equipment and $13 (=1/3 * $38/hour) for installation labor. This occurs annually since 2005, or for 15 years generating social costs of about $84,500. Over the 15 years since 2005 implementation of the first IC, the estimated total monitoring cost totals $2,668,759.

Other costs are considered. EGLE must allocate time and effort in regulating and reviewing. EGLE billed for $9,457.52 on November 8, 2023, for wages and benefits for EGLE staff working on the Ford-Kingsford IC. This invoice covered just over ¾ of the year, November 2022, to September 2023. This is comparable to a 2012 ARCADIS estimate of average expected state labor cost of $15,000 per year. Adjusted to 2020 prices and over 15 years provides an estimated cost to state regulation of $242,628. In 2017, EGLE offered a brownfield redevelopment grant of $60,000 to expend on investigating the Local Inc. property contamination, requiring the investigation to be completed before the sale of the property.

ARCADIS provided a generalized expected future cost of the Ford-Kingsford IC in 2012 over a thirty-year time frame. In this analysis, three discount rates over three future cost streams are analyzed. There is a 15-year, 30-year and a 50-year scenario of future annual costs of $2,003,000 dollars, measured in 2020 values. Under higher discount rate assumptions, future costs are discounted by more than under lower discount rate assumptions. Accordingly, should the annual cost of the IC be expected to persist for the next 30 years, the present value of those future costs would be about $51.7 million if the social discount rate is equal to one percent, or $18.9 million should it be ten percent. The calculated present values in the table can be interpreted as the value society would place on the associated future stream of costs at different discount rates.

		Years		
		15	30	50
Discount Rate	1%	-$27,772,000	-$51,692,000	-$78,509,000
	5%	-$20,790,000	-$30,791,000	-$36,566,000
	10%	-$15,235,000	-$18,882,000	-$19,859,000

Table E-1: Projected Future Costs

Summary

In 2012, ARCADIS estimated that the overall site costs of the IC operation over 30 years would be $55,723,750 in 2012 prices, or $60,089,600 in 2020 prices (ARCADIS 2012). Over the fifteen years between 2005 and 2020, we estimate that the total costs of supporting the Ford-Kingsford site is $27,571,400. As a midpoint prediction of the value of future costs, 2021 and beyond, a thirty-year projection of estimated annual O&M costs at a discount rate of five percent, produces an additional future cost of $30,691,000. Combined we anticipate total site cost to be $58,262,400.

Ford Kingsford Recommendations

1. To prevent contaminant exposures resulting from delayed implementation of RCs or groundwater ordinances, the state should explore means for expediting the implementation of such ICs.

2. Require all ICs and RCs be submitted to the department and made available to the public in Env. Mapper.

3. EGLE should receive copies of all RCs recorded under Part 201 and Part 213. Additionally, EGLE should have more staffing dedicated to tracking the status of pending RCs and ICs.

4. EGLE should consider the possible generation of hazardous conditions, such as explosive vapors (e.g., methane) from the biodegradation of organic materials (wood, charcoal, landfill content) in groundwater. Properties within a specified distance of such sources should be eligible for free groundwater, indoor air, and soil vapor testing, particularly in situations in which the department has not become aware of a contamination.

APPENDIX F: HITACHI MAGNETICS SITE SUMMARY

Location	7800 Neff Road, Edmore, MI, 48829
EGLE district / contact	Grand Rapids District Dave Wierzbicki (WIERZBICKID@michigan.gov)
EPA Superfund? (link)	no
EPA contact	
Contaminants	TCE
Exposure pathways	Drinking water, soil
Background	General Electric owned and operated a magnet producing plant in Edmore, MI from 1952 until 1973, when GE sold it to the Hitachi Magnetics Corporation, which continued the operation through 2004. In May 1985 MDNR sent results of the Wolfe Creek Sediment Contaminant survey to residents near the ditch, informing them it was contaminated with metals, including Mercury, and oils. Additional sampling events were conducted in in 1996 and 2000, and contaminated sediments were removed in 2003. Also in 1985, the MDNR informed GE that the potential for groundwater contamination must be addressed in future investigations, and GE identified metals in groundwater during a 1985 Remedial investigation (RI), and TCE was detected at 1,400 ug/l in MW-7D, SE of the Ceramics Building in October 1986 as part of a subsequent RI; and starting in 1986 drinking water wells around the property were monitored. Monitoring and targeted soil excavations continued through 2008. With the plume migrating offsite to the east, from 1997-1998 RCs were registered for 28 parcels near the property. In 1999 bottled water was provided to four nearby homes, municipal water was extended to additional properties, and Home Township implemented a groundwater ordinance requiring well abandonment and municipal hookups. The plume continued to migrate east of the site, and in 2003 a groundwater extraction system was implemented at the Hitachi Magnetics site, though its footprint would not affect the plume's leading edges. In 2004 Hitachi Magnetics shuts down its operations, registered an RC for the property with Montcalm County, and donated the property to the Village of Edmore. The village registered additional RCs for the property in 2008, and then sold a portion of it to Ryan's Equipment. Monitoring of the plume continued, and concentrations of TCE fell slowly. In 2011 a farm just northeast of the main site installed an irrigation well into the plume, in violation of the parcel's RC and the Home Township ordinance. EGLE (DEQ at the time) required plugging of the well in a September 14, 2011 letter, which was done on 1/23/2012. By 2016 the plume had migrated over 1.5 miles from the source of the contamination. Monitoring continued downgradient of the plume through 2021. In 2018 GE shut down the groundwater treatment system to conduct a rebound study. Apparently, the results indicated the MNA coupled with the institutional controls were adequate to protect against exposure, and in 2022 EGLE indicated that it anticipated receiving an NFA request for the site soon. From August 2020 through March 2021, GE conducted a vapor intrusion study in the vicinity of the occupied buildings on Quicksilver Lane by installing and sampling several sub-slab vapor pins in the former LODEX building and several locations exceeded the EGLE non-residential Volatilization to Indoor Air Pathway (VIAP) screening levels (SLs) for TCE. GE conducted a pilot

	test in June of 2021 for the installation of a Sub-Slab Depressurization system (SSDS) in the former LODEX building, and in November 2021 submitted a design for the SSDS that was constructed and began operation in June of 2022. In July of 2022 GE installed eight soil gas wells between the former LODEX building and the Ryan's Equipment and Village of Edmore DPW buildings to the north and west to further investigate potential VIAP exposure risks, and results exceeded the TCE SLs at seven of the eight locations. GE submitted a work plan in October 2022 to install several vapor pins in the Ryan's Equipment and DPW buildings to further evaluate the VIAP. Vapor Pin sampling early in 2023 has documented low detections of acetone, PCE, 111-TCA, and TCE beneath the concrete slab of the former Boiler House, Stacy, and Miller buildings as well as the recently constructed Ryan's Equipment Building #1. Only three exceedances of TCE were detected during the initial sampling event and all were contained within the eastern half of the Stacy Building. The Stacy Building is currently unoccupied, and three additional quarterly sampling events will take place.
Status	EGLE is awaiting an NFA proposal.
Formal ICs used	Restrictive covenants, township ordinance
Alternative ICs used	Alternative water (bottled and municipal connections)
IC failures	2011, irrigation well withdrew contaminated water from the TCE plume.
Other remedial activities	Groundwater treatment system, soil excavation, well monitoring, surface water monitoring
Expanding plume	No. Email with Dave Wierzbicki in October 2022 indicated that the plume has not migrated much and that concentrations of TCE are steadily declining.
Timeline	**1952-1973:** General Electric operated at the site; magnets and carbide cutting tools were produced. **1973-2005**: GE sold the property to Hitachi Magnetics Corporation (HMC) in 1973; they operated and produced magnets until 2005. **"Mid 1980s":** Drainage ditch for a lagoon area" (one of the source areas) was backfilled and remediated under the direction of DEQ. (ERM report p. 35). **1986 – 1999**: drinking water wells around property are monitored. (ERM report p. 21) **1988**: At least one monitoring well with elevated TCE levels (ERM report p. 32). Highest level recorded in November at 5,100 ug/L (ERM report p. 28) **1989**: Soil gas study conducted by Beak. TCE found 800 feet northeast, east, and southeast of Storm Water Pond 1. TCE not found around the boiler house. **1991-1992**: Settling ponds decommissioned and excavated (ERM report p. 5) **1992**: Soil and gas survey conducted by Geraghty and Miller. Found TCE on some parts of the property, non-detect at others. **1994**: Soil sampling by BBL. Found TCE on some parts of the property, non-detect at others, metals at all, and PCBS and SVOCs at others. **1997**: BBL excavates suspected contamination locations for additional soil analysis. TCE was detected in 6 of 18 test pits. **1997-1998**: RCs registered for 28 affected parcels (ERM report segment 003). **1998**: Highest TCE reading throughout the monitored history: 5,100 ug/L at well MW7S. EPA drinking water standard is 5 ug/L. **1999?:** TCE found in groundwater, bottled water provided to affected residents (4 homes) **1999:** The municipal water supply extended to residents in the impacted area. The summary does not specifically say when the contamination was discovered.

	1999: Home Township groundwater ordinance requires well abandonment as part of municipal hookup and prohibits ground water use that could lead to human/animal exposure. **2001**: Residential wells on Deja Road north and south of M-46 monitored quarterly (starting in July). **2001**: Harding ESE excavates contaminated soils at one part of the site. **2001**: Harding ESE drills 42 soil borings for additional analysis: 21 reporting TCE, PCE in 22. **2003**: Groundwater extraction system implemented (10/1/03). Well MW7S at 650 ug/L. **2004**: HMC ceases manufacturing operations and shuts down its on-site production wells. **2007**: HMC registers an RC with Montcalm County for the property (prohibits discharges to a particular drain, maintenance of caps, extraction of groundwater – with limited exceptions, restrictions on soil disturbance) (ERM report segment 002). **8/27/2007:** HMC donated the property to the Village of Edmore . **2007**: AMEC excavates additional contaminated soil. Results indicate contaminated soils at the excavation location were removed. **2008**: Buildings demolished down to slabs **2008**: MACTEC excavates additional soils. Does not detect TCE in excavation walls. **2008:** Village of Edmore submits Baseline Environmental Assessment that includes an RC for the areas where the buildings used to exist. **2009:** The village sold a portion of site to Ryan's Equipment . **2011**: In May, a farming operation to the east installed a large volume irrigation well in the TCE plume footprint despite the restrictions. This resulted in spray irrigation of groundwater impacted with TCE. (ERM report p. 22). Following EGLE involvement the property owner with the spray irrigation well had the well abandoned and plugged in January 2012. **2015**: AMEC Foster Wheeler drilled 10 borings in southern part of the site, found TCE in 6. MW7S at 16 ug/L. **2015**: CB&I report states that water treatment has decreased onsite TCE levels except for one monitoring well where concentrations have remained consistent. **Through 2016:** General Electric (GE) and Hitachi conducted additional groundwater investigations to define the extent of the TCE and metals contamination. The TCE plume has migrated over a mile and a half with the leading edge approximately 3,800 feet northeast of the M-46 and Deja Road intersection. TCE and metals are also migrating approximately 2,400 feet from the source areas to the southeast and likely discharging to a pond on the adjacent property to the south. (EGLE site summary) **2016-2021**: GE sampled over 30 private wells near the downgradient edge of the plume and all results were non-detect for the contaminants of concern. **Late 2018:** GE shut down the groundwater treatment system to conduct a rebound study and evaluate the need for continued extraction and treatment of the groundwater. They are also conducting a vapor intrusion study in the vicinity of the occupied buildings on Quicksilver Lane. **7/11/2022**: Email from Dave Wierzbicki (EGLE): "Due to the success of the MNA demonstration after the groundwater treatment system shut down, no detections in the downgradient drinking water wells, and the installation of the vapor mitigation system at the former LODEX building, we anticipate receiving a draft NFA for the facility in the near future." **11/3/2022:** Email from Dave Wierzbicki regarding lack of ICs and restrictions east of Deja Road: "EGLE agrees that additional restrictions and / or institutional controls are needed, and we have asked Hitachi and GE to propose appropriate mechanisms to reliably restrict contaminated groundwater use at the facility. MW-58 TCE concentrations are currently ranging from 4-6 ug/l." (still above drinking water criteria for TCE). And regarding plume migration since 2016: "Semi-Annual sampling of several monitor wells has demonstrated that the plume has not expanded significantly. Please refer to Section 3. of the

	attached April 2022 report that discusses the Mann Kendall statistical analysis of results demonstrating mostly stable or decreasing trends." **7/17/2023**: Email from Dave Wierzbicki confirms that they are still awaiting an NFA, pending the implementation of alternative ICs: "As we have discussed, we are continuing to work with GE and the local health department to implement an Alternate Institutional Control (AIC) for the facility that will supplement the restrictive covenants and use ordinance to minimize exposure risks to the contaminated groundwater. I anticipate that we will see a draft NFA after we get the AIC in place and are assured that the groundwater monitoring trends support moving towards the NFA, perhaps sometime next year"
Public health cases	Unknown
Impacted recreation	Unknown. The only potentially affected surface water was the pond south of the site, but TCE levels near there have not exceeded the GSI TCE threshold of 200 ppb.
Impacted property value	Unknown.

Exposure Pathway Evaluations (prior to implementation)

Drinking water

Were criteria exceeded?	Yes (EGLE site summary p. 5, ERM Current Conditions report p. 30)

Remedial responses implemented

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?
RCs at affected parcels	RC	1997-1998	Yes	Prohibit groundwater use. Yes.
Alt. water (bottled and municipal)		1999	Yes	Uncontaminated drinking water provided. Yes.
Home township GW ordinance	ordinance	1999	Yes	Prohibits groundwater use. No, in 2011 an irrigation well was discovered.
Soil excavation	remediation	2001	Perhaps	This was attempting to remediate the source (preventing plume contribution?)
GW extraction and treatment	remediation	2003	Perhaps	Treatment at the source.

	RC at the site	RC	2007	Yes	Prohibits groundwater use, soil disturbance, and requires cap maintenance.
Were soil criteria to protect drinking water exceeded?	No , p. 39 states that no knowledge of soils exceeding groundwater protection criteria for Area 3 and no known source areas for Areas 1 and 2. (ERM Current Conditions report p. 38-39)				
Remedial responses implemented	**Name**	**Type**	**Year**	**Anticipated to prevent exposure?**	**How? Successful?**

Groundwater surface water interface (GSI)

Were criteria exceeded?	Not in the southern or eastern plume lobes, but yes in northeastern lobe (though it is not expected to reach targeted surface water feature – pond).				
Remedial responses implemented	**Name**	**Type**	**Year**	**Anticipated to prevent venting to surface?**	**How? Successful?**
Were soil criteria to protect GSI exceeded?	No. P. 38 states no known source areas in Areas 1 or 2. P. 39 states that no knowledge of soils exceeding groundwater protection criteria for Area 3. (ERM Current Conditions report p. 38-39)				
Remedial responses implemented	**Name**	**Type**	**Year**	**Anticipated to prevent leaching?**	**How? Successful?**

Soil direct contact

Were criteria exceeded?	Unsure, ERM report (pgs 38-39 does not evaluate this pathway.) However, it is likely that the criteria were exceeded prior to source/soils removal.				
Remedial responses implemented	**Name**	**Type**	**Year**	**Anticipated to prevent venting / leaching?**	**How? Successful?**

Volatilization to indoor air

Were groundwater volatilization to indoor air criteria or screening levels exceeded?	Mostly no. The only time the criteria were exceeded was in 1988 at MW-7S with a TCE Reading of 5,100 on the site of Hitachi Magnetics. ERM report says soils in Areas 1, 2 or 3 do not exceed these criteria.

Remedial responses implemented

Name	Type	Year	Anticipated to prevent exposure	How? Successful?

Were soil volatilization to indoor air criteria or screening levels exceeded?	Unsure. ERM report does not address these criteria.

Remedial responses implemented

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?

Ambient air

Were criteria exceeded?	No. ERM report pages 38 and 39 say soils in all three areas (Area 1, 2, and 3) do not exceed these criteria.

Remedial responses implemented

Name	Type	Year	Anticipated to prevent venting / leaching?	How? Successful?

Source materials

Any present?	Yes, at the former facility source materials were present. Contaminated soils were removed from the former facility and non-detects were reported for the excavated areas.

Remedial responses implemented

Name	Type	Year	Addresses source materials	How? Successful?
Soil excavation	remediation	2001	Yes	Removed contaminated soils from the source
GW extraction and treatment	remediation	2003	Yes	Treatment at the source.

Note: The ERM Current Conditions Report provides a detailed assessment of the exposure path criteria, but that was only at the time of the report (2016) after RCs, ordinances, and water treatment were already in place; it does not assess the exposure pathways at different times in the site's history. Furthermore, it assesses those pathways at different points of the plume. Area 3 includes the source site. For the full picture we must make inferences from the available narratives.

Update: After getting additional report material from EGLE, Table 3-2 lists exposure pathway assessment for each monitoring well.

Hitachi Magnetics Site IC Cost Breakdown

Estimated Social Costs of IC

The expected (average) costs in 2020 dollars are associated with installation and sampling of monitoring wells, and water delivery to affected households. To understand the costs (mainly associated with monitoring well installation and sampling of these wells), consider the timeline over four phases of the project based on the installation of monitoring wells. The phases facilitate structuring costs along a timeline of the project. In phase 1 (approximately 1973-1997) 29 monitoring wells were installed and monitoring/sampling occurred. During phase II (approximately 1998-2004) 16 monitoring wells installed, monitoring/sampling occurred, 21 existing wells were abandoned, municipal water hookups occurred for 21 households, and bottled water was provided to some affected households. In phase III (approximately 2004-2018) 16 new monitoring wells installed and monitoring/sampling occurred in the new and existing locations. Finally, in phase VI (approximately 2017-2020) monitoring of existing locations continued and the groundwater treatment center was shutdown.

Past Costs

Monitoring well installation occurred in phases II-IV and monitoring and sampling occurred in each phase. Early in phase II (1998-2004), TCE was found in the groundwater and bottled water was provided to four affected households. Twenty-one households also received new municipal waterline hookups leading to new utility bills. Additionally, twenty-one wells were abandoned.
Monitoring costs - Installation and sampling

Installation of monitoring well expected costs is $27,016 per well. The expected cost associated with sampling is $1,078 per year.

- Phase I: 29 monitoring wells installed which is 29 X $27,016 per well = $783,469; phase I sampling occurred over 24 years at 29 locations which is 24 X 29 X $1,078 per year = $750,288.
- Phase II: 16 monitoring wells installed which is 16 X $27,016 per well = $432,259; phase II sampling occurred over 6 years at 16 new and 29 existing locations which is 6 X (29 + 16 = 45) X $1,078 per year = $1,041,348.
- Phase III: 16 additional monitoring wells installed which is 16 X $27,016 per well = $432,259; phase III sampling occurred over 14 years at 16 new and 45 existing locations which is 6 X (45 + 16 = 61) X $1,078 per year = $1,961,960.

- Phase IV: no additional monitoring wells installed, but sampling occurred over 3 years at 61 existing locations which is 3 X 61 X $1,078 per year = $197,274.

Water delivery/access costs (in 2020 values) are as follows:

- Bottled water delivery during early phase II: 4 households @ $35 per household per month (approx. expected cost in 2020 dollars) over 2 months which is 4 X 2 X $35 = total expected cost $280.
- Municipal water hookup to 21 households during phase II: 21 households @ $18,450 per household (approx. expected cost in 2020 dollars) which is 21 X $18,450 = total expected cost $387,450.
- Additional cost of the mainline extension for the municipal hookups @ $222 per linear foot (LF) X 1320 LF (approx.) = total expected cost $293,040.
- There were 21 abandoned wells with an average value of $1,150 per well which is 21 X $1,150 = total cost $24,150.
- New water utility bills occurred for the 21 households with new municipal water @ $959 per household per year (approx. 2020 dollars) which is 21 X $959 = total cost $20,139 over 22 years for a total realized cost of $443,058

Potential Costs

Loss in Property Values

Farm production loss

There is one field that could have been impacted (possible that the crop had to be voluntarily destroyed by the owner).

