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Residential soil programs for historic smelters: a framework for managing offsite legacy impacts in closure and long-term stewardship

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Abstract

Historic smelters for metals such as copper often operated in an era before emissions control equipment was commonly used; air emissions often deposited metal-bearing particles on nearby soils for decades. To address potential human health concerns from legacy particulate-metal emissions, responsible parties have often entered into voluntary programs with the appropriate state agency.

Since 2013, GHD has led the development, implementation and management of comprehensive soil programs across 6 US cities and towns for responsible parties. The initiative integrates community engagement, soil sampling, data management, and remediation (soil removal and replacement) within a unified and scalable framework, supporting thousands of parcels across multiple active townsites.

A hallmark of a soil program is its outreach strategy, centred on transparency, responsiveness and culturally informed communication. Tailored public-facing efforts – including door-to-door engagement, community open houses and multilingual materials – have achieved participation rates exceeding 80% in some communities and helped secure long-term social licence for these projects that may continue for more than a decade.

The program leverages a robust central database to manage millions of data records specific to thousands of land parcels or properties across multiple active townsites. This structured approach provides a repeatable, evidence-based model that can be adapted to similar projects worldwide.

This paper highlights the lessons learnt from large-scale soil programs, including integrating outreach with technical workflows, maintaining data defensibility over long program durations and managing multistakeholder expectations. These soil programs demonstrate how technically rigorous, community-centric remediation can protect public health while strengthening trust between industry and local communities.

Keywords: *legacy smelter emissions, residential soil contamination, community-centred, stakeholder engagement*

1 Introduction

Smelting has been central to industrialisation but it also left some of the most persistent environmental legacies in mining. Smelters often released airborne contaminants – arsenic, lead, cadmium, zinc and copper – that spread far beyond facility boundaries, potentially polluting soils, groundwater, vegetation and urban environments. Unlike typical mine sites, smelter impacts often extend into surrounding towns through decades of atmospheric deposition, creating liabilities that persist for generations. Many cases, such as the Everett smelter in Washington, only came to light decades after closure, requiring large-scale residential and industrial remediation (Washington State Department of Ecology 2026).

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Smelter closure requires more than technical clean-up alone. Effective management must integrate community and stakeholder engagement, environmental remediation, public health protection and long-term stewardship. To address these offsite legacy impacts, this paper presents the structured, time-tested residential soil program as a framework for managing legacy contamination and supporting sustainable closure.

2 Regulatory and programmatic framework

Historic smelting activities released metal-bearing particulates (e.g. lead and arsenic) that accumulated in nearby residential areas over decades of operation. While many of these activities predate modern environmental regulations, contemporary expectations increasingly encompass the evaluation and management of potential offsite risks to human health and the environment.

The program often operates under voluntary agreements with state regulatory agencies, enabling proactive management of legacy conditions in parallel with closure planning objectives. In some townsites, impacted areas overlap with or are adjacent to Native American communities with lands, introducing additional governance, jurisdictional and cultural considerations central to responsible long-term stewardship.

Under a voluntary remediation program, the responsible party performs soil characterisation and, where needed, remediation (e.g. soil removal and replacement) within a defined study area comprising properties most likely to have been affected by historical air emissions (the primary offsite transport mechanism for smelter-associated metals). The work plan structure supports regulatory alignment by clearly specifying target constituents, clean-up levels, sampling methods, QA/QC requirements, and health and safety expectations, and reporting deliverables.

A key program design element is adaptability: the study area may be re-evaluated and expanded based on the spatial distribution of metals in surficial soil and whether observed mixtures/ratios are consistent with a smelter emission signature, with revised boundaries submitted to the agency for acceptance where warranted.

3 Program framework for long-term stewardship

The soil program was designed and evolved as a scalable framework capable of supporting long-duration implementation across multiple communities. Core elements include:

- integrated community engagement and access coordination
- systematic residential soil investigation and laboratory analysis
- centralised data management to support long-term defensibility
- targeted soil removal and replacement where criteria are exceeded.

Rather than treating these components as discrete activities, the framework emphasises integration to support continuity, adaptability and transparency over time. This approach aligns with closure and stewardship principles that recognise stewardship as an ongoing process rather than a discrete project phase.

4 Community engagement and social licence

Sustained community participation is fundamental to the success of residential soil programs associated with closure and long-term stewardship. Outreach strategies were tailored to each townsite to reflect local context, language needs and cultural considerations, supporting informed participation and long-term trust. In townsites involving Native American communities, engagement required early and ongoing coordination with tribal leadership and designated representatives, with approaches grounded in respect for their sovereignty, established protocols and community priorities. This adaptive, place-based engagement framework was critical to building and maintaining social licence across diverse townsites.