Economic Assumptions:

- In 2020, the average price of corn was approximately $3.5 per bushel.
- In Michigan, the average production of corn was approximately 168 bushels per acre.
- Based on the map, the one field in question was approximately 27 acres in size.

Based on these assumptions, the value of a corn crop, the most likely row crop to be produced in Michigan, would have been:

27 acres X 168 bushels/acre X $3.50/bushel = $15,876 in total value

Recurring Costs (into the future)

Monitoring costs

- New installation and continuing monitoring costs
- New loss in production

Potential Costs

- Health related costs associated with unintentional exposure
- Loss in Property Values
- Farm production loss

Monitoring costs and monthly water bills are the primary sources of recurring and future costs. However, as the plume migrates there is a real potential for future costs for installing new monitoring wells and for future extensions of the municipal water system and well abandonment. The probability of these later costs and expected costs of these later future costs are uncertain and omitted from these cost considerations.

Future costs are discounted to present values in 2020 dollars. We use three discount rates to test sensitivity but select the midpoint of 5% to represent the true social discount rate. While 61 monitoring wells are established, we conjecture, without evidence, that the true number of wells monitored will decrease to 45. We also conjecture no additional residential properties are added to the monthly municipal water system, but this leaves unexamined new property development that is forced onto municipal water rather than allowed to establish a water well system. That is, any new residential structures are assumed to be ambivalent between the use of well and municipal water service.

Using the same 2020 costs and projecting out 20 years, 45 monitoring wells are operated with a per well annual cost of $1,078. Additionally, 21 residential properties continue to incur annual water bills of $959. Collectively, that amounts to an additional cost of $68,649 per year, or $1.37 million over 20 years in 2020 dollars. Discounted at 5%, this presents a present value cost of $855,518 in 2020 dollars.

Unmeasured Costs

Documenting expenditures on technical consulting for documenting the nature, threat and mobility of plumes has been a challenge across all selected sites. Even for orphaned sites, where public funds are secured for site analysis, records of expenditures for initial and follow-up monitoring of the plume are largely absent. In the case of Hitachi Magnetics, two parties are responsible for the status of the site, but little accounting is provided for the investment in monitoring the site or evaluating the performance of mitigation efforts and/or effectiveness of the IC.

Summary

In summary, we estimate that water access and plume monitoring are the primary costs of this IC, resulting in $3.87 million in realized costs from 1997 to 2020. Future costs, including ongoing residential costs for water service and monitoring of the plume will generate $1.37 million in expenditures over the next 20 years. Discounted, that represents a present value cost of $0.86 million.

Hitachi Magnetics Recommendations

1. Do not wait for the transfer of ownership to implement an RC for a contaminated property. Either grant EGLE the authority to record RCs on contaminated properties or amend the statute to require non-responsible property owners to record RCs on their property as part of their due-care obligations.
2. The state's 811 program (MISS Dig) should be expanded to include potential pollutant exposure (via contaminated groundwater or soils).

APPENDIX G: K&L AVENUE LANDFILL SITE SUMMARY

Location	**8606 West K&L Ave** **Oshtemo Township, Kalamazoo County** **Kalamazoo, MI 49009**
EGLE district / contact	Superfund Section Wally Wagaw WagawW@Michigan.gov 517-648-1540
EPA Superfund? (link)	Yes, with EPA as the lead agency. https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0502812
EPA contact	Shari Kolak kolak.shari@epa.gov (312) 886-6151
Contaminants	1,4 dioxane is the primary, among others (benzene, vinyl chloride, dichloroethane, lead, cadmium, zinc)
Exposure pathways	Drinking water
Background	In the early 1960s KL Avenue landfill was a garbage dump for the township but became a county sanitary landfill in 1968 that accepted industrial waste. Five million cubic yards of refuse and an unknown amount of bulk liquid and drummed chemical waste was disposed at the landfill. The landfill was ordered closed by the department in May 1979 when VOC contamination was discovered in ten residential wells. Levels of contamination in the groundwater exceeded federal and state drinking water standards. Many residential wells were closed and 36 homes were connected to municipal water mains by Kalamazoo County. Eleven private wells were replaced with deeper wells. Beginning in 1997, municipal water was extended to residents in subdivisions to the northwest of the site after contamination was found in several domestic wells (suspected of being site-related). The landfill contaminant plume has continued to spread over 2.5 miles long. Three surface water bodies are located nearby (Dustin, Springwood, and Bonnie Castle Lakes). In 1980, as a part of the closure plan, a partial bentonite clay cap was placed on the landfill to reduce soil permeability and retard contaminant migration. Gas monitoring wells, soil gas probes, and gas vents were also installed on the landfill to provide information on methane generation and to vent the facility. The site was placed on the Superfund National Priorities List in September 1983. The EPA initiated a remedial investigation/feasibility study to determine the nature and extent of contamination and to evaluate cleanup alternatives. The EPA issued a Record of Decision (ROD) in September of 1990 identifying the selected cleanup alternative which requires the extraction and treatment of contaminated groundwater and a modified RCRA cap over the landfill. In 1992, Oshtemo Township, Kalamazoo County, the City of Kalamazoo, and The Upjohn Company created the KLA Group (named as such for KL Avenue) for the purpose of facilitating effective implementation of site remedial activities. Pfizer first became involved at the Site in 2003 when it merged with the successor to Upjohn, the Pharmacia & Upjohn Company. Pfizer has since stepped in to take a leading role in the KLA Group on behalf of The Upjohn Company. In 1992, a Consent

	Decree was entered into between USEPA and the KLA Group giving the Group primary responsibility for implementing the USEPA-selected remedial activities. Work on the remedial design was placed on hold pending a study looking into the use of bioremediation as a possible remedy. The potentially responsible parties (PRPs) paid for the entire study, which began in 1996 and was completed in 1997. The results of the study showed that some of the contaminants of concern in the landfill contents and the leachate are indeed biodegradable although time has shown that the rate of biodegradation was insufficient to prevent the expansion of the plume. In 1998 and 1999, the PRPs conducted a mass water level survey of domestic wells and monitoring wells to determine how the local hydrology interacts with the regional hydraulic discharges. The results were evaluated to determine if MNA remains an appropriate remedy for the groundwater plume. The nature and extent of groundwater contamination led the EPA and EGLE to request the PRPs to design and implement some type of source control for the groundwater emanating from the landfill. The PRPs investigated semi-passive, in-situ measures that can manage and remediate contaminated groundwater. A second Focused Feasibility Study was submitted to the EPA and EGLE in Fall 2001 and a third FFS was submitted in the Fall of 2002. Additional groundwater contamination was found in a subdivision about 1.5 miles northwest of the site during residential well monitoring in 1999. Residents were given bottled water until municipal water was provided in the fall of 1999. The PRPs also conducted a groundwater investigation in this area to delineate the problem and eventually installed monitoring wells in the area that are sampled semi-annually. In 2002, EGLE investigated the GSI at the two nearby lakes and detected contamination just below maximum contaminant levels (MCLs). Since the contaminant concentrations were not compared to the GSI criteria, an inquiry was made to the PM asking if data could be provided for comparison to the GSI criteria. The PM conducted a file search and no information regarding the GSI concentrations was found. In 2002, EGLE performed vertical soil gas surveys near the landfill and close to nearby residences to determine if landfill gas migration was an imminent threat at the site. Although elevated levels of methane were found in the soil gas near the landfill, methane was not detected near any of the residences. In 2002, 2005, and 2008, EGLE investigated a salvage yard and four other potential contaminant source areas and determined that the groundwater contamination was from the KL Ave landfill and these other properties were not contributors. The EPA initiated a ROD amendment in 2002 to address potential risk to nearby residents should the plume expand and affect additional residential wells. The EPA established a service area within which the PRPs must supply the residents with municipal water. The service area encompassed all the groundwater contamination known at the time and included a small buffer zone. With EGLE’s concurrence, the ROD amendment was signed by the EPA on February 27, 2003. Oshtemo Township (one of the PRPs) extended municipal water to residents both within and outside the EPA defined service area in 2002. These areas are where contamination existed at levels below the federal MCLs. EGLE contributed $82,000 to supply clean water to an area that

	had not been linked to the landfill but where groundwater contaminants exist at concentrations greater than the Part 201 drinking water criteria. In 2004, Oshtemo Township requested an informal resolution action by the EPA to reevaluate the EPA's decision to uphold the ROD and require an impenetrable cap on the landfill. The dispute was dropped by the township and the landfill capping resumed. It was completed in October 2006. The PRPs agreed to install a portion of the Enhanced Landfill Gas Extraction system as part of the cap construction. In 2008, the PRPs converted the existing passive gas venting system to an active system to accelerate the landfill contaminant destruction prior to leaching to the groundwater. 1,4-Dioxane was discovered in 2004 as a new landfill contaminant in both monitoring and residential wells at concentrations greater than the drinking water criterion throughout the site. It was detected at the downgradient edge of the buffer zone established in 2003 and forced consideration of an expanded buffer zone (an additional 1,000 feet of property). The PRPs submitted a revised petition to substitute MNA for the ROD-specified pump and treat of the groundwater. EPA issued a ROD amendment in 2005 to change the groundwater remedy from pump and treat to MNA (https://semspub.epa.gov/work/05/919490.pdf). EGLE did not agree with the amendment due to the uncertainties with the defined extent of the contamination to the northwest and the lack of ICs to limit access to the contaminated groundwater (see the EGLE's legislative report for West K&L Landfill). EPA released the first Five Year Review in May 2009. It concluded that the remedy was protective for the short-term. Long-term protectiveness relies on compliance with the ICs and long-term stewardship of monitoring, maintaining, and enforcing the landfill and groundwater ICs. Stewardship will require amending the proposed GRUZ (Groundwater Use Restricted Zone) and implementing a county wide groundwater use ordinance. As the groundwater plume expands, the PRPs extend municipal water to homes in the affected areas. In November 2013, municipal hooks were provided to seven residences that accepted hook up agreements. EPA issued the Second FYR in May of 2014. The EPA deferred protectiveness of the current remedy until several actions are taken (source control/contingent remedies to reduce dioxane in the groundwater; continue characterizing contamination and movement NW of landfill; monitoring methane gas & take appropriate measures if needed). A public hearing was held on June 2, 2015, regarding the GRUZ. The PRPs had been meeting with Kalamazoo and Van Buren Health Departments since 2013. Kalamazoo County approved the PRPs application for a GRUZ on December 2, 2015. This formally implements ICs where groundwater results have been reported above the Part 201 criteria and a 1,000 ft downgradient buffer zone. The Kalamazoo Board of Commissioners approved the GURZ on January 19, 2016. The addendum to the Second FYR was signed in April 2017. EPA's conclusions follow: Active remediation of the 1,4-dioxane plume is needed to reduce concentrations in groundwater and achieve a decreasing trend in wells at the leading edge of the plume. Post treatment, the rates of attenuation should be reevaluated to determine if cleanup goals can be met within a reasonable time frame. The EPA recommends the PRPs fully evaluate contingent remedial

	alternatives and emerging technologies and implement a full-scale contingent remedy within two years after EPA amends the ROD. To address the fact that groundwater contamination was not fully characterized to allow for a protectiveness determination in 2014, four profile borings were drilled (DW-47, 48, 49, and 51) in March 2016. Vertical aquifer profile from these borings showed 1,4-dioxane was either non-detect or below the EGLE emergency rules criterion of 7.2 ppb. In June 2016, three additional monitoring wells were drilled by the PRPs (P-78, 79, and 80). Sampling of these wells in July showed concentrations of 1,4-dioxane in these wells were below 5.2 ppb. However, a residential water supply well located along Fish Hatchery Road, which is downgradient of these monitoring wells, showed a 1,4-dioxane concentration of 8.4 ppb. The downgradient extent of the contamination does not appear to be fully characterized to reflect the DEQ emergency rules of 7.2 ppb. To address dissolved methane concerns in the 2nd FYR PRPs conducted interviews with 5 homeowners to see if they are using the groundwater for irrigation and if irrigation well components are located inside an enclosed building. Four homes had dissolved methane in their irrigation well water below the screening level of 10,000 ppb (the Part 201 Flammability and Explosivity Screening Level). One home had dissolved methane in their irrigation water slightly higher than 10,000, but indoor air sampling confirmed methane was not in indoor air. The Third FYR was released by EPA in April 2020, with the following points. The remedy for the K&L Avenue Landfill Superfund Site currently protects human health and the environment because the remedy prevents direct contact with landfilled waste and eliminates risks to public health associated with potable groundwater use by connecting homes that exceed groundwater cleanup criteria to the Kalamazoo County water supply, or by providing an alternate water supply (i.e., new replacement wells) at impacted homes in VBC, or by providing bottled water. A Kalamazoo County groundwater ordinance is also in effect to prevent potable groundwater use and the installation of new potable wells. However, in order for the remedy to be protective in the long-term, the following actions need to be taken: issue a decision document to change the 1,4-dioxane DWC to 7.2 µg/L and to include ICs and alternate water supplies for affected homes in VBC; submit a Contingent Remedial Alternatives Evaluation Report that fully evaluates potential contingent remedies [including EISB (enhanced in situ bioremediation)] against the nine NCP criteria, to achieve groundwater RAOs and prevent further migration of the 1,4-dioxane plume into VBC; issue a decision document to incorporate the selected contingent remedy; implement the selected contingent remedy; submit an amended GRZ application to Kalamazoo County that includes the additional Kalamazoo County properties affected by the change in 1,4-dioxane DWC (plus buffer); pursue a groundwater ordinance with VBC or place deed restrictions on affected VBC properties; and revise the ICIAP to incorporate all LTS (long-term stewardship) components. The December 2020 Golder and Associates report re-evaluates contingent remedies (enhanced in-situ bioremediation and P&T). It argues that current remedy (MNA) is still protective of human health and least costly, and that the other remedies would be significantly more expensive, be more disruptive to the community, have a larger carbon footprint, and have only marginal, localized impacts on the plume while not significantly reducing the time estimate for MNA to bring the plume down to safe levels (50 years). The EGLE Legislative Report states that the agencies have reviewed the Addendum to the Third FYR, but that document does not exist on the EPA's website for K&L Ave Landfill. It appears that

	the information in the supposed addendum is the same as what is in the Third FYR. (PM noted he is not aware of an addendum to the Third FYR so reference to an addendum is an error). There is an Explanation of Significant Differences (ESD) document on the EPA website which was released in August 2021. The ESD revises the 1990 ROD and its amendments. It revises the drinking water criterion of 85 ppb in the ROD to the current DWC of 7.2 ppb for 1,4-dioxane. The ESD also articulates alternate water supply and groundwater IC requirements for properties in Van Buren County that are located outside the jurisdiction of Kalamazoo County, and where no municipal water supply source is available to residents of Van Buren County. Specifically, it documents a decision to allow: 1) the use of properly located replacement wells, as an alternate water supply source, for properties within the proposed Van Buren County groundwater restricted zone area and 2) potable groundwater use at properties within the proposed Van Buren County groundwater restricted zone, provided that data and other records demonstrate that the criteria listed under Section IV of this ESD continue to be met. **From the EGLE MPART website for K&L Ave. Landfill** https://www.michigan.gov/pfasresponse/investigations/sites-aoi/kalamazoo-county/west-kl-avenue-landfill Groundwater samples were taken and analyzed for PFAS in October of 2019 (2 monitoring wells adjacent to the landfill and two MWs downgradient. "On January 27, 2020, EGLE received the sample results: the highest PFOS + PFOA groundwater sample result was 153 ppt." "On April 20 and April 21, 2020, Golder Associates Inc., collected the second round of PFAS groundwater sampling from 10 monitoring wells (stepped out from the 2019 samples). Trace levels of PFAS compounds were detected in each sample. The Part 201 criterion of 70 ppt (PFOS and PFOA combined) was exceeded (at three locations: P-28, P-30, and P-31 with combined PFOS and PFOA concentrations of 90 ppt, 132 ppt and 117 ppt (primarily PFOA), respectively." [(EGLE promulgated state drinking water standards for 7 individual PFAS compounds on August 3, 2020; two of those became Part 201 cleanup criteria (PFOS & PFOA)]. Additional sampling proposed by the West KL PRP Group at 13 locations (17 monitoring wells) was anticipated to occur in July 2020 pending USEPA approval. No further information is available at this website or in the legislative report. This website does not have the Spring 2021 sampling data that was provided by the PM. **The following information was obtained for the EGLE PR project manager:** "Data Summary Report- Spring 2021 Annual RA Groundwater Monitoring" dated May 26,2021. Table 2 gives a summary of analytical results and Figure 6 depicts PFAS Concentration Map. A. These wells located within the confines of the LF, were sampled for PFAS in Spring 2021: Trace levels of PFAS were detected in each sample except P-34 and P-46 (non-detect). PFOS was detected in 4 wells East of Dustin Lake (P-31, P-48, P-49, and P-51) above Part 201 of 16ppt PFOA was detected above Part 201 of 8ppt in 22 wells in the vicinity of 1st street. B. "Fall 2021 Residential PFAS Monitoring Results" dated September 12, 2021. Table 2 contains monitoring results for three wells slated to be exempt by KHD for irrigation purposes pending PFAS sample results.