4.1 Outreach challenges associated with demographic diversity and ownership change

Outreach in residential soil programs is inherently complex due to the diversity of affected populations and the dynamic nature of property ownership. Unlike industrial sites with a single landowner, townsite programs must engage a heterogeneous mix of homeowners, renters, absentee landlords, tribal entities, municipal owners and institutional stakeholders, each with differing motivations, concerns and decision-making authority.

Demographic diversity poses a fundamental challenge for outreach. Townsites often include long-term residents with multigenerational ties to the community, recent immigrants, seasonal occupants and vulnerable populations with limited access to digital communication or transportation. Outreach strategies that rely solely on written correspondence or electronic communication are often insufficient in these settings. Program experience demonstrates that effective engagement requires a combination of direct mail, door-to-door outreach, staffed local offices and in-person meetings tailored to the communication preferences of different demographic groups.

Language and cultural considerations further influence participation. In some communities, multilingual materials and culturally appropriate messaging were necessary to ensure that program objectives, access requirements and remediation activities were clearly understood. In townsites involving Native American communities, outreach required early and sustained coordination with tribal leadership and designated departments, such as environmental and cultural resources, and tribal employment offices. Respect for tribal sovereignty and adherence to established consultation protocols were critical to building trust and enabling voluntary participation.

Ownership changes over time introduce additional complexity, particularly for long-duration programs typical of closure and post-closure stewardship. Property turnover through sales, inheritance, foreclosure or rental transitions can disrupt the continuity of outreach and delay access for sampling or remediation. Program records show that maintaining current ownership information required ongoing coordination with county tax assessors, the use of geographic information system (GIS)-supported databases, and targeted follow-up for undeliverable mail and non-responsive parcels.

Absentee ownership and rental properties present distinct challenges. In these cases, decision-making authority may rest with landlords who do not reside in the community and may have limited incentive to engage promptly. Conversely, tenants may experience uncertainty or concern regarding disruptions associated with sampling or remediation but lack the authority to grant access. Addressing these situations required clear delineation of roles, consistent messaging to both owners and occupants, and, in some cases, extended outreach timelines to align interests and obtain consent.

Municipal and institutional ownership, including rights of way, alleys and public parcels, introduced additional governance considerations. While access to these parcels was often more straightforward due to single ownership, participation depended on maintaining strong working relationships with local governments and aligning with municipal priorities and schedules. Program experience indicates that sustained engagement with town officials was essential to maintaining momentum and avoiding delays.

Collectively, these outreach challenges underscore the importance of viewing community engagement as a core element of long-term stewardship rather than a supporting activity. Programs that anticipate demographic diversity, ownership turnover and governance complexity are better positioned to maintain participation, preserve social licence and deliver defensible outcomes over extended time frames.

5 Centralised database management system

Effective management of offsite legacy impacts in closure and long-term stewardship contexts requires more than technical investigation and remediation. It also requires sustained institutional knowledge, regulatory defensibility and community transparency over extended time frames. In the Townsite Smelter Program, a centralised database management system (CDMS) serves as foundational infrastructure that integrates technical data, outreach activities and governance requirements into a single framework.

Residential soil programs generate large volumes of data, including parcel boundaries, ownership records, access agreements, sampling locations, laboratory results, remediation actions and communication histories. Unlike traditional mine-site datasets, this information must be maintained at the individual property level and remain traceable across years or decades. Program experience shows that decentralised spreadsheets or project-specific file repositories are insufficient, particularly when ownership changes and regulatory oversight continues beyond active remediation.

The CDMS provides a single source of truth that links each parcel to its program life cycle, from eligibility determination through sampling, remediation, restoration and post-completion documentation. Integration with GIS enables spatial visualisation of study areas, participation status, exceedances and remediation progress, supporting internal decision-making and external communication. This spatial context is particularly valuable in communities with complex land ownership patterns, including Native American lands, municipal rights of way and mixed residential uses.

From an outreach perspective, centralised data management supports sustained community engagement. Ownership and contact information are routinely updated from county assessor records and tracked alongside outreach attempts, returned mail and access outcomes. By preserving outreach history, the CDMS reduces reliance on individual staff knowledge and supports continuity as personnel and contractors change over time.

The CDMS also underpins regulatory transparency and defensibility. Sampling results, laboratory data and remediation documentation are stored in structured formats that support auditability and regulatory review. This is particularly important where programs operate under voluntary frameworks and where closure obligations may be revisited as land use changes or stewardship responsibilities transition between parties. A traceable data record helps responsible parties demonstrate due diligence long after fieldwork concludes.