	The three wells at West KL Ave. (9135, 9237 and 9825) sampled for PFAS in September 2021 came in clean/below 201 criteria. The PRPs resampled those three wells for confirmation in the Spring of 2022. (See attached Semi-annual DSR Report, Table 2).
Status	Open
Formal ICs used	Restrictive Covenant at the source/landfill property was filed in April of 1994. Restricts interference with response actions; no extraction of groundwater for any purpose; no activities or uses that affect the integrity of the cap or interfere with monitoring or treatment at the facility. Groundwater Restricted Zone (GRZ) pursuant to the Kalamazoo County Sanitary Code approved by the Kalamazoo County Board of Commissioners at their December 1, 2015, meeting. The GRZ incorporates the West KL Landfill property (87 acres) and areas to the west along West KL Ave., North First St., Chadds Ford Way, southern portions of Wickford Drive and West Main Street to the north of their contiguous properties. The GRZ comprises approximately 414 properties in the western portion of Oshtemo Twp. **Pending ICs:** Per the PM on July 2023: The KLA Group (PRPS) have provided a revised GRZ map for Kalamazoo Co. depicting changes to the groundwater restrictions based on the revised 7.2 ppb criterion for 1,4-dioxane plus a buffer zone. The agencies are currently reviewing the proposed GRZ. Approval pending. **Per PM July 2023:** EPA & EGLE have reviewed & approved the draft ordinance for Van Buren Co. And the PRPs are currently working with the county to have it approved by the County Commission. **From the 2021 Explanation of Significant Differences (to amend the 1990 ROD):** in 2019 the KLA group assessed the feasibility of extending the Kalamazoo Co. Municipal water supply to Van Buren Co. residents. There are significant legal and administrative challenges and expenses (approx. $5 million to connect 43 homes). There are also significant administrative challenges to coordinate between three different municipalities and legal jurisdictions (City of Kalamazoo, Almeda Twp, and Oshtemo Twp). As a result, they are pursuing a groundwater restricted zone in VB Co. The KLA Group is working with the Van Buren/Cass County District Health Department to amend the District's Environmental Health Code to include a process to establish a groundwater "Restricted Zone" in the affected area in Van Buren County as the preferred approach to establish the needed ICs. (See ESD for details.) As an alternative to municipal water, the PRPs are providing clean water via installation of replacement wells screened in the deeper, uncontaminated portions of the aquifer at homes both above and below the DWC of 7.2 ppb for 1,4-dioxane. EPA received a request from the KLA Group to amend the Site remedy to allow the use of clean aquifers for private water supply wells in this county so that properly located and installed private wells can continue to be used for water supply purposes and appropriate ICs can be developed for groundwater use in Van Buren County. To evaluate the protectiveness of clean aquifers for potable use in Van Buren County, EPA requested that the KLA Group perform a hydrogeologic assessment of conditions in the vicinity of 22nd Street, Fish Hatchery Road, and Sunset Drive. The results of this assessment are described in a technical memorandum entitled "Revised Hydrogeologic Assessment – 22nd Street, Fish Hatchery Road and Sunset Drive Area, Van Buren County, West KL Avenue Landfill, Kalamazoo, Michigan" dated July 31, 2020 (Revised Hydrogeologic Assessment). Based on the information in this assessment, EPA has determined that the use of existing private wells (subject to the criteria under Section IV of this ESD) is protective of human health. Additionally, EPA has determined that

	use of properly located replacement wells (subject to the criteria under Section IV of this ESD) is protective of human health and that these wells can be used as an alternate potable water supply source at this time. (See ESD for details.)
Alternative ICs used	Bottled water; Municipal hookups; Replacement wells in VB Co.
IC failures	None reported
Other remedial activities	Source control (soil and clay cap, then an impermeable cap) Residential well monitoring and sentinel monitoring well installation Pump and treat planned, but never implemented Monitored Natural Attenuation (MNA) Active and passive gas venting systems at the source. Other remedial activities being evaluated to address 1,4-dioxane
Expanding plume	Yes, currently entering Van Buren County.
Timeline	**Early 1960s**: K&L used as a township garbage dump **1968**: became a county sanitary landfill accepting industrial waste **1979**: pollutants detected in residential wells, State closes landfill, Kalamazoo County starts providing water to affected homes **1980**: soil and clay cap installed at source **1983**: Added to the NPL **1986**: EPA RI/FS finds plume is expanding **1986-1988**: EPA conducts RI/FS **1990**: EPA first ROD calls for pump and treat, monitoring, and well abandonment **1992**: Consent Decree between KLA group and EPA **1994**: RC recorded. Restricts groundwater use on the landfill property and adjacent properties. Restricts uses and activities on the landfill property. **1998**: Contaminants migrated to Springwood Hills subdivision **2000**: KLA starts residential well monitoring program **2003**: ROD amendments: establish service area within which municipal water must be provided. **2004**: 1,4-Dioxane found at edge of buffer zone, zone extended 1,000 feet **2005**: ROD amendments (recommendations: expanded municipal hookups, well abandonment, county ordinance, MNA replacing P&T, 5-year reviews) **2006**: KLA installs an impermeable cap **2007**: MNA implemented **2008**: passive gas venting system converted to active landfill management (extraction) system with enclosed flare **2014**: KLA submits application to Kalamazoo County for a Groundwater Restricted Zone. **2015**: Methane investigation near Skyview Estates. Not an indoor air threat. **2015**: KLA MNA report contends it is effective at protecting human health, other remedies not needed **2016**: GRZ goes into effect **2016**: (November) EGLE issues 6-month emergency rule lowering 1,4-dioxane DWC to 7.2 ppb **2017**: (October) EGLE promulgates rule change for 1,4-dioxane DWC to 7.2 ppb 2017: EPA and EGLE disagree with KLA that MNA is adequate, call for evaluation of remedial alternatives (2017 FYR Addendum) **2018**: KLA evaluates in-situ biodegradation (89% dioxane reduction but limited scope: 10 ft.)

	2019: KLA GW Model report says MNA will leave small residuals of 7.2 1,4-dioxane in 50 years. Other remedies still not needed. KLA samples 58 wells in Van Buren County, all non-detect. 2020: April: EPA issues 3rd FYR. "PRP should submit a contingent remedial alternatives evaluation report." **2020**: December: Golder and Associates submits a report evaluating remedial options (in-situ bioremediation and P&T), still argues that MNA is the best approach. **2021**: IC: GRZ expansion proposed for KC; PRPs propose GW ordinance for VB Co. (These were recommendations in the Third FYR – asked PM for status) **2019-2022**: PFAS sampling. **Feb. 2022**: Email discussion with Wally Wagaw states that the KLA groundwater model is being reviewed by EGLE, and that the model boundary has been extended upwards of 6,000 feet west of Campbell Creek.
Public health cases	None on the record
Impacted recreation	None on the record
Impacted property value	None on the record

Exposure Pathway Evaluations (prior to implementation)

Drinking water

Were criteria exceeded?	Yes, EPA's Third Five Year Report (p. 8). Benzene, vinyl chloride & dichloroethane > MCLs. Exceedances of Part 201 DWC of 7.2 ppb for 1,4-dioxane reported much later. No EGLE exposure evaluation available.

Remedial responses implemented

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?
Municipal hookups	Alt IC	1979+	Yes	Clean municipal water provided. Yes
Soil and clay cap	Other remedial (IC? See notes below)	1980	No	
Restrictive covenant	RC for the landfill property	1994	Only at the landfill. Yes	No use of groundwater. No development or construction or use of the property or activities that will affect the integrity of the cap. Yes.
Impermeable cap	IC (by the KLA Group)	2006	No	Does reduce leaching.

	Residential and sentinel monitoring	Other remedial		Possibly	Clean water will be provided if contamination detected.
	MNA	Other remedial	2007	No	
	Groundwater Restricted Zone	Kalamazoo County Ordinance (per Sanitary Code)	2015	Yes	Use of contaminated GW prevented and clean municipal water provided. Yes.
Were soil criteria to protect drinking water exceeded?	Not evaluated				

Remedial responses implemented

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?

Groundwater surface water interface (GSI)

Were criteria exceeded?	Unknown: The EGLE Legislative Report states that in 2002, EGLE investigated the GSI at the two nearby lakes and detected contamination just below the MCLs (Fed DW standards). The PM did a file search and did not find information related to an appropriate GSI investigation. No EGLE exposure evaluation to rely on.

Remedial responses implemented

Name	Type	Year	Anticipated to prevent venting to surface?	How? Successful?

Were soil criteria to protect GSI exceeded?	Not evaluated

Remedial responses implemented

Name	Type	Year	Anticipated to prevent leaching?	How? Successful?

Soil direct contact

Were criteria exceeded?	Likely YES with industrial waste in the landfill. In EPA's Third Five Year Report (p. 8) the answer is no, but that was based on 1989 risk assessment (concentrations of surface soils at the landfill did not exceed EPA cancer and noncancer acceptable risks). No recent information reporting soil concentrations compared to Part 201 SDCC cleanup criteria (i.e., no EGLE exposure evaluation available).

Remedial responses implemented

Name	Type	Year	Anticipated to prevent direct contact?	How? Successful?
Soil and clay cap	Other remedial (part of the closure plan)	1980	Yes.	Prevents contact with waste and contaminated soil. Yes.
Restrictive covenant	RC	1994	Yes	No development, construction, or any type of use of property. No activities that will affect the integrity of the cap. Runs with the deed. Yes.
Impermeable cap	IC (by KLA Group)	2006	Yes	Prevents contact with waste and contaminated soil. Yes.

Volatilization to indoor air

Were groundwater volatilization to indoor air criteria or screening levels exceeded?	No (EPA's Third Five Year Report p 8, p. 28) Vapor Intrusion not considered a threat (EPA's 2005 ROD p. 8). **NOTE** this was only related to methane. An exposure evaluation for this pathway for non-methane VOCs was not located.

Remedial responses implemented

Name	Type	Year	Anticipated to prevent exposure	How? Successful?
Municipal hookups	Alt IC	1979	No. VI not identified as concern	Does not address VIAP
Restrictive Covenant	RC	1994	No. VI not identified as concern	Does not address VI but does not allow residential, commercial, or industrial use of development on landfill facility

County Ordinance	IC	2016	No. VI not identified as concern	Does not address VIAP

Were soil volatilization to indoor air criteria or screening levels exceeded?

No (EPA's Third Five Year Report p 8, p. 28) Vapor Intrusion not considered a threat (EPA's 2005 ROD p. 8). **NOTE**: this was only related to methane. An exposure evaluation for this pathway for non-methane VOCs was not located.

Remedial responses implemented

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?
Municipal hookups	Alt IC	1979	No. VI not identified as concern	Does not address VIAP
Restrictive Covenant	IC	1994	No. VI not identified as concern	Does not address VI but does not allow residential, commercial, or industrial use of development on landfill facility
County Ordinance	IC	2016	No. VI not identified as concern	Does not address VIAP

Ambient air

Were criteria exceeded?

No (EPA's Third Five Year Report p 8). NOTE: This is based on a 1989 risk assessment. No recent exposure evaluation for this pathway has been located.

Remedial responses implemented

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?
Restrictive Covenant	IC	1994	No. Ambient air not identified as concern	Does not address ambient air but does not allow residential, commercial, or industrial use or development on landfill property
Impermeable cap	IC (by KLA Group)	2006	No. Ambient air not identified	Did not address ambient air specifically but does significantly reduce volatiles & particulates

				as a concern	

Source materials

Any present?	Yes. Contents of the landfill.				
Remedial responses implemented	**Name**	**Type**	**Year**	**Addresses source materials?**	**How? Successful?**
	Soil and clay cap	Other remedial	1980	Only direct contact with	Prevents direct exposure to source materials but does not prevent continued leaching.
	Restrictive Covenant	IC	1994	Only direct contact with	Prevents direct exposure to source materials but does not prevent continued leaching.
	Impermeable cap	Other (IC?)	2006	Yes	Prevents exposure and leaching, but sources remain in place and continue to contribute to the plume to some extent.

Additional notes:

EPA’s Third Five Year Report identifies the impermeable cap as an IC (Table 2, p. 20)

In EPA’s 2017 Addendum to the 2nd Five Year Review, EPA states:
“EPA Position on MNA/Contingent Remedy: The record for at least the last 10 years of data does not support a finding that the current MNA remedy is working for 1,4-dioxane. The leading edge of the plume continues to expand (as discussed below) especially at lower levels. Even though the PRP modeling predicts the 1,4-dioxane plume will attenuate below 85 ppb within 30 years, the 1,4-dioxane plume (under decreasing source and contingent remedy scenarios) will remain above 10 ppb, even after 50 years. This is higher than the DEQ's emergency rule 1,4-dioxane drinking water criterion of at or above 7.2 ppb. Therefore, MNA is not acceptable. In addition, the PRPs' model prediction that the greater than 85 ppb 1,4-dioxane plume will substantially collapse within 10 years with the current MNA and source control remedy is not supported by the previous ten years of data.”

“EPA agrees that the model predicts no significant difference in the greater than 85 ppb 1,4-dioxane plume configuration after 10 years of active remediation (contingent remedy scenarios) compared to the current MNA remedy. However, the model does predict significant changes in the greater than 10 ppb hut less than 85 ppb 1,4-dioxane plume configuration after 30 years of active remediation (pumping at Skyview Estates) compared to the current MNA remedy. (See Figures 15a-c of the draft Groundwater Performance Monitoring Report). After 30 years of pumping at Skyview Estates, the greater than 10 ppb hut less than 85 ppb plume shrinks and retracts toward 22nd Street whereas after 30 years under the current MNA remedy, the greater than 10 ppb plume expands further downgradient into Van Buren County (see Figures 13a-c of the draft Groundwater Performance Monitoring Report). EPA could not verify the PRPs' statement that implementation of a contingent remedy will not reduce remedial time frames as no tables were provided in the modeling report showing the estimated 1,4-dioxane concentrations under the contingent remedy scenarios."

EPA calls on the KLA to re-evaluate contingent remedies.

In December 2020 Golder and Associates submits a report evaluating 2 alternatives (enhanced in-situ bioremediation and pump and treat). They contend that MNA is still protective of human health and least costly, and that the other remedies would be significantly more expensive, be more disruptive to the community, have a larger carbon footprint, and have only marginal, localized impacts on the plume while not significantly reducing the time estimate for MNA to bring the plume down to safe levels (50 years).

This came after EPA's 2020 3rd FYR. EPA's most recent document (the 2021 ESD) does not address Golder's assessment.

The project team posed three questions to the EGLE PM on 9/1/23. The questions and the answers received on 10/18/23 are below:

1. What is the status of the re-evaluation of the Golder groundwater model boundaries?

"As I also indicated in my last e-mail, the MODELING effort continues. The contractor is collecting more field data to incorporate in the MODEL. They will incorporate analytical results of the new monitoring well installed between Fish Hatchery Road and Campbell Creek; incorporate the results (1,4-Dioxane concentrations) of the Fall 2023 semi-annual monitoring results into the model; conduct calibration run with biodegradation; conduct calibration run with no degradation etc. We have a conference call scheduled in November to discuss the updated model. We anticipate to wrap-up this modeling effort by the beginning of 2024."

2. Why was there never an evaluation of volatilization to indoor air pathway?

"As I mentioned to you in my e-mail dated 8/30/23, VIAP has not been deemed to be an issue at this site (at least since I took over the project) for the following reasons: the KLA Group and the agencies have been closely watching the status of the VOCs at this site over time. We have observed that the concentration of the VOCs has been steadily decreasing over the years, possibly due to localized natural attenuation (MNA). One can easily compare the original iso-concentration plume map (figure) to the current isopleths for verification. Geochemical conditions have changed throughout the plume over time and will likely continue to change. More importantly, there are no structures, or residential units near the landfill for VIAP to be of concern." Methane from the Landfill is being extracted and sent to the flare via pipes.

3. What was the official response from EGLE and EPA to the alternative remedies Golder and Associates proposed in December 2020?

"With respect to the "alternative remedies" proposed by Golder Associates Inc., the agencies' position all along has been that regardless of the MODEL outcome, an active remedy (source control) at the Landfill is needed to contain the plume and meet RAOs. Without source control and an active remedy, MNA on its own will never achieve RAOs at this site.”

K&L Landfill Site IC Cost Breakdown

Estimated Social Costs of ICs

Estimating the social costs of the Institutional Control (IC) is complicated by many confounding issues, including the size of the plume and its eventual migration, and changes in regulation that saw a decrease in allowable parts per billion of a key COC at the K&L site. This is further confounded by lack of dated records of action, like date of well closure or municipal water hookup, for instance to recognize the timing or value of both public and private costs in managing and responding to the IC of this site.

To document and account for expenditures, various EPA and EGLE reports were reviewed. Specifically, references to actions were noted and any reference to expense is recorded. Such reports include Five-Year Reviews and Records of Decision (RODs), amongst others. Additionally, requests for information were made to the KLA Group requesting accounting for direct and ancillary costs associated with specific aspects of the site, including the costs of administering and monitoring the site, costs of specific actions, like installation of a non-permeable cap or installation and sampling from monitor wells. Requests for information also inquired on the number of properties impacted and social and private costs of implementing mandates imposed on such properties.

For measuring the economic costs of the IC, we broke the site’s timeline into four distinct phases, plus ongoing – which provides a best estimate of the ongoing costs expected well into the future. Specifically for the K&L analysis, each phase is associated with a set number of household properties impacted. Recurring costs within a phase are assumed to persist for all years of the phase – possibly resulting in an overestimate of the total cost for that category. This simplifying assumption is required because there are no consistent records of when recurring expenditures started or ended for each of the individual cases.

Phase	Start Year	End Year	Years	Res. Properties	Monitoring Wells
Phase 1	1979	1994	15	22	1
Phase 2	1995	2006	11	263	16
Phase 3	2007	2016	9	421	26
Phase 4	2017	2022	5	513	32
Ongoing	2023	+	Ongoing	513	32

Table G-1: K&L Landfill Cost Phases

Phase 1 started when the state of Michigan closed the K&L Landfill in May 1979, acknowledging an environmental affliction and restricting property use around groundwater extraction. It ended in April 1994 with the implementation of the first ROD, first negotiated in 1992 establishing restrictive covenants on groundwater extraction around the affected area. Phase 2 concluded in 2006 with the implementation of the ROD amendment that established a strategy of monitored natural attenuation (MNA). The third phase concluded with the establishment of the Groundwater Restriction Zone (GRZ) ordinance which creates a blanket restrictive covenant on groundwater use within the affected area in Kalamazoo County and reserves capacity to impose the same on affected properties in Van Buren County. The final phase brings the site up to date for the start of this project in 2022. From this point annual costs are projected into the future and discounted to 2022 dollars.

Within each phase, both one-time and annual costs are recorded on a per-unit basis. That is, for costs realized at the residential property level, the costs are reported as the average cost per residential property, times the number of residential properties impacted in the phase. If it is an annual cost, the cost per unit estimate is further multiplied by the number of years in the phase.

The unit bases for cost estimates include site costs, per-residential unit/household costs and per-specified-unit costs. The latter include the costs of digging a monitoring well, for example, where the actual count is not related to the size or number of households impacted. Costs recorded per residential unit entail all those costs that are incurred by more than one residential property, like supply of bottled water as a temporary step to supplying potable water not from the contaminated ground water. Such costs accrue only to residential lots that realized that expense each year and only for those years where that expense was realized. Finally, site costs are those costs that are specific to the site as a whole, like administrative costs, or cost to compile an EPA report on the status of the site, etc.

Actual reported costs at the K&L site were recorded on a per-unit basis as a point estimate. Where point estimates were not available, a range of costs were developed based on internet searches and other site reports representing a maximum and minimum expected per-unit cost. The midpoint between those two extremes were then recorded as the point estimated, per-unit cost for that category.

Cost Estimates

Water Provision Costs:

Water provision costs are the costs associated with supplying existing houses with potable water, either during a transition from private well access to groundwater to municipal hookup and delivery, if required. Given the blanket nature of the GRZ ordinance, which restricts well drilling and well water in the afflicted area, nearly all existing wells in the impacted area were eventually subject to forced cessation. In total about 525 residential lots were required to connect to municipal water. Accordingly, through phase 4, 513 residents lost access to their existing wells or were restricted from use of groundwater and connected to municipal water.

Alternatively, 23 wells appeared to persist through further drilling through the underlying confined aquifer, not impacted by the COCs with additional drilling costs. A total of 375 wells required proper capping to restrict access and reduce the potential for further contamination from surface waters. In addition, approximately 162 houses required water delivery during Phase 2 and nine required water delivery in Phase 3 as stop-gaps until municipal water could replace their contaminated well water. Finally, residents placed on municipal water systems are required to pay monthly water bills. .

Point estimates of the per household cost of connecting to municipal water systems is approximately $18,450 based on calculations using estimates provided by a 2020 legislative report (EGLE 2020). Over the 525 residential plots impacted, we estimate that total realized costs of municipal water hookups to be around $9.69 million. These hookups coincide with monthly municipal water bills totaling $4.24 million from Phase 1 through Phase 4 based on average annual costs of $612 per household (KLA Group 2022). Those residential properties that were able to avoid municipal water hookup by drilling to a deeper, confined aquafer had an additional drilling cost of about $23,600 each, resulting in an additional cost of $542,800. Closing, or capping existing residential water wells costs about $4,000 each, leading to an additional realized cost of $1.50 million (KLA Group 2022). Finally, the approximately 171 households requiring temporary water delivery incurred an additional realized cost of $48,960. Collectively, we estimate that about $21.74 million has been spent up to 2022 for access to potable water in the aftermath of the IC.

Phase	Phase 1	Phase 2	Phase 3	Phase 4	Total
Households Requiring Water Delivery	0	162	9	0	171 Households
Households Requiring Municipal Water Connection	36	123	65	0	224 Households
Households Requiring Well Drilling	11	0	0	12	23 Households
Abandoned Wells	12	217	97	49	375 Households
Total of New Water Utility Costs by Homeowners	36	123	65	301	525 Households
Total Remediations' Needed	95	625	236	362	1,328 Remediations
Minimum Costs	$1,497,780	$4,121,300	$1,701,150	5,914,660	$13,234,890
Maximum Costs	$2,884,480	$7,401,325	$2,883,200	$8,571,585	$21,740,590
Total Average Costs	$1,853,080	$5,067,850	$2,144,530	$6,953,710	$16,019,170

Table G-2: K&L Landfill Water Provision Costs

Property Value Losses

Because the K&L plume impacts third-party properties and places restrictions on those property uses, there is a potential that property values will be negatively affected. Measuring the pre- and post-IC property values against comparable properties over the same period was beyond the scope of this study. However, a review of academic and popular press articles addressing how property values respond to intrusions of groundwater plumes is informative. The findings favor that residential property values are not impacted by the presence of groundwater contamination (Malone and Barrows 1990, Page and Rabinowitz 1993, Dotzour 1997, Guignet 2013). However, more recent studies employing more sophisticated estimation techniques have shown some evidence of a negative impact on residential housing values. Case, Colwell et al. (2006) tracked properties over multiple sales to determine that groundwater contamination initially reduces the selling prices of residential condominiums by 4.7 percent. Recognizing that public memory is limited, time may reverse any negative consequences of the initial public announcement of contamination. Boyle, Kuminoff et al. (2010) shows that groundwater contamination may negatively affect the price of residential real estate, but that effect fades over time (Kiel 1995). Others show no effect even before and after site remediation (Guignet 2013). That is, when the contaminant is made public, potential buyers and sellers will bid down the property value, but as memory of that contaminant fades, the price will return to parity with equitable properties. In the long-run, property values are not impacted.

The findings may differ, however, for development of properties for residential use, and for commercial properties. Mercer and Morgan (1982) show that an IC will reduce developer interest in developing virgin or agricultural property into residential housing. It also has significant bearing on property values for non-residential uses, as commercial and industrial buyers fear the transference of liability from the original property owner to the new (Page and Rabinowitz 1993). A study across five communities in Minnesota determined that losses in commercial property values and commercial property development due to groundwater contamination resulted in a loss of $20.7 million (2022 prices) in property tax revenues (Freshwater Foundation 1989, Page and Rabinowitz 1993). In addition to properties directly impacted by the groundwater contamination, periphery properties may also experience property value losses due to stigma effects from proximity to an environmental toxic site (McCluskey and Rausser 2003, Messer, Schulze et al. 2006). Estimating the effects on non-developed properties or commercial/industrial properties was beyond the scope of this study but remains an area of consideration.

Site Management Costs
Site management costs are all those costs associated with maintaining the site, undertaking the annual and semi-annual reporting requirements imposed by relevant state, local and federal agencies and implementing policy directives at the site, including monitoring of conditions. Since Phase 1, 64 monitoring wells have been installed, where each corresponds with a fixed installation cost of $45,700 (National Research Council 2013) and recurring monitoring costs totaling $672,208 up to 2022 (KLA Group 2022). The remaining site-specific costs were provided directly by the KLA Group (2022), including laboratory analysis costs, which were reported in full up to 2022 as $1,343,333, reports to regulating agencies totaling $1.03 million to produce and the pursuit of ordinances creating the GRZ added another $100,000 in site expenses. Finally, annual operating overhead was determined to be around $16,500 per year, or about $660,000 through 2022. Collectively, realized site expenses totaled $5.27 million through 2022.

Site Costs	Phase 1	Phase 2	Phase 3	Phase 4	Totals
Wells Installed	1	15	10	6	32
Well Installation	$45,700	$685,500	$457,000	$274,200	$1,462,400
Well Sampling	0	0	$361,958	$310,250	$672,208
Well Laboratory Analytics	0	0	$723,333	$620,000	$1,343,333
Reports to Agencies	0	0	$600,833	$429,167	$1,030,000
Annual Operating Costs	$247,500	$181,500	$148,500	$82,500	$660,000
Ordinances	0	$50,000	$50,000	0	$100,000
Total Site Management Costs					$5,267,942

Table G-3: K&L Site Management Costs

Compliance Costs
Compliance costs entail both explicit and implicit expenses accruing to private and public property owners in the impacted area for meeting compliance under the IC, or in this case, the GZR ordinance. While there are many compliance issues associated with toxic spill sites and costs associated with meeting those compliance, most such costs or restrictions are immaterial to large-picture concerns. Of those costs that are material, most of the explicit compliance costs have already been accounted for in the above estimates. However, some implicit compliance costs may warrant discussions. Principle among these may be unmeasurable costs like the lost option for irrigating farmland from groundwater sources or the option for direct access to groundwater

rather than through a municipal water system. Such costs are often reflected in property values. As we have discussed, at least residential property values tend not to be adversely impacted by groundwater contamination, at least in the long run if municipal water sources are available. We did not identify industrial use restrictions that would pose an evident social cost, though there may be unobservable opportunities foregone. Consider a water bottler or the precision die machining firm, which otherwise may target the local area for operation. Without the option of well water access, such companies may never approach the local community for developing properties and there is no way to know if this resulted in missed opportunities for the regional economy, let alone for the state as a whole. Hence, while compliance costs may exist, it is difficult to measure the true extent of compliance costs. We therefore conjecture that total cost estimates provided here represent overall conservative estimates of the actual social and private costs of the IC.

Future and On-going Costs

While it is difficult to predict the future, some future costs can be anticipated, and history provides guidance as to what unanticipated costs may be realized in the future. Recurring or annual expenditures will be realized with reasonable predictiveness. These include the $16,500 annual operating overhead, the average annual reporting costs (though not equal for all years), collection of well samples and laboratory analysis and the annual municipal water bills by 525 residents. Collectively, it is anticipated that annual ongoing costs will total $498,700 per year, in 2020 dollars. Should this be viewed from a decision point today, assuming a social discount rate of 2.5% annually, the present social value of this stream of future costs over 30 years totals $10.438 million. That is, this is what society would be willing to pay to avoid future costs of this IC. This excludes consideration of expanding the footprint of the impacted area to entail future expected plume migration, of which there is some potential. It also excludes the potential added costs that may be associated with tightening federal or state regulations that will put more properties or constraints under this institutional control – an outcome that was experienced in 2015. Should we assume a more aggressive discount rate of 3%, that value would be reduced to $9.77 million. Similarly, if the social discount rate is 2% the current value of the future stream of costs would increase to $11.17 million.

Site Costs	Units	Annual Cost	2.5% over 30 years	2.5% over 30 years	2.5% over 30 years
Annual Operating Costs	$16,500/year	$16,500	$345,350	$323,407	$369,542
Municipal Water Bill	525 units @ $612/year	$321,300	$6,724,903	$6,297,622	$7,195,981
Monitoring					
Collection of Samples		$34,500	$722,095	$676,215	$772,678
Analysis of Samples		$69,000	$1,444,190	$1,352,430	$1,545,355
Reporting Costs		$57,400	$1,201,399	$1,125,065	$1,285,557
Present Value of Future/Ongoing Costs		$498,700	$10,437,937	$9,774,740	$11,169,112

Table G-4: K&L Landfill Future Costs

Summary

This assessment details the findings of economic and cost accounting of the impact of the K&L Landfill institutional control. While it is not feasible to account for all private and social costs incurred because of the imposition of the IC instead of full and active contaminant removal from the site. The report breaks the report out into three cost categories. The first considered the social and private costs of replacing groundwater sources of potable water. The second is the administrative costs of managing the contaminated site – both of which can logically be tied to the act of implementing an IC rather than contamination removal. The final overreaching category of private and social costs are projected future costs discounted to today's values.

These cost estimates represent a lower-bound of the actual expected site costs and include about $16.02 million to maintain water access to impacted residential properties, $5.27 million to oversee the site and meeting reporting and monitoring requirements and $10.44 million in today's value of ongoing annual expenditures 30 years into the future. Collectively, this asserts the private and social cost of this IC is $31.01 million.

K&L Landfill Recommendations

1. Responsible parties or responsible agencies should more thoroughly consider the potential for the expansion of a plume's leading edge and its subsequent impacts and costs. To the extent possible, every effort should be made to prevent a plume's leading edge from expanding.

2. Eleven years transpired between the discovery of the contamination at the landfill and EPA's issuing of the initial record of decision (1990). EPA acknowledged the plume was migrating in 1986. Decisions regarding remedial actions for the leading edge of a plume should be approached with a sense of urgency.

3. Information related to actual on-site data and comparisons to Part 201 clean-up criteria were difficult to find, making a proper exposure pathway evaluation very difficult. Lacking that information makes the administrative record incomplete and difficult to replicate. A standard template that directly and concisely evaluates the exposure pathways for a contaminated site should be part of the administrative record, and updated as needed when new information becomes available, or clean-up criteria change.

4. KLA cited an increased carbon footprint of P&T as one of the consequences of a more active clean-up program for the plume. Green energy, such as solar, should routinely be included when long-term remedial alternatives are considered.

APPENDIX H: LINCOLN BRASS WORKS SITE SUMMARY

Location	**2051 Rosa Parks Blvd. (West of Rosa Parks Blvd, Vermont St. to east, Dalzelle to north, Marantette to south); City of Detroit**
EGLE district / contact	Warren District Office Beth Vens, vensb@michigan.gov 586-484-1030
EPA Superfund?	No
EPA contact	
Contaminants	Tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, and several other contaminants including lead.
Exposure pathways	Volatilization to Indoor air, Direct Contact,
Background	This is a 2.5-acre site. Lincoln Brass began operating in 1917 in a former residence which grew into several interconnected buildings totaling 97,750 sq. feet. Lincoln Brass manufactured brass castings; other operations included a brass foundry, grinding, machining, assembly, testing, plating, parts cleaning, and other related operations. Some products were cleaned in a 1,1,1-trichloroethane or trichloroethylene dip tank. The foundry ceased operations in June of 1993. Sampling at that time was conducted in the former drum storage and foundry vault areas to evaluate the extent of trichloroethylene detected in the soil and beneath the building. Samples were also collected outdoors. Samples were initially analyzed for VOCs, PNAs, and metals. The highest concentrations of TCE were found beneath the building floor. Groundwater was not encountered in any of the 12 borings drilled at the site, including those drilled to a depth of 19-21 feet below ground surface. The site was presented to RRD management in June of 1996. All samples except for lead (under the floor of the building) met industrial and commercial soil direct contact criteria at that time. The review primarily addressed the contaminated soil and direct contact hazards; however, indoor air exposures were cited as a concern. The department did not yet have generic indoor air criteria or significant knowledge about the vapor intrusion pathway. A review by an RRD toxicologist concluded the cement floor served to prevent indoor air exposure. The RAP did conduct an indoor air evaluation using the 1994 ASTM RBCA approach and determined noncancer and cancer risks were acceptable. The review team and management concluded that the proposed limited industrial/commercial (type II, III and IV) closure was protective of human health and the environment. It was determined that the building floor and a portion of the paved parking lot must be maintained as a barrier to prevent exposure both for direct contact and inhalation hazards. DEQ signed an approval letter for a limited industrial closure pending a restrictive covenant [recorded in 1997 (see Formal ICs)] and a legally enforceable agreement (draft available; never signed and finalized). The existing concrete floor and paving was proposed as a barrier for the Limited Land Use Based Closure Agreement. In November 2016, the owner of the building supplied reports to EGLE showing soil gas and indoor air samples above residential vapor intrusion screening levels for trichloroethylene. The work was conducted by the owner for refinancing purposes and was the first environmental

	investigation since 1996. Indoor air levels were as high as 89.2 µg/m^3 and soil gas samples were as high as 540,000 µg/m^3. The owner voluntarily closed the building to prevent further exposure. A public health order was issued by the Detroit Health Department (DHD) officially closing the building. The building's tenants included a Head Start day care/learning program for ages 0-5 and various commercial uses. An administrative office for the Head Start program was also present. The consultant for the owner evaluated mitigation strategies for exposures but none were implemented, and the building remained closed. . On November 14, 2016, the DHD and Matrix Human Services (Brad Coulter, president & CEO) sent a letter to the parents of the children in the Head Start Program (current and previous 6 years) informing them of the contamination/exposure issue. A copy of the Public Health Order (PHO) was included along with the CDC ToxFAQ sheet on TCE. The PHO stated that "A remediation plan approved by DEQ, DHD, and Michigan Department of Health and Human Services (DHHS) must be implemented." That part of the PHO was not followed; the building and remediation was conducted without the departments' approvals. The PHO also stated that no venting of the building could occur unless approved by the DEQ. In 2018 the Property was sold, and the building was removed. The new owners sought permission to remove the direct contact barrier to conduct excavation of the site. This permission was granted and the building was removed and private remediation was conducted. A draft No Further Action (NFA) report was submitted to the department.
Status	Open. A draft NFA Report dated July 26, 2022 was submitted to the department. The PM provided brief comments in October of 2022 and other staff provided comments on the draft RC. Per the PM (1/6/24 email), no further communications have been received from the owner regarding the NFA report.
Formal ICs used	A Declaration of RC was recorded in Detroit on 1/2/1997. Restrictions on the property are as follows: • The owner shall restrict activities at the property that may result in exposures above levels established in the RAP • Existing barriers, parking areas, roadways and other continuous soil coverings shall not be disturbed. • Soil excavation, relocation or related activities must comply with Part 201 Section 120(c) • No wells shall be permitted at the site • No future construction or redevelopment activities which impact soil barriers or other cover shall be allowed A draft new RC is included in the draft NFA report. The report indicates that the former RC was rescinded or will be.
Alternative ICs used	None noted.
IC failures	The original RC failed because a use occurred that was not allowed for the property. The RC did not provide a level of specificity that described the types of land uses and activities approved or not approved for the property. Item #1 of the RC says "the owner shall restrict uses to those compatible with the limited commercial land use category" but does not describe the land use or state what the limited commercial subcategory is and only refers people to the 1995 MERA Op Memo #14. The department approved a closure for limited industrial use which also allows commercial II and III but not the commercial I subcategory which includes schools and day cares. In November 2016, the owner of the building supplied reports to EGLE showing soil gas and indoor air samples above TCE residential vapor intrusion screening levels. The owner was testing the property for refinancing purposes with the help of AKT Peerless. One of the buildings was

	leased to a Head Start program which included the presence of young children. I The owner claimed she did not know about the RC; the property was purchased with cash and past title work did not show an RC existed. Additionally, the tenants and the city were not aware of the RC.
Other remedial activities	In 2018 the Property was sold by 2051 Rosa Parks LLC to 20th St. Properties LLC (Ford Motor Co.) for $2.4 million The new owners sought permission to remove the direct contact barrier to excavate contaminated soils. This permission was granted, and a private remediation was conducted including demolition of the buildings.
Expanding plume	No; in the 90s, groundwater was not encountered in any of the 12 borings drilled at the site, including those drilled to a depth of 19-21 feet below ground surface.
Timeline	**1917**: Lincoln Brass Works started operations **1993**: Lincoln Brass Works stopped operations **Post 1993:** Soil sampling was conducted. **1996**: Dames and Moore Remedial Action Plan and Closure Report **June 1996:** District presented the site to management & obtained approval December 1996: Approval of RAP and Notice of Intent to Approve Limited Land Use Based Closure **January 02, 1997**: Declaration of RC (Detroit) recorded by the Register of Deeds, Lincoln Brass Works sells the property to Renaissance Properties, Inc. (see Beth Vens email from 9/22/22) for $400K (from the Wayne County Deeds record search) **December 2005:** Bayview Loan Servicing LLC acquires the property, likely through foreclosure (see Beth Vens email 9/22/22). **September 22, 2011:** Rosa Parks LLC acquires property from Bayview Loan Servicing for $270K cash (see https://mail.friedmanrealestate.com/ford-completes-purchase-of-former-brass-factory-for-corktown-campus/). **October, 2016**: Indoor air and soil gas samples are collected by AKT Peerless for the owner for refinancing purposes. The information was provided to the DEQ who conducted follow-up indoor air sampling at nearby residential properties (no exceedances). October 28, 2016: Owner voluntarily closes the building after learning about the high concentrations of TCE. **2000 through Fall 2016:** Per the draft NFA Report, Human Matrix Services occupied the building. (did not specify that children were present that whole time). **August 15, 2018:** Property purchased by 20th Street Properties LLC (Ford Motor Co.) for $2.4 million. . (https://mail.friedmanrealestate.com/ford-completes-purchase-of-former-brass-factory-for-corktown-campus/). **2018 -2019**: After purchase, the building was removed, and a private remediation conducted. **July 2022:** PM received the draft NFA report. **October 2022:** Comments provided to GHD (consulting firm) from both the PM (draft NFA Report) and Kevin Schrems (draft RC)
Public health cases	None reported, however: (February 26, 2017, mLive) In Detroit, a Head Start day care center at 2051 Rosa Parks Boulevard was among multiple tenants relocated in October after indoor air samples at the redeveloped Lincoln Brass Works facility in Corktown showed high levels of TCE. It is not clear whether anyone who was in the building for long periods of time faces health problems. Matrix Human Services and the DHD sent letters to more than 1,000 parents of children who attended the Detroit preschool program. Parents (current year & previous 6 years) were told to take their children to a doctor if they had health concerns.

	Another newspaper article (AP Feb. 8, 2018) stated that Matrix Human Services used the building, including for administrative offices, since 1997 (19 years). (The draft NFA Report says 16 years.) A July study commissioned by Matrix showed the building was safe if it were well-ventilated for purposes of short-term entry, so staff could finish moving to a new office location in Detroit. The city denied an open records request from The Detroit News seeking names and contact information of the letter recipients and denied a request from the project team. Head Start students at the Rosa Parks site may have gone to any of the 24 other locations the organization has in Detroit. Neither the =DHD nor the DHHS took blood samples of the children or adults exposed to Matrix's former Corktown site. Project team members spoke with Scott Withington (9/13/22) from the DHD, who could not provide details about how long children had been in the building or how many were there when the vapor intrusion issue was discovered. The owner at the time was conducting a Baseline Environmental Assessment (BEA) and collecting samples when the problem was identified. It was the owner that shut down the building. Scott then worked with the Department of Health and Human Services (DHHS) and EGLE to confirm and reinforce the evacuation and closure of the building.
Impacted recreation	None reported.
Impacted property value	None reported.

Exposure Pathway Evaluations (prior to implementation)

Drinking water

Were criteria exceeded?	No. 1996 RAP: Groundwater was not encountered at the site (to 21 ft.) Draft NFA determined this pathway not complete and criteria not applicable because GW not encountered, RC will restrict use of groundwater & municipal water provided.