The CDMS is also transferable across organisational boundaries. Whether stewardship remains with the consultant, transfers to the responsible party or is shared with public agencies, the CDMS preserves decisions, actions and outcomes in a durable record. This aligns with closure and stewardship principles that emphasise transparency, intergenerational responsibility and systems that persist beyond individual projects or teams.

Overall, program experience indicates that centralised data management is not a supporting function but a core enabler of long-term stewardship for offsite legacy impacts. By integrating technical, social and governance information, the CDMS supports consistent decision-making, sustained community trust and defensible outcomes throughout the project life cycle.

5.1 Automation

A key lesson from long-running townsite soil programs is the value of purposeful automation within centralised data management systems. These programs span long time frames, and personnel, contractors, ownership patterns and regulatory interfaces inevitably change. In this context, manual processes increase the risk of inconsistency, data loss and institutional knowledge gaps.

Automation was introduced to support repeatable workflows at scale. Automated linkages between parcel records, GIS layers, ownership data, outreach status, sampling results and remediation outcomes reduced manual handling and improved consistency across thousands of properties. This allowed teams to track parcel-level status in near real time while maintaining a defensible historical record of actions and decisions.

Automation proved particularly valuable for outreach and access coordination. Automated tracking of mailings, returned correspondence, outreach attempts and access agreements helped teams identify non-responsive parcels, absentee owners and properties undergoing ownership transitions. These insights supported targeted follow-up rather than repeated broad outreach campaigns, improving efficiency while respecting community sensitivities. By embedding outreach workflows within the CDMS, the program reduced reliance on individual staff memory and supported continuity as personnel were rotated over the life of the program.

From a governance and stewardship perspective, automation strengthened regulatory defensibility and transparency. Automated validation checks, standardised data structures and consistent reporting formats supported regulatory review and audit readiness. This is especially important in voluntary and post-closure contexts, where documentation may be revisited years later or when land use changes.

Automation also supported scalability and adaptability. As new townsites were added or the program scope evolved, standardised workflows enabled rapid deployment without redesigning data structures or outreach processes. This flexibility supports adaptive management and systems that can evolve alongside community needs and stewardship obligations.

Program experience also shows that automation should be implemented deliberately and transparently. Automated processes were most effective when paired with clear governance, routine quality checks and human oversight to keep community interactions responsive and culturally appropriate. Automation did not replace engagement; it helped sustain engagement consistently and equitably over time.

Overall, integrating automation within centralised data management emerged as a key enabler of long-term stewardship. This underscores the value of investing early in automated, parcel-level systems that support continuity, defensibility and trust across the closure life cycle.

6 Sampling and characterisation methodology

6.1 Target constituents and clean-up levels (land use-based)

Sampling and analysis plans (SAPs) for soil programs are often informed by the US Environmental Protection Agency's *Superfund Residential Lead Sites Handbook* (US Environmental Protection Agency 2024) and are agreed upon by the responsible party and jurisdictional state agency. These plans define target constituents (TCs)—typically metals selected based on historical smelter operations and exposure considerations for developed properties—and compare results with clean-up levels that vary by land use, such as residential and non-residential settings. The framework also allows site-specific clean-up levels, such as those developed through probabilistic residential risk assessment, to be applied alongside established regulatory values for other constituents and land uses.

6.2 Use areas, eligibility and accessible-area concepts

To support scalable implementation, properties are subdivided into 'use areas', such as front yards, back yards, side yards, driveways/parking areas and certain unpaved rights of way that are functionally associated with adjoining UAs. Sampling focuses on 'accessible' areas where direct contact with bare soil or soil covered by grass/gravel is plausible and excludes impervious surfaces, areas beneath structures, certain drainage features and locations presenting unacceptable safety concerns (e.g. unstable retaining walls).

6.3 Composite sampling design and depth intervals

Representative UA concentrations are determined using composite samples collected by combining aliquots distributed across the UA. Samples are collected by depth interval to support exposure assessment and excavation planning; the SAP typically specifies 0–3 inches (0–7.6 cm) and 6–12 inches (15.2–30.5 cm) as standard intervals collected initially, with deeper intervals (12–18 inches [30.5–45.7 cm] and 18–24 inches [45.7–61.0 cm]) analysed only under defined conditions (e.g. when the 6–12 inch (15.2–30.5 cm) results exceed clean-up levels). Initial sampling is often capped at 24 inches (61 cm) due to the lower probability of human health-relevant exposure below that depth.

6.4 Field controls, documentation and laboratory deliverables

Field operations emphasise defensibility through standardised tools, decontamination procedures, chain of custody, and structured documentation captured in daily field reports and electronic field data systems, where practicable. The SAP describes an integrated data flow from field to laboratory to validation and reporting, including electronic data deliverables, data validation, and database loading to support systematic QC review and consistent output generation (property reports and program summary reporting).