Remedial responses implemented

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?
RC		1997	Yes	Prohibited DW wells. To our knowledge no wells have been drilled. Yes.
Demo/ excavation & draft NFA		2018 - 2019	unknown	
New draft RC		2022	Yes, if filed	DW wells prohibited (new draft RC has not been recorded to date)

<table>
<tr><td>Were soil criteria to protect drinking water exceeded?</td><td>1996 RAP: GW was not encountered. Pathway not evaluated.
NFA report indicates the criteria not applicable because RC will restrict use of groundwater. Pathway not evaluated.
Yes. PM states the draft NFA report indicates Part 201 drinking water protection soil criteria were exceeded.</td></tr>
<tr><td>Remedial responses implemented</td><td><table><tr><th>Name</th><th>Type</th><th>Year</th><th>Anticipated to prevent exposure?</th><th>How? Successful?</th></tr><tr><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Groundwater surface water interface (GSI)</td></tr>
<tr><td>Were criteria exceeded?</td><td>1996 RAP: Groundwater was not encountered and due to the highly developed nature of the vicinity, surface runoff will be intercepted by sewers. GSI not likely to be impacted.
Draft NFA report says criteria not applicable and pathway not complete because groundwater was not encountered during initial investigation.</td></tr>
<tr><td>Remedial responses implemented</td><td><table><tr><th>Name</th><th>Type</th><th>Year</th><th>Anticipated to prevent venting to surface water?</th><th>How? Successful?</th></tr><tr><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td></td><td></td></tr>
<tr><td>Were soil criteria to protect GSI exceeded?</td><td>1996 RAP: Groundwater was not encountered.
Draft NFA report says related criteria not applicable because groundwater was not encountered during initial investigation. Per the PM, the draft NFA report states these criteria were exceeded in soil.</td></tr>
<tr><td>Remedial responses implemented</td><td><table><tr><th>Name</th><th>Type</th><th>Year</th><th>Anticipated to prevent leaching?</th><th>How? Successful?</th></tr><tr><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Soil direct contact</td></tr>
<tr><td>Were criteria exceeded?</td><td>Yes, per the 1996 RAP:
PNAs: outdoor & indoor samples < Industrial SDCC. VOCs: outdoor & indoor sample < industrial SDCC. Arsenic: outdoor & indoor samples < industrial SDCC. One outdoor & 3 indoor samples > the residential SDCC of 7.6 ppm. Outdoor soil lead samples < the residential SDCC of 400 ppm; one indoor sample (1,300 ppm) > res SDCC (400 ppm) & industrial SDCC (900 ppm).
Yes, per the draft NFA Report which states soils exceeding nonresidential Direct Contact Criteria were removed.</td></tr>
</table>

Remedial responses implemented	**Name**	**Type**	**Year**	**Anticipated to prevent exposure?**	**How? Successful?**
	RC		1997	Yes.	No. Restricted activities and uses not clearly identified. Unknown if the Head Start kids were exposed to the contaminated soils.
	Demo/ excavation & draft NFA		2018 - 2019	Yes	Soils exceeding nonresidential DCC removed.
	New draft RC		2022	Yes, if filed	Routine exposure of children not allowed. Residential uses not allowed and gives examples but does not include schools or day cares in the first part of the RC. Does include in Exhibit 2.

Volatilization to indoor air

Were groundwater volatilization to indoor air criteria or screening levels exceeded?	Groundwater not encountered.

Remedial responses implemented	**Name**	**Type**	**Year**	**Anticipated to prevent exposure**	**How? Successful?**

Were soil volatilization to indoor air criteria or screening levels exceeded?	In November 2016, the owner of the building supplied reports to EGLE showing soil gas and indoor air samples above residential vapor intrusion screening levels for trichloroethylene. (1996 RAP determined indoor air risks were acceptable.) Yes. Draft NFA report indicated that nonresidential SVIIC were exceeded and those soils removed however, exceedance of VIAP screening levels remain.

Remedial responses implemented	**Name**	**Type**	**Year**	**Anticipated to prevent exposure?**	**How? Successful?**

	Building closed and tenants relocated.		2016	Yes	Closed by the owner in October and officially closed by the DHD in November.
	Demo/ excavation & draft NFA		2018 - 2019	Unknown	Soils exceeding nonres SVIIC removed. Exceedances of screening levels remain.
	RC		1997	Yes, at the time	Barriers left in place and only nonresidential exposures allowed however failure of the RC occurred. Children exposed.
	New Draft RC		2022	Yes, if filed. Not filed as far as PM knows	No bldgs. or use of bldgs. unless a) complies with 20120a(18) or b) evaluation of indoor air or c) engineering controls.

Ambient air

Were criteria exceeded? (Volatile Soil Inhalation and Particulate Soil Inhalation)	At the time, no. Plus, the building and pavement covered the highest VOC contaminated soils. Yes, per the draft NFA report (VSIC).

Remedial responses implemented

Name	Type	Year	Addresses the pathway?	How? Successful?
Building closed and tenants relocated.		2016	No	Meant to address indoor air exposures
Demo/ excavation & draft NFA		2018 - 2019	Yes	Soil with exceedances of VSIC criteria removed
RC		1997	Yes	Existing barriers left in place and protection of those barriers.

	New Draft RC		2022	Yes, if filed	Draft NFA stated no exceedances of nonres VSIC and PSIC
Source materials					
Any present?	Source materials remained in place throughout most of the history of the site. Per the draft NFA report, the source was removed by way of removing exceedances of certain criteria i.e., the SVIIC but exceedances for other criteria and pathways remain in soil demonstrating some of the source remains in place.				
Remedial responses implemented	**Name**	**Type**	**Year**	**Addresses source materials?**	**How? Successful?**
	Demolition of buildings and soil excavation & draft NFA		2018 - 2019	Unclear	The draft NFA states source was removed for some pathways, but contamination remains for others. Exceedances/contamination remains in place. Additional information would need to be presented to EGLE and reviewed to verify the work and evaluations conducted and the new RC filed ,

Lincoln Brass Works IC Cost Breakdown

Past costs

The costs associated with Lincoln Brass can be grouped into four general categories. The first are the opportunity costs associated with the inability to utilize the built-up structures at the site. This includes the period from 1997 to 2000, and then 2016 to 2018. Note that from approximately 2000 until 2016, the building was in use by a Head Start program and various commercial tenants. It was determined that human occupation of the facility was deemed unhealthy by current standards due to observed levels of VOCs in the soil and that tenants were unaware of the IC on the property restricting uses. This likely caused significant, but in many cases immeasurable, costs on Head Start administrators and the 224 affected families as they adjusted schedules and locations to accommodate last minute changes. In addition, over 1,000 children went through this Head Start program in the 16 years it operated and those families also experienced disruptions if they pursued health checkups for their children exposed to the TCE plume. The second is property taxes paid during the periods of non-use. The third is the costs directly associated with implementing and supervising the IC. In the current case, IC-related costs are limited to soil borings for air and soil samples. The fourth area is the expected heath costs due to exposure to VOCs (period 2000 to 2016) where children (Head Start) and workers may have been exposed to pollutants.

To estimate the opportunity costs of not utilizing the property's structures, we assume that from the period of 1997 to 2000 property earnings loss is 100% of its potential earnings, as measured by going commercial and industrial lease rates in the Detroit area. Accordingly, the commercial space afforded by the structures was estimated to be 92,750 square feet. We used estimated 2022 class B rent based on the average rate of $25 per square foot of commercial space. This rate is treated as a constant real rate of opportunity rents foregone for the purpose of this analysis. The second period of facilities disuse was from 2016 to 2018, where once again, 100% of the facility's 92,750 square foot of commercial space was not used. Alternatively, during the period of 2000 to 2016, renovations were made to the structure to place the office square footage into commercial uses, including for a Head Start classroom, among others. This 16-year period entailed a period of fixed investment in renovations that had to be abandoned when realizing the facilities were operating out of compliance with health standards. Records suggest that about 75% of the facility's square footage were utilized, leaving about 25% of the facilities unused. Only this share of the unused facilities will form the basis of lost facilities costs due to the IC. We view this as liberal as it appears that the IC may not have posed a use constraint during this period, but one may be able to argue that a single, larger tenant or buyer may have been a viable user of the facility in the absence of the IC in place.

	Use Restriction	Lost Earnings
1997-2000	100%	$4.875 million
2000-2016	25%	$0.813 million
2016-2018	100%	$3.250 million
Total		$8.938 million

Table H-1: Potential opportunity costs of restricted use.

Lost Use Costs of the IC (2020 prices)

These cost estimates omit consideration of the 2000 investment in facilities renovations for hosting the Head Start program and other commercial uses. Given the 16 years for recovering any facilities renovation costs, we assume that the lost value of those investments had already been depreciated and largely excludable from final estimated social costs.

The IC and associated property value degradation of the facilities due to not removing the source contamination resulted in lost tax revenues to the state and local governments. Accordingly, the reduction in market value of the facilities would degrade the assessed and therefore taxable value of the property. This IC was not overly restrictive to property use, mandating that no renovations be undertaken that will result in a disturbance of the soil and the cement barriers separating the facility's interior from the soil. Accordingly, we anticipate a small overall effect on property values. Since industrial property taxes are levied on personal property, we assert that during years of disuse, industrial personal property (IPP) taxes from this facility dropped to zero. However, this is not to suggest that that tax revenue is no longer collected by the City of Detroit (the taxing entity). As a proxy for expected IPP reduction from the IC, we assert industrial property is equal to the market value of the property.

Using current rental rates for industrial properties in the Detroit area (https://www.compass-commercial.com/q1-industrial-market-report-for-detroit-mi-2/) of $5 per square foot per year (up to $10.20 per square foot), and asserting 65,000 square foot of facilities, we estimate the sale value of the property in the absence of the IC. CAPM calculations, using a discount rate of 5%, generate an expected book value of $6.5 million (=5*65,000/.05). The assessed value will be one-half the market value and the taxable value will be no higher than the assessed value. In this case, we assume assessed and taxable values are equal. For five years tax revenues reduce by 100%, while for 16 years, they reduce by 25%. Using constant 2020 prices, the City of Detroit levies a millage rate of 63.5080 on IPP. Accordingly, $412,802 (=63.5080*$6.5m/1000) in annual tax revenues are forgone in each of the five years of no use, or $2.064 million. For the 16 years of 75% utilization, only 25% of the expected annual tax revenue of $412,802 was foregone, or $103,201. Over 16 years, this amounts to $1.651 million in lost tax revenues.

Some costs associated with managing the IC are largely deferred for this site as little management took place in monitoring the plume. There were late cases of boring and testing, but this mostly took place in 2016. We largely view site management costs as immaterial for this site.

Summary of Costs:

1. Opportunity costs $8.938 million
2. Industrial Personal Property taxes. $3.715 million

Recurring costs (into future)

Because Ford Motor Company repurposed the facility and excavated the source soils, future expected costs are limited. Ford, however, indicated that for their planned redevelopment, they may invest in a vapor intrusion barrier to their planned multi-story commercial building plan. The expected cost for installing such a system has not been included in the final estimates.

Potential costs

Potential costs include health costs associated with building use by head-start and government offices during the period from 2000 to late 2016.

From “Risk Evaluation for Trichloroethylene” (EPA p. 408), cancer risk is identified as 1 in 10,000 (P = 0.0001). We assumed there were approximately 1000 children in the head start program. Thus, the cost associated with cancer would be multiplied by a factor of 0.1 (risk 0.0001 X number of children 1000).
Estimates of the cost for treating kidney cancer include medication ($50,000) + the course of treatment ($200,000) + and potential surgery ($250,000) = $500,000.

Taking the probability times the treatment cost, 0.0001 X $500,000 = $50 per person. If approximately 1,000 individuals were exposed, this would make the total cost associated with people potentially having kidney cancer at $50,000.

Unmeasured costs

It is unclear how many tons of soil were excavated from the property, and thus, this is one potential unmeasured cost.

Additionally, while we have a statistically based estimate for kidney cancer, it is unknown if anyone associated with the property in the past developed cancer. Each known case of cancer would increase the costs of developing cancer.

Lincoln Brass Works Recommendations

1) The 1996 RAP for this site did not sufficiently address the potential migration of contaminated groundwater off site. Although groundwater was not encountered to a depth of 21 ft., the Detroit area does have perched groundwater that has the potential to migrate. There is the potential for perched groundwater to migrate via utility corridors or across property lines. RCs should more explicitly restrict activities that would exacerbate the potential for the migration of contaminated groundwater under such circumstances.

2) The main body of the RC should clearly identify uses, activities and populations that are not allowed on the property (e.g., day cares and schools are not permitted). The updated RC forms have been significantly improved but could still be clearer in the restrictions. e.g., "The types of activities and uses NOT allowed include the following: …"

3) There is evidence that the existence of the RC and use restrictions for the property was not known by the tenants and subsequent owners of the property. The operator of the Head Start program and the property owner in 2016 were unaware of the prior contamination and the use restrictions for the property. RCs should be more easily obtained when a property transfer is being considered. It should be attached to the deed and provided to the prospective owner or lessee of the property by the seller/lessor.

4) According to 20121(6) of Part 201, an RC is required to be submitted to the department within 30 days of being filed with the Register of Deeds. Efforts should be made by the department to follow up on pending RCs in the department database (reference numbers are provided to parties requesting one for potential RCs) and if they are recorded, they are entered into Environmental Mapper. Consideration should be given to those RCs that may have been recorded during a self-implemented cleanup without notification to the department, i.e., the department should be alerted so they can be entered into their database.

5) Recommend that staff require appropriate terminology in submitted reports such as relevant pathway and applicable criteria (e.g., "not applicable" inappropriately used because RC prevents exposure.) The department needs to hold consultants to the same language and terminology that they hold staff to (it creates confusion).

APPENDIX I: WASH KING LAUNDRY SITE SUMMARY

Location	**M-37, Baldwin, MI, 49304** **NW1/4 SEC22 T17N R13W** **Pleasant Plains TWP, MI 49304**
EGLE district/Superfund contact	Superfund Section, Central office Lansing PM: Mark Reimann, ReimannM@michigan.gov, 517 290 9379
EPA Superfund? (link)	Yes. https://cumulis.epa.gov/supercpad/cursites/csitinfo.cfm?id=0502992
EPA contact	Shari Kolak (kolak.shari@epa.gov) (312) 886-6151
Contaminants	Trichloroethylene, tetrachloroethylene, PFAS, cis-1,2-dichloroethene, trans-1,2-dichloroethene
Exposure pathways	Drinking water is the primary pathway.
Background	Privately owned laundromat & dry-cleaning facility in operation from 1962 to 1991 discharging laundry waste, PCE and TCE to a series of unlined seepage lagoons. PCE also leaked from a UST creating another source area. PCE & other laundry related contaminants detected in residential wells in 1973. Subsequent findings of PCE contamination in the groundwater led to the state issuing a Notice of Noncompliance and Order to Comply to the Site owner in 1976. PCE detected in the Wash King well and the adjacent restaurant well in 1977. Owner ceased all dry-cleaning operations in 1978. First hydrogeological investigation in 1979 determined the plume was migrating in a northerly direction towards the Pere Marquette River (PMR). 30 residential wells downgradient of the site were impacted by PCE. In 1983, the State negotiated with the owner to construct a public water supply system to serve affected businesses and residences. Two public supply wells (a primary well and a secondary back-up well) were completed in a deeper uncontaminated aquifer and were operational in 1984. From the Fourth FYR: "The supply wells went into operation in 1984 and residences and businesses within the Site (and close to the site) were required to connect to the new water supply. Other residences nearby that did not connect to the CWS (community water supply), participate in a residential well sampling program that occurs on an annual basis." Site placed on the NPL in 1983. October 1991, Wash King filed for bankruptcy. EPA's first Record of Decision (ROD) was issued in 1993. ROD called for off-site disposal of contaminated lagoon sediments, building demolition, and installation of a groundwater pump and treat (P&T) system along with a shallow soil vapor extraction (SVE) system near the former building. Deed restrictions to prevent exposure to contaminated groundwater were selected as part of the remedy along with groundwater monitoring. Lagoon sediments were viewed as

	surface soil since they had dried out and sample results indicated excavations of shallow soil were not warranted. Operable Unit One (OU1) consists of groundwater and soil remedies addressed in the first ROD. The Fourth FYR states: "One of the primary remediation components is groundwater extraction to capture contaminated groundwater with physical/chemical treatment for both organic and inorganic contaminants to restore the aquifer..." In 1996, a document entitled Explanation of Significant Differences included these changes: no excavation of the lagoons; no deed restrictions on the area to be remediated. The Wash King Laundry building was dismantled in September of 1999. April 2002: The SVE and groundwater P&T systems were operational. In 2006, the Optimization Evaluation and the First Five Year Review (FYR) recommended additional activities i.e., supplement the groundwater monitoring well network; conduct a capture zone study; delineate and more aggressively address PCE source area beneath the former building; install additional optimally located and higher-yield groundwater extraction wells. Beginning in 2009, In-situ bioremediation (ISBR) of Area of Concern (AOC) -1 was implemented. Following two years of ISBR and performance monitoring soil and groundwater sampling, the ISBR was only partially effective, as low permeability portions of the till unit were not effectively treated Subsequent FYRs acknowledged remaining source areas (beneath the former wastewater lagoons and piping run) and required further evaluation. Source area soils were deemed OU2 in 2014. The ROD for OU2 was finalized in February 2021. Vapor wells were installed in September 2016 and April 2017 and air samples collected on a quarterly basis. The analytical results of soil gas samples collected during quarterly sampling from September 2016 to February 2018, indicate that VOC concentrations are below the VIAC at all vapor well locations. The SVE system was shut down. June 2018, preliminary PFAS sampling completed. PFAS was present in some of the well samples. EGLE implemented a PFAS monitoring plan and additional groundwater and residential well sampling was conducted. September 2016: Third FYR. Groundwater ICs are needed until the cleanup standards are met. (Not needed at OU1 because no exposure to groundwater or soil.) Recommends amending the ROD to include groundwater ICs. February 2021, ROD for OU2. Contaminated soils at former building area, former piping run and former seepage lagoon act as a continuing source of groundwater contamination. In-Situ thermal remediation (ISTR) was selected as the remedy ($16.9M). September 2021, Fourth FYR states that groundwater ICs are necessary. The Explanation of Significant Differences to the OU2 ROD was finalized in June 2023. The OU2 ROD called for replacement of the Baldwin CWS backup well since it is in the location of the

	intended ISTR. However, the DWEHD of EGLE determined that the backup well cannot be replaced without the main well. The ESD calls for the replacement of the remaining components of the Baldwin CWS which includes the main well, well house, and replacement of various system components and equipment inside the well house. A cost estimate of $662,178 is included in Attachment 1 of the ESD.
Status	Active
Formal ICs used	None however, EPA is now recommending ICs. From the Fourth FYR: • Develop an ICIAP (IC Implementation and Assurance Plan) for contaminated groundwater and soils. Identify the needed ICs, ensure they are effective, and ensure that a LTS (Long Term Stewardship) plan is reviewed and developed so that ICs are properly maintained, monitored, and enforced. • Complete a decision document for the ICs • Develop and implement the ICs • Develop a LTS plan or develop equivalent LTS procedures and protections and incorporate them into the site O&M Plan.
Alternative ICs used	In 1984, owner constructed a public water supply system to serve the residences and local businesses affected. (See above) (*The PM does not consider this an alternative IC since the CWS is an engineered system.)*
IC failures	None recorded.
Other remedial activities	Public water supply system, groundwater P&T system, shallow SVE system, demolition of building and drainage and removal of sumps. Later, additional monitoring wells, more and higher yield groundwater extraction wells.
Expanding plume	Per a 7/21/2022 email from Keith Krawczyk, the groundwater plume is being contained. Per 9/27/2023 email from new PM Reiman: Based on the monitoring well data we have downgradient from the extraction wells, the plume appears to be contained. We are not seeing exceedances of site VOCs downgradient of the 5 operating extraction wells.
Timeline	**1962**: Facility first in operation **1973**: Contamination first detected in residential drinking water wells **1976**: The state issued an Order of Noncompliance and an Order to Comply. **1978**: Owner ceased all dry-cleaning operations **1979**: First hydrogeological investigation **1983**: Site listed on the NPL **1984**: Two new public drinking water supply wells became operational **1991**: Wash King filed for bankruptcy **1993**: EPA's first Record of Decision (ROD) **1996**: Explanation of Significant Differences Document **1999**: The building was dismantled/demolished **2002**: The SVE and groundwater P&T systems were operational **2006**: The Optimization Evaluation and First Five-Year Review **2011**: Second Five Year Review **2014**: Source area soils were identified as OU2. **2016**: Third Five Year Review **2016 & 2017**: Vapor samples collected and all results below applicable criteria. SVE shut down.

	2021: ROD for OU2 was finalized and Fourth FYR completed. ICs and related documents regarding the contaminated groundwater and soils are recommended. Recommendation to develop a monitoring and contingency plan to address PFAS in the groundwater treatment system should it become necessary. **2023**: Explanation of Significant Differences Document finalized in June.
Public health cases	Drinking water sample collected from private property adjacent to site. This property is not hooked up to the community water supply. PFOA detected in drinking water sample above the maximum contaminant level (MCL) for PFOA. Michigan Department of Human Health and Safety and EGLE has notified resident of exceedance. (per PM Reimann 9/27/23)
Impacted recreation	None recorded
Impacted property value	None recorded

Exposure Pathway Evaluations (prior to implementation)

Drinking water

Were criteria exceeded?	Yes (https://semspub.epa.gov/work/05/263897.pdf) First FYR (PCE detection in 1976 & State issued a Notice of Noncompliance)

Remedial responses implemented

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?
Community Supply Wells	Alt IC	1984	Yes	Provided uncontaminated drinking water (deeper wells) to affected residences and businesses
GW Pump and treat	Other remedial	2002	No, not in the short term	groundwater extraction with physical/chemical treatment to restore the aquifer.
GW monitoring	Other remedial	2002	Yes & no	Many of the wells were used to monitor the treatment system; some were in place to make sure those not on the community water supply were not exposed.
Enhanced pump and treat	Other remedial	2007	No, not in the short term.	Improve groundwater pump and treat system to restore the aquifer

Were soil criteria to protect drinking water exceeded?	Not evaluated.

Remedial responses implemented	<table><tr><th>Name</th><th>Type</th><th>Year</th><th>Anticipated to prevent exposure?</th><th>How? Successful?</th></tr><tr><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr></table>

Ground water / Surface water

Were criteria exceeded?	Yes (First FYR identified acceptable risks to humans from surface water, but risks to aquatic organisms not evaluated). Per PM, groundwater plume is stable and the middle branch of the Pere Marquette River has not been impacted. Some exceedances of GSI criterion of 60 ppb for tetrachloroethylene in the groundwater however, no indication that the middle branch of the PM has been impacted nor that the GSI criterion has been exceeded at the groundwater surface water interface.
Remedial responses implemented	<table><tr><th>Name</th><th>Type</th><th>Year</th><th>Anticipated to prevent exposure?</th><th>How? Successful?</th></tr><tr><td>GW Pump and treat</td><td>Other remedial</td><td>2002</td><td>Yes</td><td>Groundwater extraction with physical/chemical treatment to restore the aquifer.</td></tr><tr><td>GW monitoring</td><td>Other remedial</td><td>2002</td><td>Maybe</td><td></td></tr><tr><td>Enhanced pump and treat</td><td>Other remedial</td><td>2007</td><td>Yes</td><td>Improve the GW pump and treat system to restore the aquifer.</td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr></table>
Were soil criteria to protect GSI exceeded?	Not evaluated.
Remedial responses implemented	<table><tr><th>Name</th><th>Type</th><th>Year</th><th>Anticipated to prevent leaching?</th><th>How? Successful?</th></tr><tr><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr><tr><td></td><td></td><td></td><td></td><td></td></tr></table>

Soil direct contact

Were criteria exceeded?	No. The 1993 ROD indicated unacceptable risks to lagoon sediments from arsenic and lead, but further investigation determined arsenic was below soil background

	levels and lead was less than the 400-ppm residential soil direct contact criterion (~1996). See pg. 7 of Fourth FYR.
Remedial responses implemented	

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?

Volatilization to indoor air

Were groundwater volatilization to indoor air criteria or screening levels exceeded?	No (https://semspub.epa.gov/work/05/969711.pdf) Page 17: VI investigation completed in 2018. The data indicated that the VOC concentrations are below the site-specific VIAC at all locations.
Remedial responses implemented	

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?

Were soil volatilization to indoor air criteria or screening levels exceeded?	No (https://semspub.epa.gov/work/05/969711.pdf) Page 17: VI investigation completed in 2018. The data indicated that the VOC concentrations are below the site-specific VIAC at all locations.
Remedial responses implemented	

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?

Ambient air

Were criteria exceeded?	Unknown and not likely; this pathway was not evaluated
Remedial responses implemented	

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?

Source materials

Any present?	https://semspub.epa.gov/work/05/969711.pdf (page 21)

<table>
<tr><td></td><td>Yes. The on-going source areas in the till unit (vicinity of the former building and lagoon sediments) continue to propagate dissolved phase PCE contamination into the aquifer. Groundwater is not expected to meet RAOs in a reasonable time frame.</td></tr>
<tr><td>Remedial responses implemented</td><td>
<table>
<tr><th>Name</th><th>Type</th><th>Year</th><th>Anticipated to address source?</th><th>How? Successful?</th></tr>
<tr><td>GW Pump and treat</td><td>Other remedial</td><td>2002</td><td>To some extent</td><td></td></tr>
<tr><td>Shallow SVE</td><td>Other remedial</td><td>2002</td><td>To some extent</td><td></td></tr>
<tr><td>Building demolition</td><td>Other remedial</td><td>2002</td><td>Potentially</td><td>Made the soils accessible.</td></tr>
<tr><td>Enhanced pump and treat</td><td>Other remedial</td><td>2007</td><td>To some extent</td><td></td></tr>
</table>
</td></tr>
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</table>

Additional Notes

An issue with this site is that ICs were never put into place even though the 1993 ROD called for them. The 2021 Fourth FYR states that ICs on the groundwater are necessary. Update from the PM requested on 12/13 and resent on 01/2/23.

This site highlights the problem of leaving a contaminant source in place, when it was relatively more feasible to have it removed than at some other larger sites (e.g., Wickes). Moving forward with the initial planned soil excavations (which were abandoned) would have saved some of the later effort.

Wash King Site IC Cost Breakdown

PAST COSTS

We note that in the reviewed documentation there does not appear to be a clear point of origin for a formal IC announced. It appears to be first discussed (or assumed) in the 1993 EPA ROD, and in then in the 2006 FYR the following consideration was made "Consistent with the ROD and ESD, it is appropriate to now conduct an evaluation to determine if ICs and other measures are now necessary at the Site, given the likely lengthy duration of continuing O&M" (p. 28). There is also a reference in the 2016 FYR in Table 3 (p. 24, 27 of PDF) a recommendation of "no ICs in place" and "ICs were not implemented because it was anticipated that the ISBR remedy would remediate the source area under the WKL building." Therefore, below we attempt to estimate costs based on the timeline of events over several periods while assuming an IC was indeed in place. To estimate costs associated with an IC (or potential IC in place), we assume that a "start" date was around the 1983-84 period, when 20 residents and 3 businesses were moved onto new public drinking water. We made this start date assumption since this type of action is consistent with early-stage activities where ICs have been put into place (this is based on reflecting on other evaluated sites in this study). Thus, the costs associated with the establishment of the new public drinking water as well as those associated with abandoning private wells (occurred between 1983-84) are the first assumed costs with this site. Additionally, the economic values for each set of costs were extrapolated from Site specific reports and, where necessary, prior sites evaluated. Finally, costs are in 2020 dollars, but in the construction of period cost we also include the reference year/report, for example, the 1993 EPA EOD report.

Starting in 1984, a new public drinking water supply went online and 20 residents and 3 businesses inside the site were required to connect to the new supply. An EGLE site report showed the cost of the new drinking water source (installation) was $90,948 (2020 dollars), and we include the assumed municipal hook up $12,000 (per resident/business) and first-year annual water bill $786 (per resident/business) in this cost. Additionally, we include the estimated value of each abandon well, $2,318. The total cost (sum of individual costs) for the transition 1983-1984 was estimated to be about $438,361 (2020 dollars).

In 1993, the Record of Decision (ROD) by the EPA called for: (1) off-site disposal of contaminated lagoon sediments; (2) building to be demolished; (3) and installation of a groundwater pump and treat (P&T) system; and (4) a shallow soil vapor extraction (SVE) system near the former building. In 1999, the building was dismantled (cost unknown). In 1988, initial groundwater monitoring wells were installed (estimated 11 wells), followed by additional monitoring wells in 1994-2002 (estimated 8 wells), and reboring 2007-2008 (estimated 30 wells in total). According to the 1993 EDO EPA report, the cost of installation of these wells in 2020 dollars is estimated to be $23,508, and the annual operation and maintenance (O&M) was reported to be $547,145. We used this set of costs for the period 1988-2002 as the 2011 FYR provided revised costs for later years. The total costs associated with groundwater monitoring from 1998-2002 are estimated to be $14,356,215 in 2020 dollars.

In 2002, the P&T and SVE systems were operational, and the SVE were in use until about 2008 (P&T remained). The original P&T system included 5 extraction wells. New wells were added in 2008 (approximately 1; used to 2011) and 2010 (approximately 4). The maximum number of these wells in use at any time was on average 7 (two original wells and 5 new wells). Total P&T wells installed was approximately 10. Following the 2011 FYR cost schedule (p. 268) the combined groundwater monitoring, P&T O&M, and SVE were in use from 2002-2008. The costs for the combined groundwater monitoring, P&T O&M, and SVE effort were $1,512,752 in 2020 dollars. The 2006 FYR provided cost estimates for groundwater monitoring and P&TG O&M, once the SVE was shutdown. The total costs here were $$1,150,215 in 2020 dollars. Combining all three periods of groundwater monitoring, P&T O&M, and SVE, 1988-2002 (15 years), 2003-2008 (6 years), and 2009-2020 (12 years), the total costs were $17,019,182 in 2020 dollars.

What follows next is a list of other events along the timeline that we assumed did not influence the associated costs with the IC (this does not include the cost of reporting as these costs are discussed and included later). In 2006, the Optimization Evaluation and the First Five Year Review (FYR) recommended additional activities: (1) supplement the groundwater monitoring well network; (2) conduct a capture zone study; (3) delineate and more aggressively address PCE source area beneath the former building; and (4) install additional optimally located and higher-yield groundwater extraction wells. Costs associated with items #1 and #4 were addressed above. In 2009, 67 injection points associated with bioremediation were installed as concerns that neither the P&T nor SVE systems could effectively remove the PCE from the Wash King Laundry building zone. Subsequent FYRs acknowledged remaining source areas (beneath the former wastewater lagoons and piping run) and required further evaluation. Source area soils were still deemed problematic in 2014. In September 2016, the third FYR revealed that groundwater ICs are needed until the cleanup standards are met (they were not believed to be needed at OU1 because there was no exposure to groundwater or soil) and it recommended amending the ROD to include groundwater ICs. Then in February 2021 (ROD for OU2) showed contaminated soils at former building area, former piping run and former seepage lagoon act as a continuing source of groundwater contamination. In-Situ thermal remediation (ISTR) was selected as the remedy. Finally, in September 2021, the fourth FYR states that groundwater ICs are indeed necessary.

The last set of pasts costs are referred to as "Other Costs" and include unexpected or non-routine costs as well as reporting costs. The known unexpected or non-routine costs were reported in the FYRs for 2011, 2016 and 2021 and totaled $500,614 in 2020 dollars. The FYR report costs (2006, 2011, 2016, and 2021) total was $70,766. The combined total "other costs" are $571,380.

RECURRING COSTS (INTO FUTURE)
Based on the last documentation, it appears that the groundwater monitoring and P&T will continue forward in time as the only known recurring cost. We estimate these costs using the annual groundwater monitoring and P&T O&M costs provided in the 2006 FYR inflation adjusted to 2020 dollars, and for a 15-, 30-, and 60-year time-period, with a 1%, 5%, and 10% discount rate. These estimates range from $729,520 (15 years with 10% discount rate) to $4,308,995 (60 years with a 1% discount rate). For summarizing costs below, we use the median value, $1,473,468 (30 years with a 5% discount rate) as the total cost estimate for future groundwater monitoring and P&T O&M.

Summary
The table below summarizes the costs based on the timeline of events discussed above.

1983-84: Transition to alternative water	**$438,361**
1988-2020: Groundwater monitoring (P&T O&M + SVE added in later years)	$17,019,182
2006-2020: Other costs	$571,380
2020 and beyond: Future P&T O&M and groundwater monitoring (median)	$1,473,468
Total	$19,502,391

Table I-1: Costs for each phase of the timeline.

There are limitations to these estimates. First, while the reports (e.g., the EPA FYR and EOD) provide many estimates or tallies of known costs, it is conceivable that these estimates did not account for everything. For example, we included estimates based on prior experience of municipal water hooks-ups and water bills that were not clearly accounted for in the FYR. Second, some estimates may overvalue activities while others may undervalue activities. For example, there is a significant cost difference between the groundwater monitoring activities of the period 1988-2002 and 2009-2020. Third, the costs estimated in this report do not include the costs associated with bioremediation (the 2016 FYR identified this cost as about $500,000), which were known to have occurred, but they are not consistent with an IC. Further, there were also estimates for thermal remediation (not implemented) that may be a future solution, and thus, a future cost.

Wash King Recommendations

1. Prioritize the investigation and identification of all source areas and removing or preventing those source areas from continuing to contaminate and migrate.

2. To prevent contaminant exposures resulting from delayed implementation of RCs or groundwater ordinances, the state should explore means for expediting the implementation of such ICs.

APPENDIX J: WICKES MANUFACTURING TCE PLUME SITE SUMMARY

Location	**310 Palmer Park Road, Mancelona, MI, 49659**
EGLE district / contact	Gaylord District Janice Adams PM (ADAMSJ1@michigan.gov)
EPA Superfund? (link)	No
EPA contact	
Contaminants	TCE
Exposure pathways	Drinking water, GSI, vapor intrusion
Background	*Mt. Clemens Metal Products* manufactured automotive parts using trichloroethylene (TCE), chlorinated solvents, and plating processes. It operated at this location from 1948 until 1967. During operations, scrap steel saturated with chlorinated paraffin was stockpiled outside of the plant, and untreated wastewater from the manufacturing processes was discharged to three earthen seepage pits. (Aerial photographs from 1992 show that the seepage lagoons were covered over by facility expansion sometime between 1981 and 1992.) The property was sold to Gulf and Western in 1967 and they operated until 1985. Wickes Manufacturing operated at the site from 1985 to 1990. DURA Automotive operated at the site from 1990 to 2008. Records indicate that TCE was used only up until the mid-1960s. In 1986 Wickes disclosed that TCE had been used at the site by Mt. Clemens Metal Products due to disclosure requirements of the Clean Water Act. EPA conducted groundwater testing and discovered TCE in groundwater and drinking water. In 2003 the Wickes site became a state funded facility because Wickes was not responsible for the TCE contamination. The plant was demolished in 2011-12 by the owner with no EGLE oversight. The EGLE PM stated that no soil was removed during demolition of the building, however groundwater, soil, soil vapor, and VI testing was conducted by RRD prior to and after the demolition. Per Len Mankowski (from AMEC Engineering & Consulting of MI - previously MACTEC - an environmental contractor working for EGLE on Wickes since 2003), the building slab remains intact and there was nothing observed during their subsequent investigation in 2017 to indicate any significant soil disturbances (i.e., no soils removed) thus contaminated soils remain in place under the concrete slabs. Investigations conducted by EGLE have determined that the TCE contaminated groundwater plume extends over six miles beyond the facility northwest to the Schuss Mountain/Shanty Creek Resort and the Cedar River, has a depth of over 450 feet, and a width exceeding 1.25 miles at the leading edge of the plume. This is an orphan site without any viable responsible party and is thus a state-funded site. TCE concentrations in the plume are more than 80 times the drinking water criterion. State alternate water funds were used to fund a drinking water supply system to all properties with existing groundwater users within the known area of the plume. The drinking water supply system is continually being extended as the TCE plume migrates and contaminates private drinking water

	wells. The Health Department of Northwest Michigan (HDNWM) samples the private drinking water wells located outside the drinking water supply system quarterly to annually. The Mancelona Area Water and Sewer Authority (MAWSA) was created in 2000 at the suggestion of DEQ to combine the Mancelona Village, Mancelona Twp., and the Schuss Mtn. Water and Sewage Authority to provide clean drinking water to properties affected by the Tar Lake (non-TCE) and Wickes TCE plumes. In 2016, EGLE funded MAWSA to complete a high-pressure main extension from the Mancelona well field to the Cedar River well field along with a storage tank. EGLE also provided $1,000,000 to the MAWSA to construct a water tank/booster station for additional storage. The design and construction of the water tank/booster station were completed in July of 2019. In December 2018, TCE was detected in a private drinking water well on Windy Hill Drive where municipal water was not available. The extension of municipal water supply to this area was completed in December of 2019. The extension of municipal water to the Pinebrook Condos was completed in early 2019. All the residences with contaminated well water have been connected to MAWSA. Drinking water is drawn from wells located east of Mancelona and from the Cedar River Well Field near Schuss Mountain. EGLE funds provide residents with connection to the main, abandonment of their private well, and replumbing in their home for the transition. EGLE also covers the cost of tap fees and meters from MAWSA. This is approximately a cost of $7,500 if a resident were to pay for it themselves (per MAWSA during 2/2022 presentation). The most recent sampling of the monitoring wells and the surface water sampling took place in the Fall of 2022. The groundwater model is continuously being expanded with new data. The following tasks have been completed during the investigations at the site: groundwater monitoring, surface water monitoring, estimation of groundwater capture zones to project theoretical 5 and 10-year capture zones for the Cedar River Well Field, expansion of the groundwater model, geophysical surveys, modeling of the groundwater to evaluate wellhead protection of the Cedar River Well Field and the Shanty Creek/Schuss Mountain Summit well field, pump tests, gamma logging, sentinel well installation and volatilization to indoor air pathway (VIAP) investigations onsite and offsite. The fieldwork has been conducted in the Cedar River Well Field/Aquifer Sentinel Well Expansion area to further delineate the extent of the groundwater contamination and to assess the vulnerability of the Cedar River Well Field and the Shanty Creek/Schuss Mountain Summit Well Field, which are downgradient of the TCE plume. Slug tests have been performed on the monitoring wells near the Cedar River Well Field. The following tasks are on-going through 2023: groundwater, surface water, and vapor intrusion investigations; install sentinel wells as necessary; expand municipal water system toward the Shanty Creek/Schuss Mountain Resort well field which is downgradient from the Cedar River well field; continue updating the groundwater model with new data; continue annual sampling of the Cedar River and Shanty Creek; continue monitoring the effects of production well pumping; and continue community outreach program and web site management. The magnitude of the groundwater contamination and costs of remediation at this site prohibit the performance of groundwater cleanup (from EGLE site summary). The Remediation and Redevelopment Division (RRD) will continue to assess and track the extent and nature of

	groundwater contamination and provide alternative drinking water supplies to affected areas consistent with available funding. Volatilization to the indoor air pathway (VIAP) investigation onsite and offsite continues. The VIAP investigation offsite has included indoor air sampling at four commercial buildings. Mitigation systems have been designed, installed, and operating for three commercial buildings. The fourth commercial building continues to be investigated and monitored. If the groundwater is not remediated, potential downgradient receptors include the Cedar River community well system, the Shanty Creek/Schuss Mountain Summit Well Field, and additional individual residential wells. The VOC plume has created a massive brownfield that extends off-site for six miles, affecting 1,198 parcels of residential property (per PM and EGLE site legislative report page 7). EGLE staff have been contacted by several property owners with concerns about health and complaints about the negative impact on their property values.
Status	On-going
Formal ICs used	Well First Policy: Implemented in 2005 by the Health Department of Northwest Michigan (HDNW). Designed to be an IC to prevent exposure to TCE in groundwater. Connection to public water is required as soon as it becomes available. When public water is not available, the policy outlines well construction and sampling requirements. The area affected by the policy is regularly reviewed and modified as TCE contaminated groundwater moves and as information about the location of TCE is updated. Well construction and sampling requirements when public water is not available include: targeted well depth; drilling technique (mud rotary drilling methods must be used, entire well casing must be grouted, and pumping and surging required to develop the well); water quality sampling; HDNW final inspection; connection to public water when available; and well abandonment. A permit process is in place with the HDNW to prevent installation of wells in the contaminated groundwater. Property owners must demonstrate a sustainable supply of uncontaminated groundwater before a building permit or a water well permit is issued. There is no RC for the former Wickes Manufacturing facility. Per District staff regarding the former manufacturing facility which is contained within the Wickes TCE Plume site: “When (if?) the property ever gets sold and developed, they will certainly have to place restrictions to assure the property is used safely. The current owners are aware of this, and any future owner will certainly be working with us to assure safe use for whatever their plans may be.” From a July 2023 email from the EGLE PM: “Deed restrictions on the groundwater, soil, and soil vapor at the plant area are needed. These deed restrictions should also include engineering controls, vapor barrier etc., in any future buildings constructed on site. The current property owner has not agreed to having EGLE, RRD, place deed restrictions on the property. EGLE, RRD, will continue to work with the property owner on institution controls being placed on the property.” (There is an October 2007 RC for the former Wickes Effluent Pond in Mancelona Twp., Antrim Co., Mancelona, MI on Palmer Park Rd. This property is not a part of the Wickes TCE Plume site. The RC requires the following: the owner shall prohibit all activities that may interfere with any element of the response activities; the owner shall prohibit activities that may result in exposures above concentrations greater than unrestricted residential criteria including use of the groundwater; the owner shall manage all soils, media and debris in accordance with waste management requirements; DEQ must be notified of any intent to transfer the property.)

Alternative ICs used	Municipal water connections
IC failures	None reported.
Other remedial activities	No remedial activities other than demolition of the former manufacturing facility. Some remediation occurred at the Wickes Effluent Pond site south of the plant, however, it is not a part of the Wickes TCE Plume site. The main activities are monitoring of the groundwater plume and sampling of soil, surface water, groundwater, soil vapor, VI investigations, and providing safe drinking water (via the municipal system) to residents and commercial buildings.
Expanding plume	Yes
Timeline	**1947–1967**: TCE was used in auto parts production by Mt. Clemens Metal Products (since out of business) (8, 16:41, Fact Sheet 2 2019)) **1967-1985**: Operated by Gulf and Western (8, 16:41) **1985-1990**: Operated by Wickes Manufacturing (8, 16:41) **1986**: Wickes disclosed TCE was used by Mt. Clemens Metal Products; EPA sampled the groundwater and discovered TCE in groundwater/drinking water. (8, 16:41) **[1988-1989**: waste-settling lagoons and landfills (TCE sources) are removed on the Wickes Effluent Pond site (8, 22:00)] **1990-2008**: Operated by DURA Automotive (8, 16:41) **2000**: EGLE works with local communities to form MAWSA to provide municipal water hook-ups for all residents affected by Wickes and Tar Lakes plumes. (8, 1:13:00, Fact Sheet 2 2019) **2003**: Site becomes state-funded facility (8, 16:41) **2003**: EGLE starts down-gradient investigations (8, 27:47) **2005**: Initial Well First Policy implemented (8, 1:04:00) **[2007**: RC for the Wickes effluent pond (12.4 acres) (Not a part of TCE plume site.)] **2011-12**: Manufacturing plant demolished by the owner (8, 16:41; AMEC) **2011**: MAWSA must upgrade the capacity of its initial pipes. (8, 1:04:00) **2012**: Well-first policy area extended (8, 1:04:00) **2018**: Well-first policy area extended again (8, 1:04:00) **2019:** MAWSA extended the water system to the Summit Village association's Windy Hill Area **2023:** MAWSA is currently extending the water system in Phase 1 and Phase 2 in Summit Village Association near Deskin Road and Forest Trail. The residences in Phase 1 and Phase 2 will be connected to the municipal water early in the Fall of 2023.
Public health cases	None to date (MACTEC 2008 report, p. vi) Have not observed continued exposure in the area (8, 1:48:00)
Impacted recreation	Actively discharging to the Cedar River, but below GSI thresholds for TCE (<200 ppb)
Impacted property value	The VOC plume has impacted 1,198 residential properties. EGLE staff have been contacted by several property owners with concerns about health and complaints about the negative impact on their property values. (EGLE site summary)

Exposure Pathway Evaluations (prior to implementation)

Drinking water	
Were criteria exceeded?	Yes. Per MACTEC 2008, the following analytes were detected above the Part 201 generic residential drinking water criteria: TCE; benzene; tetrachloroethylene; tetrahydrofuran; chromium, iron, and manganese.

	Name	Type	Year	Anticipated to prevent exposure?	How? Successful?
Remedial responses implemented	Well First Policy		2005	Yes	If safe groundwater water is not available, prevents development of private wells in contaminated GW; requires connection to municipal water if available (see above)
	EGLE has invested $15 million to fund MAWSA and also $12 million (EGLE Wickes Fact Sheet #5) to do the following: extend water mains to new areas; hook up homes to new/existing water mains if TCE is detected in the residential well; provide funding to the HDNW to sample residential wells near the edges of TCE impacted groundwater; expand the current monitoring well network and collect groundwater samples twice a year to monitor the location of TCE in groundwater; monitor the effect of pumping on the groundwater system to identify engineering alternatives; annually update technical reports.				Yes, by preventing exposure to contaminated groundwater and providing safe, clean drinking water.
Were soil criteria to protect drinking water exceeded?	Yes, per AMEC Tech Memo No. 39. Some soil samples under and around the former plant had concentrations > the Soil DWPC for TCE (mostly) and Perc. TCE concentrations were 170-990 ppb (DWPC = 100 ppb).				

Remedial responses implemented

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?
Soil & GW investigations conducted around the time of the demolition		2017-2018	No	No – sampling only

Groundwater surface water interface (GSI)

Were criteria exceeded?	Yes, some TCE exceedances of the GSI criterion of 200 ppb at the former plant site (AMTEC, 2008). No exceedances at the Cedar River above the 200 ppb GSI criterion (8, 59:30). Will eventually reach Shanty Creek, but not above the 200-ppb limit. Unlikely to reach Lake Bellaire. (8, 1:54:00; 2019 Fact Sheet 9).

Remedial responses implemented

Name	Type	Year	Anticipated to prevent venting to surface?	How? Successful?
Groundwater and surface water investigations			No	Monitoring only.
EGLE funds the following: sample groundwater and surface water at the Cedar River where TCE in groundwater vents to it			No	Monitoring only. Exceedances of the GSI may require further action.

Were soil criteria to protect GSI exceeded?	Criterion for TCE = 4,000 ppb; per AMEC Tech Memo No. 39, some soil samples under and around the former plant had concentrations of 170-990 ppb. Based on this, soil criteria to protect GSI were not exceeded.

Remedial responses implemented

Name	Type	Year	Anticipated to prevent leaching?	How? Successful?
Soil and groundwater investigations were conducted around the time of demolition		2011	No	Sampling only.

Soil direct contact

Were criteria exceeded?	No, not TCE (or PCE) at the former manufacturing plant site (2019 Fact Sheet 13). TCE residential SDCC = 1.1E+5 (DD) ppb. Max soil TCE concentration from any of the source areas at the facility = 5,800 ppb.
Remedial responses implemented	(see table below)

Name	Type	Year	Anticipated to prevent venting / leaching?	How? Successful?
Soil and groundwater investigations were conducted around the time of demolition		2011	No	Sampling only.

Volatilization to indoor air

Were groundwater volatilization to indoor air criteria or screening levels exceeded?	Yes. The groundwater data from MacTec Tech Memo No. 6 (2004 sampling at the plant source areas) shows that groundwater concentrations at the plant facility do exceed the Residential GW Not in Contact VISL of 10 ppb and the Shallow GW SL of 7.3E-2 ppb. Tech Memo 39 (2018 report on groundwater & soil sampling conducted 2017-18 at former plant and across the street at commercial buildings). 2 monitoring wells near Schuss Mtn had TCE in groundwater at concentrations > VIAP SLs. Tech Memo-48: GW > VIAP SLs @ MW-206 & MW-G WT
Remedial responses implemented	(see table below)

Name	Type	Year	Anticipated to prevent exposure	How? Successful?
VIAP investigations onsite and offsite continue. The VIAP investigation offsite has included indoor air sampling at four commercial buildings. Mitigation systems (sub-slab depressurization) have been designed, installed, and operating for three commercial buildings. The fourth commercial building continues	GW & SV studies & SSDSs	SSDS Installed 2020 Investig. & monitoring since 2017	Mitigation systems yes, Monitoring potentially.	SSDSs installed (2022 AMEC reports) or under evaluation (2019 Fact Sheet 13). Yes.

	to be investigated and monitored.
Were soil volatilization to indoor air criteria or screening levels exceeded?	Yes. Tech Memo 39 reports exceedances of the residential soil VISLs (0.33 ppb) and the residential soil vapor VISLs (67 ug/m^3). Per Tech Memo 6, soil concentrations from the former manufacturing facility exceed the Residential Soil VISLs of 0.33 ppb. And per Fact Sheet #13: TCE levels in shallow soil vapor below the former plant exceed vapor intrusion screening levels year-round. TCE levels in shallow soil vapor seasonally exceed vapor intrusion screening levels on properties to the west of the former plant. Yes, across the street from source area (8, 52:00) In downgradient locations, levels exceed the criteria (10ppb), but the pathway is not complete, so they will continue to monitor. (8, 54:00). TM-48 reported no exceedances of TCE in soil vapor downgradient near Schuss Mountain

Remedial responses implemented

Name	Type	Year	Anticipated to prevent exposure?	How? Successful?
VIAP investigations onsite and offsite continue. The VIAP investigation offsite has included indoor air sampling at four commercial buildings. SSDSs have been designed, installed, and operating for three commercial buildings. The fourth commercial building continues to be investigated and monitored.	GW & SV studies & SSDSs	SSDS Installed 2020 Investig. & monitoring since 2017	Monitoring potentially. Mitigation yes.	SSDSs (2022 AMEC reports) or under evaluation (2019 Fact Sheet 13). Yes.

Ambient air

Were criteria exceeded?	No information was located referring to an ambient air pathway evaluation. However, the soil data from Tech Memo 6 indicates that the current residential soil ambient air criteria are not exceeded at the former manufacturing facility.

Remedial responses implemented

Name	Type	Year	Anticipated to prevent	How? Successful?

				venting / leaching?	

Source materials

Any present?	Low levels of TCE remain in the soil where the buildings used to be (2019 Fact Sheet 11). Tech Memo 39 reports max concentration of TCE and PCE at the former plant at 990 and 560 ppb, respectively. TCE was reported in 13/40 soil samples. PCE was reported in 6/40 soil samples. Soil vapor hotspots coincide w/ bldg. footprint & extent of the TCE groundwater plume footprint in the source area. The PM has stated that EPA did not conduct any remedial actions at the Wickes Manufacturing plant and no waste or contaminated soils were removed after the demolition of the plant building by EGLE nor by the owner (per Amec). The RRD PM stated that RRD has conducted soil, VI, soil vapor, and groundwater sampling on the former plant property prior to and after the demolition of the building. (See June 19, 2023, email from Janice Adams: Although residual TCE remains under the former building and continues to leach to the groundwater, the Department does not believe the residual contamination constitutes a source nor that DNAPL is present.)

	Name	Type	Year	Addresses source materials	How? Successful?
Remedial responses implemented					

Wickes Additional References

1. EGLE link: https://www.michigan.gov/egle/0,9429,7-135-3311_4109_9846_30022-385691--,00.html

2. EGLE Factsheet: https://www.michigan.gov/documents/deq/deq-rrd-WICKES-WickesManufacturingTCE_PlumeFact_Sheets1-12_525506_7.pdf

3. EGLE Plume mapper: https://ifrastructure.amecfw.com/wickes/

4. https://www.michiganradio.org/environment-science/2017-07-18/northern-michigan-community-tries-to-stay-ahead-of-massive-contaminated-plume

5. http://dekrealty.com/tce-plume-antrim-county/

    a. Interesting 10-minute video assuring the public that the homes in the affected area are safe.

6. https://conservetorch.org/tce-plume/

7. http://www.nwhealth.org/pubs/Public%20Meeting%20Flyer_2-9-2022.pdf

8. https://www.youtube.com/watch?v=4jb_O3Vfdgg

Wickes TCE Manufacturing Site IC Cost Breakdown

To assist in cost considerations, the IC was broken out into three distinct Phases based on dates for which the recognized plume was expanded. Each phase represents an expansion of the number of properties impacted and therefore facilitates accounting for recurring costs. As the Well First policy is largely seen as the declaration of the IC and was first implemented in 2005, related costs incurring from 2005 forward are subject to inclusion if found to be realized after and because of the IC. Phase 1, therefore existed from 2005 to 2012, when the Well First policy was extended due to plume migration. It was subsequently expanded in 2018, which marked the end of Phase 2 and the beginning of Phase 3. We limit Phase 3 to two years ending in 2020 – marking the end of past costs under this study. All effects beyond 2020 are future and ongoing expenditures. Accordingly:

- Past Costs
    - Phase I 2005-2012
    - Phase II 2012-2018
    - Phase III 2018-2020
- Recurring Costs
    - Future costs 2020+

Past Costs

The immediate costs of the IC in Phase 1 included the direct investment in new water sources for the impacted properties. This required state investment in municipal water line extensions from the Mancelona Municipal Water System to the impacted properties, including all relevant pumping substations. Additional costs ensued, including the cost of supply bottled water to impacted households until connected to the Mancelona municipal water system, capping existing residential wells, drilling monitoring wells, and running tests on monitoring and residential wells, to name a few. These costs were compiled by phase, where data afforded and over all phases where data does not provide sufficient detail.

While the Wickes plume impacts 1,198 residential properties, just over 550 residential wells were identified as disabled by the TCE plume. Consistent with records, rural properties required to connect to municipal water systems were not necessarily connected to the municipal wastewater system. The timing of the effects is important to account for the number of months each effected residence was required to cover monthly water utility bills, set at $79.50 per month on average. Collectively, there are 3,319 water service years required to supply water to residential households, and each service year costs the respective household just under $80. Total estimated past cost is $1.4 million. In addition, based on the assumption that the average impacted household required six-months of bottled water before being connected to the municipal system, it was estimated that overall cost of bottled water delivery was about $132,500.

Residential properties connected to municipal water also required a fixed investment required to extend municipal water service lines and for connecting to the extended main lines. Total linear feet of the new main line installation were determined by line diameter. Cost estimates of main line installation by line diameter were applied on a per linear foot basis. Consideration was limited to main line installations of 6 or more inches in diameter. In total, some 315,000 linear feet of municipal water mains were installed, and 550 homes were connected. This was the single largest cost to the Wickes site, with actual costs exceeding $14 million. Residential wells were routinely sampled and tested for contamination at the state's cost. On average, 45 residential drinking wells were sampled per year. In addition, from the 130 permanent monitoring wells installed, just under 1,500 samples were collected. The cost assessment used per-unit cost estimates of laboratory tests of residential well water samples, of test well samples and of installing test wells to derive overall testing costs. This excludes sampling and costs borne by MACTEC Engineering and Consulting of Michigan, Inc., and other third-party consultants in their respective contractual work with the state. Laboratory tests of residential and monitoring wells, and costs of installing monitoring wells totaled $6.4 million between 2005 and 2022.

Finally, there is the overhead costs of managing the site and coordinating communications across local, state, and federal agencies, supporting the local health departments, and supporting legal documentation and support for the site. There is no direct accounting for site management costs and in many cases the realized costs are not broken out from agency operating costs. However, based on similar sites, an average annual cost of $60,000 was anticipated excluding any cost for research, sampling, or report generating- totaling $1.03 million over the 15 years between 2005 and 2020. Each engineering report generated is expected to cost more than $100,000, and four such reports were observed, though more likely exist. Therefore, another $1,000,000 was allocated as a lower envelope of the costs of engineering studies and technical reports generated since 2005.

Combining the past costs from 2005 to 2020, a social cost of $66,900,000 was estimated for the Wickes site. The actual cost in a best-case scenario may be as low as $36.7 million or as high as $91.7 in the worst-case scenario.

Cost Category	Best Case	Expected	Worse Case
Phase 1 (2005-2012)	$3,019,499	$4,437,048	$4,682,346
Phase 2 (2012-2018)	$4,878,132	$10,317,619	$11,110,357
Phase 3 (2018-2020)	$4,517,886	$6,256,080	$7,513,926
Municipal Water Extensions	$24,707,597	$46,264,956	$68,810,939
Total Past Costs	**$36,753,114**	**$66,905,703**	**$91,747,568**

Table J-1: Wickes costs by phase.

Recurring and Future Costs

This site has expected ongoing and recurring costs as well as expected intermittent future costs. Depending on the future migration of the plume, additional residential lots may be impacted, requiring well abandonment and connections to municipal water systems. However, it appears that housing developments west of the plume are anticipating the expansion of the plume and will develop with connections to the municipal water system. That is, residential connection to municipal water around the Shanty Creek Resort appears to be a matter of course for these developments.

Accordingly, new residential lots that connect to municipal water may lose the option of utilizing a private water well, but they also gain the cost savings afforded municipal hookups including well-drilling cost avoidance and well pump operations and maintenance and annual testing of water quality. However, they gain the additional costs associated with monthly water-use bills. Depending on the household and geology, the expected costs of connecting to a municipal water system over a private well may be negligible. Added IC-related costs, however, will be realized in extending the main municipal water line out by half a mile to meet residential development in the path of the plume. The total number of residential lots to be connected is not yet clear, but it is anticipated that the costs of connecting to the mainline is much less than the costs of drilling a new private drinking water well.[13]

Though this assessment assumes no net social costs from new residential lots, the annual utility costs of residential lots forced into municipal water systems are ongoing costs to be accounted for. At the end of 2020, about 550 residential lots were required to abandon their private water wells and connect to the Mancelona municipal water system. This study uses the expected annual utility costs of households forced to shift to municipal water as the basis of ongoing costs exerted on households' water costs. This likely understates the total effect as the number of residential units impacted by the plume is thrice the number of properties with identified well replacement.

Another ongoing cost identified is the annual costs to local and state agencies in managing the site, developing the reports and communications about the status of the plume, dealing with legal filings, etc. In 2020, the estimated annual overhead costs of managing the site were placed at just under $60,000. As there is an expectation that such activities of local and state agencies will continue indefinitely, this assessment projects equal annual expenditures in real terms in calculating the overall estimated costs of this IC. Sampling of existing residential wells will continue at a rate of about 45 per year, while about 98 samples from the 130 monitoring wells will continue. It is likely that additional monitoring wells will be installed, but this is subject to conjecture. This assessment alternatively assumes no new monitoring wells will be installed.

The collective estimated recurring annual costs total $712,000 per year. In the best-case, this may be $536,600 while the worst-case outcome is $993,000. As these costs are recurring, it may be instrumental to discount future case flows to derive a present value of the annual cost estimates. The length of the annual cost occurrence is arbitrarily set at 20 years and three discount rates were applied. The range of values estimated are shown in Table J-2, and those values can be compared with or added to the past cost estimates provided above. The overall expected value is highlighted at the intersection of the Expected Column and the 10% discount rate.

	Lower Bound	**Expected**	**Higher Bound**
5%	$6,687,000	$8,873,000	$12,370,000
10%	$4,568,000	$6,062,000	$8,450,000
15%	$3,359,000	$4,457,000	$6,213,000

Table J-2 Present value estimates of future recurring costs

Potential Costs

These two sources of recurring costs are likely not comprehensive. Individual households may, out of an abundance of caution, pursue well testing above and beyond that funded by the state. Similarly, households may preemptively install VOC filters and/or physical barriers to stave off future exposure. The universe of

[13] An option not investigated is the option of drilling a single high-volume well to meet the needs of single rural subdivision. This would create many of the efficiencies of connecting to a municipal system, while potentially reducing the overall annual costs associated with a municipal system. Though not represented in the future cost estimates, this lost option may pose a measurable cost associated with the IC.

possible sources of unforeseen future costs is vast. However, a few sources of potential costs are more foreseeable than others. For example, given the multitude of engineering studies documenting the migration of the plume, it is likely that every few years a sizeable investment in a site study will be commissioned. In this estimate of future costs, an in-depth engineering report is budgeted for every three years. In total, five more, in-depth engineering reports are estimated over 15 years in this cost projection, each with a state cost of just under $100,000. Discounting this by 5%, 10% and 15% provides expected present values of $329,300, $229,800, and $168,400, respectively, with the most likely outcome being $229,800.

Unmeasured Costs

As is the case with other sites, only socio-economic costs with a reasonable basis for estimation were enumerated, leaving some conceptual sources of costs unaccounted for. Known unmeasured or undermeasured costs for the Wickes site includes the full extent of the costs for deriving technical reports of the migration of the plume resulting in yearly estimates of the size and displacement of the plume. This site posited significant groundwater monitoring and modeling challenges with multiple plumes at different depths and the expanse of the plumes in question. The threat to municipal water systems added more urgency for accurate assessments and accordingly posited greater risk avoidance behavior, which can contribute to the overall unmeasured socio-economic cost estimates. Other unmeasured costs are relevant. Specifically, the presence of the plume adds stress to residents. The simple observation that impacted and potentially impacted residents attended locally sponsored information events is testament to unmeasured costs borne by residents. The assessment team has neither the number of such events nor attendance at information sessions to measure household time committed to learning more about the plume. The loss of economic growth opportunities is another source of unmeasured costs, where property developers may overlook the local region for development projects given the potential liabilities or demand constraints posed by the plume and associated IC. The Wickes plume discharge in otherwise desirable fishing streams may also pose a constraint on future angler tourism activity in the region. The Cedar River is a fishing destination for which a TCE discharge can have stigmatizing effect. Whether the TCE poses a threat to the freshwater fish or not, the stigma of a pollution discharge into the Cedar River may be enough to disrupt angler activity, but the extent of such a disruption is difficult to quantify without a specific study of users.

Summary

Combining the cost estimates into single expected costs of the Wickes Manufacturing TCE Plume IC, we derive a lower and upper bound and a most likely cost scenario or expected cost of $73.6 million.

Lower Bound	**$42,020,000**
Expected Costs	$73,570,000
Upper Bound	$100,740,000

Table J-3: Wickes Manufacturing TCE Plume IC cost ranges.

Wickes Manufacturing TCE Plume Recommendations

1. Better account for all the related costs associated with letting a plume migrate. MACTEC's estimate was up to $4.7M, but EGLE has already spent $25M.

2. Do not wait for the transfer of ownership to implement an RC for contaminated property. Either grant EGLE the authority to record RCs on contaminated properties or amend the statute to require non-responsible property owners to record RCs on their property as part of their due-care obligations.

3. Free-phase product, such as DNAPL or LNAPL and highly contaminated soils or groundwater, often act as continuing sources of contamination to the groundwater. Current definition of "source" in Part 201 (which was inserted/amended in 2015 - definition did not exist in statute pre-2015): (zz) "Source" means any storage, handling, distribution, or processing equipment from which the release originates and first enters the environment. Amend Part 201 to remove or change definition to be more expansive to include material already released from such equipment.

4. The department should consider the potential effect ICs and ordinances may have on property owners' ability to develop their property when clean drinking water is not available. If they are unable to develop their property because clean drinking water is not available, this potential resulting cost should be included when considering alternatives for remedial activities.

5. Improve the transparency of a property's history of contamination for prospective purchasers of properties that fall under a municipal ordinance to restrict groundwater use.

6. The owner of the property demolished the plant in 2011 without EGLE oversight because the statute allows parties to conduct voluntary work. Consider options for granting EGLE more authority for oversight of voluntary or self-implemented remedial activities.

7. Wickes highlights the need for long-term, stable sources of funding for the clean-up program. In this case, stable funding is needed to support municipal water expansion into the future.

APPENDIX K: MEIJER LUST SITE

Background

A gas station operated at 6200 South Pennsylvania Avenue in Lansing, MI from 1967 – 2014. In 1990 Meijer took over as the station's owner and new underground storage tanks (USTs) were installed. In 2014 the gas station was moved due south (adjacent to the former site), the old site was demolished, and the USTs removed. In the fall of 2014, the State of Michigan was notified of, and subsequently confirmed, the release of contaminants of concern (various components of unleaded gasoline) from leaking USTs (LUSTs) at the former gas station site. Meijer excavated over 3,500 tons of potentially contaminated soil and approximately 15,000 gallons of accumulated rainwater from the former site. Starting in December 2014 Meijer began installing monitoring wells to delineate the soil and groundwater impacts and continued to do so through 2016. By 2015 contaminants had been observed at multiple monitoring wells and at varying depths. During this initial monitoring phase, concentrations of the gasoline components at certain locations exceeded safe thresholds for drinking water, the groundwater surface water interface, and soil vapor intrusion. The contaminated site did not contain drinking water wells, surface water features, or (with the former station's building demolished) structures for which vapor intrusion could pose a threat. Meijer sought to prevent exposure along those pathways through a restrictive covenant (RC), which would prohibit the installation of drinking water wells, require vapor assessment for new buildings, maintaining an exposure barrier, and only allow for non-residential land uses. Meijer proposed the RC in 2016, though it was not recorded with Ingham County until 2023. The site currently is an empty grass-covered field. Monitoring continued through 2022, and though concentrations continued to exceed the previously mentioned thresholds at certain locations, Meijer suspended monitoring activities in 2023 because it considered the site not to "pose a risk to human health, or the environment." (ARCADIS, 2023B). Meijer based this determination on the fact that contaminant concentrations were stable or decreasing and that the implemented RC would secure the exposure pathways.

Consideration of remedial actions

ARCADIS (2016) evaluated five strategies for addressing the contamination at the site. These were institutional controls, excavation, total fluid recovery, air sparging with soil vapor extraction, and multiphase extraction. Institutional controls (ICs) were selected in lieu of the more active remedial options because of the technical difficulty in implementing these other methods, potential challenges introduced by the site's geology, and the fact that the exposure pathway evaluation indicated the contaminants to no be an imminent risk to human health or the environment. ARCADIS did not provide a cost estimate for each option, though it was cited as a precluding feature for multiphase extraction and implied in the other strategies.

Use of institutional controls

Meijer's primary use of ICs was the recording of the RC in 2023. In 2017 Meijer submitted a Public Highway Institutional Control for a portion of the right-of-way along the west-edge of Pennsylvania Avenue; however, the project team was unable to locate any description of that proposal or whether it was adopted. There was no record of it in Environmental Mapper. In support of its contention that the drinking water pathway is secure, ARCADIS (2023b) cites an Ingham County Health Department Ordinance (section 320.4 of the Ingham County Sanitary Code) which prohibits the installation of new and private water wells where municipal water is already available, as was this case for this section of Lansing. ARCADIS (2023b) also states that Meijer will pursue an IC for a Bank of America-owned property north of the affected site which may be affected by the contamination in the future.

Timeline
1967 – Gas station begins operation.
1990 – Meijer takes over the operation of the gas station, replaces some of the USTs.
2014 – Meijer moves the station to an adjacent property, demolishes the old building, removes the old USTs. Contaminants in the soil are reported to EGLE and subsequently confirmed. Soil is excavated, rainwater removed, and monitoring wells installed.
2015 – Monitoring continues, contaminants discovered at multiple locations around the site.
2016 – RC proposed for the site in lieu of more active treatment options (e.g., additional excavation, pumping and treating, soil vapor extraction)
2017 – Public Highway Institutional Control proposed for right-of-way along the affected property.
2023 – RC registered for the affected property. Meijer suspends monitoring activities.

Costs
Meijer offered to share the costs incurred in responding to the contamination at its site. However, it only shared estimates for broad categories (listed below) without any additional breakdowns of those costs, such as time ranges or budgeted amounts.

Category	Cost
Project management and H&S	$54,000
Site investigation	$312,000
Restrictive covenants and administrative institutional controls	$23,000
EGLE reporting and meetings	$69,000
Total	**$458,000**

Table K-1: Meijer cost estimates for responding to the contamination.

Implications for this study
The limited scope of this data and its late arrival within the project timeline prevented the team from conducting the in-depth cost analysis that it conducted at the seven case study sites. The seven case study sites included in this project's analysis lacked a LUST example. Considering that there are over 10,000 facilities classified under the state's Part 213 program (for regulating LUSTs)[14], such a site would be an important contribution to the analysis. Though the Meijer Gas Station site provided a window into the evaluation of ICs at a LUST site, there were several aspects of it that would have made it difficult to estimate the costs of ICs and, therefore, not an ideal candidate for this study. First, there were initial active remediation actions taken (soil excavation and water drainage) that make it harder to isolate costs attributable to the use of ICs. It is easier to attribute all subsequent incurred costs to ICs at sites where they were the only utilized approach. Second, the primary IC at this site was not formally implemented until 2023, which would have left a short time window from which to attribute subsequent costs. Lastly, though the project's Final Assessment Report (ARCADIS 2016) evaluated an IC-focused approach against more active remedial measures, no cost breakdowns were provided in the assessment. Without this information it is difficult to evaluate Meijer's decision making with regards to the economics of responding to the contamination.

[14] https://www.egle.state.mi.us/RIDE/inventory-of-facilities/facilities

APPENDIX L: REFERENCES

Abdalla, C.W. 1990. Measuring Economic Losses From Ground Water Contamination: An Investigation Of Household Avoidance Costs 1. JAWRA Journal of the American Water Resources Association 26:451-463.

Abdalla, C.W. 1994. Groundwater Values from Avoidance Cost Studies: Implications for Policy and Future Research. American Journal of Agricultural Economics 76:1062-1067. doi: 10.2307/1243392.

Abdalla, C.W., B.A. Roach, and D.J. Epp. 1992. Valuing Environmental Quality Changes Using Averting Expenditures: An Application to Groundwater Contamination. Land Economics 68:163-169. doi: 10.2307/3146771.

ARCADIS (2007). Ford Motor Company Kingsford Products Company: Former Site Interim Response Action Plan and Construction Documentation Report. Ford-Kingsford Products Facility (Court Case Number 04-1427-CE). Kingsford, MI, ARCADIS.

ARCADIS (2012). Ford Motor Company Kingsford Products Company: Remedial Action Plan. Ford-Kingsford Products Facility (Court Case Number 04-1427-CE). Kingsford, MI, ARCADIS.

ARCADIS (2106). Former Meijer Gas Station #24 Final Assessment Report. Submitted to EGLE, March 22, 2016. Lansing, MI.

ARCADIS (2020). Ford Motor Company Kingsford Products Company: Progress Report #52. Ford-Kingsford Products Facility (Court Case Number 04-1427-CE). Kingsford, MI, ARCADIS.

ARCADIS (2023a). Ford Motor Company Kingsford Products Company: Progress Report #55. Ford-Kingsford Products Facility (Court Case Number 04-1427-CE). Kingsford, MI, ARCADIS.

ARCADIS (2023b). Site Status Report for Meijer #324 Gas Station. Submitted to EGLE, April 10, 2023. Lansing, MI.

Beeler, M., Nasir, I., Willig, M. 2020. Risk-Based Management of Groundwater Contamination in Michigan: An Analysis of Part 201 of the Natural Resources and Environmental Protection Act. Submitted to EGLE, April 2020. Lansing, MI. https://deepblue.lib.umich.edu/handle/2027.42/154825

Boyle, K.J. and R.C. Bishop. 1987. Valuing wildlife in benefit-cost analyses: A case study involving endangered species. Water resources research 23:943-950.

Boyle, K.J., N.V. Kuminoff, C. Zhang, M. Devanney, and K.P. Bell. 2010. Does a property-specific environmental health risk create a "neighborhood" housing price stigma? Arsenic in private well water. Water resources research 46.

Case, B., P.F. Colwell, C. Leishman, and C. Watkins. 2006. The impact of environmental contamination on condo prices: a hybrid repeat-sale/hedonic approach. Real Estate Economics 34:77-107.

City of Madison. 2022. Water Utility. May 17, 2022. <https://www.cityofmadison.com/water/water-quality/private-wells/well-abandonment/well-abandonment-frequently-asked-questions#:~:text=A%20%E2%80%9Ctypical%E2%80%9D%20abandonment%20costs%20%24800%20-%20%241500%20but,available%20to%20help%20pay%20for%20the%20well%20abandonment%3F>.

CME Group. 2024. CME DataMine. Accessed January 2024. https://www.cmegroup.com/market-data/datamine-historical-data.html.

Dames and Moore, February 22, 1996. “Remedial Action Plan for Lincoln Brass Works.”

Dotzour, M. 1997. Groundwater contamination and residential property values. The Appraisal Journal 65:279.

Dunford, R.W. 2000. Estimating ground-water damages from hazardous-substance releases. Journal of Water Resources Planning and Management 126:366-373.

Easter, K.W. and Y. Konishi. 2006. Estimating Economic Health Costs of Not Controlling Toxic Water Pollution.

EGLE (2020). Superfund Legislative Report: Fiscal Year 2020 - KL Avenue Landfill. Legislative Report. Lansing, MI, EGLE.

EPA. 2021. Explanation of Significant Differences for K&L Avenue Landfill Superfund Site Kalamazoo County, Michigan. U.S. Environmental Protection Agency: Region 5, Chicago, IL.

Freshwater Foundation. 1989. Economic Implications of Groundwater Contamination to Companies and Cities. Freshwater Foundation, Navarre, MN.

Golder Associates Inc., December 2020. “Contingent Remedial Alternatives Evaluation Update: West KL Avenue Landfill Site.”

Görlach, B. and E. Interwies. 2003. Economic Assessment of Groundwater Protection: A Survey of the Literature Final Report. European Commission.

Green, G.P. 2001. Amenities and community economic development: Strategies for sustainability. Journal of Regional Analysis and Policy 31.

Guignet, D. 2013. What Do Property Values Really Tell Us? A Hedonic Study of Underground Storage Tanks. Land Economics 89:211-226.

HomeAdvisor. 2022. How Much Does It Cost To Drill Or Dig A Well? HomeAdvisor/Angi.

HomeGuide. 2022. How Much Does It Cost To Drill Or Dig A Well?

Kiel, K.A. 1995. Measuring the Impact of the Discovery and Cleaning of Identified Hazardous Waste Sites on House Values. Land Economics 71:428-435. doi: 10.2307/3146708.

KLA Group (2022). Personal Communication from Dan Dewitt. Kalamazoo, MI.

Lazo, J.K., W.D. Schulze, G.H. McClelland, and J.K. Doyle. 1992. Can Contingent Valuation Measure Nonuse Values? American Journal of Agricultural Economics 74:1126-1132. doi: 10.2307/1242769.

Lutes, C., et al. (2022). "Cost Comparison of Soil Vapor Extraction and Subslab Depressurization for Vapor Intrusion Mitigation." Groundwater Monitoring & Remediation 42(4): 43-53.

MACTEC, October 2008. “Evaluation of Interim Response Activities for Contaminated Groundwater: Wickes Manufacturing TCE Plume Site.”

Malone, P. and R. Barrows. 1990. Ground water pollution's effects on residential property values, Portage County, Wisconsin. Journal of Soil and Water Conservation 45:346-348.

McCluskey, J.J. and G.C. Rausser. 2003. Stigmatized asset value: is it temporary or long-term? Review of Economics and Statistics 85:276-285.

"Meeting Minutes of Project Update for EGLE Staff." Institute of Water Research – Michigan State University, virtual meeting. October 6, 2022.

Mendelsohn, R. and S. Olmstead. 2009. The economic valuation of environmental amenities and disamenities: methods and applications. Annual Review of Environment and Resources 34:325-347.

Mercer, L.J. and W.D. Morgan. 1982. An Estimate of Residential Growth Controls' Impacts on House Prices. In: M.B. Johnson (ed.). Resolving the Housing Crosis: Government Policy, Decontrol and the Public Interest. Ballinger, Cambridge, MA.

Messer, K. D., et al. 2006. "Can stigma explain large property value losses? The psychology and economics of Superfund." Environmental and Resource Economics **33**(3): 299-324.

Messer, K.D., W.D. Schulze, K.F. Hackett, T.A. Cameron, and G.H. McClelland. 2006. Can stigma explain large property value losses? The psychology and economics of Superfund. Environmental and Resource Economics 33:299-324.

Michigan Department of Natural Resources, August 6, 1993. "Closeout Report for the Charlevoix Municipal Well Site."

MSU Extension (2014). "Value of Irrigation to the Southwest Michigan Economy." https://www.canr.msu.edu/uploads/235/67987/resources/SWMichiganValueOfIrrigation9-23-14.pdf .

National Research Council. 2013. Alternatives for Managing the Nation's Complex Contaminated Groundwater Sites. The National Acacemies Press, Washington, DC. doi: https://doi.org/10.17226/14668.

Nielsen, E. and L. Lee. 1987. Magnitude and costs of groundwater contamination from agricultural chemicals: a national perspective. Staff report. Economic Research Service, Washington, DC (USA). Natural Resource Economics Div.

Page, G.W. and H. Rabinowitz. 1993. Groundwater contamination: Its effects on property values and cities. Journal of the American Planning Association 59:473-481.

Powell, J.R. 1991. The value of groundwater protection: measurement of willingness-to-pay information, and its utilization by local government decisionmakers. Cornell University.

Rabinowitz, H.Z. and G.W. Page. 1995. Economic Effects of Groundwater Contamination on Real Estate.

Sarnat, C.L., C.E. Willis, and C.R. Harper. 2017. Choosing Alternatives to Contaminated Groundwater Supplies: A Sequential Decision Framework Under Uncertainty. Northeastern Journal of Agricultural and Resource Economics 16:102-112. doi: 10.1017/S0899367X00001434.

Smith, V.K. and W.H. Desvousges. 1986. Averting behavior: Does it exist? Economics Letters 20:291-296. doi: https://doi.org/10.1016/0165-1765(86)90040-6.

US EPA, September 28, 1990. "K&L Avenue Landfill Record of Decision." https://semspub.epa.gov/work/05/152353.pdf

Wierzbicki, David. "Re: Hitachi Magnetics ERM Current Conditions Report Figures and Tables." Received by Glenn O'Neil, November 3, 2022.

Other Useful References

EGLE, Property Owner's Guide to Restrictive Covenant S Imposed at Sites of Environmental Contamination, 2019

EGLE, Pilot Project Statewide Assessment of Restrictive Covenants Evaluating the effectiveness of restrictive covenants at 41 state-funded projects across Michigan, 2018

DEQ, Pilot Project Statewide Assessment of Restrictive Covenants Evaluating the effectiveness of restrictive covenants at 90 properties across Michigan, 2017

USDOE, Guidance for Developing and Implementing Institutional Controls for Long-Term Surveillance and Maintenance at DOE Legacy Management Sites, 2015

USEPA, Institutional Controls: A Guide to Planning, Implementing, Maintaining, and Enforcing Institutional Controls at Contaminated Sites, 2012

USEPA, Institutional Controls: A Site Manager's1 Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups, 2000

USEPA, A Decision-Making Framework for Cleanup of Sites Impacted with Light Non-Aqueous Phase Liquids (LNAPL), 2005

EGLE, Risk-Based Management of Groundwater Contamination in Michigan: An Analysis of Part 201 of the Natural Resources and Environmental Protection Act, 2020