7 Remediation approach: removal and replacement

7.1 Clean-up objective and remedy basis

The remedial action plan defines the clean-up objective as excavating and replacing soil within designated use areas where concentrations exceed approved clean-up levels so that post-clean-up average metal concentrations no longer exceed those levels. Clean-up is implemented on eligible residential, non-residential and publicly owned developed properties within the study area, integrating construction sequencing, QA/QC, health and safety, and reporting. This plan is agreed upon by the responsible party and jurisdictional state agency similarly to the sampling plan described above.

7.2 Property access, planning and constructability constraints

Clean-up proceeds only after the execution of property access agreements for remediation and completion of a pre-excavation inspection that documents pre-clean-up conditions using photographs/video sufficient to identify pre-existing cracks or damage. Property-specific clean-up work plans as reviewed and approved by the property owner document excavation areas, depths, restoration requirements, items to be relocated and any owner-requested exclusions.

Constructability and risk controls are incorporated through practical setback guidance for structures, improvements, utilities, vegetation and property boundaries, with provisions to limit excavation where full removal is impractical (e.g. bedrock or roots) or cannot be performed safely. Properties presenting significant safety or property-damage concerns (e.g. unstable retaining walls) may be deferred until those concerns are addressed.

7.3 Excavation, handling and restoration

Excavation is performed using mechanised equipment and hand tools as needed, with field measurements used to verify required excavation extents and depths prior to backfilling. Excavated materials are loaded and transported using controls to prevent spillage and cross contamination (e.g. protective sheeting in clean areas, immediate pickup of spills, covered/tarped loads). Backfill materials are imported from approved sources, verified through sampling and ongoing QA/QC, and graded to pre-excavation conditions; surface restoration materials (e.g. sod, gravel) are replaced to match pre-existing conditions unless otherwise agreed with the owner.

8 Operational controls: dust monitoring, decontamination, traffic and safety

Dust control is treated as a high-priority control measure during excavation, stockpiling, loading, transport and backfill activities, primarily through water application and other measures (e.g. surfactant, gravel cover, vehicle speed regulation) as needed, based on visual observations and real time particulate measurements.

Worker exposure controls, which are typically level D personal protective equipment (PPE) (AS/NZS 4501.1 or OSHA 29 CFR 1910), are often supported through personal air monitoring for metals, including a multi-metal profile. Level D PPE includes a hard hat, safety glasses, high-visibility vest, steel-toe boots, gloves, long pants and a long-sleeved shirt. Respiratory protection is not required under normal operating conditions.

Decontamination procedures for equipment and haul trucks are specified to minimise the tracking of soil from work areas and to protect clean backfill integrity, and include dry brushing, limited water use when necessary and containment of removed material into active soil stockpiles. Hauling controls include predetermined routes emphasising major roadways, covered loads, spill clean-up, traffic control measures/signage, and driver-safety requirements.

9 Lessons learnt

Lessons learnt from implementing this framework across multiple townsites include:

- Standardisation enables scalability: use-area definitions, composite sampling density, defined depth intervals and confirmation sampling frequency create a repeatable model that can be applied across large numbers of properties.
- Data defensibility requires an end-to-end system: a controlled data flow (field → lab → validation → database → reporting) with consistent nomenclature reduces errors and supports regulatory confidence years after fieldwork.
- Automation preserves continuity: automated parcel-status tracking, QA checks and reporting workflows reduce reliance on individual staff knowledge and help maintain consistency through staffing and ownership changes.
- Outreach must be designed like a workstream: defined outreach touchpoints, multilingual materials where needed and documented access outcomes improve participation and protect schedules.
- Respect for tribal sovereignty strengthens implementation: early coordination with tribal leadership and adherence to established consultation protocols improve predictability, trust and program durability where tribal lands are involved.
- Constructability drives remedy success at occupied properties: property-specific planning, practical excavation constraints (setbacks, utilities, vegetation), and restoration commitments reduce disruption and support completion.
- Operational controls protect workers and communities: dust controls with clear stop-work triggers, personal air monitoring, decontamination and traffic controls are integral to safe delivery and sustained public acceptance.
- Plan for stewardship, not just remediation: parcel-level records that persist beyond project teams support long-term obligations, future land use changes and organisational transitions.

10 Conclusion

A generic, programmatic residential soil framework for legacy smelter impacts can be implemented under a voluntary remediation pathway using 3 core pillars: (1) sustained community partnership and participation, (2) a defensible, scalable sampling approach linked to land use clean-up criteria and robust data management and automation, and (3) a property owner-approved excavation and replacement remedy. When combined with explicit dust monitoring controls, decontamination, traffic management and structured reporting, this approach provides a transferrable model for closure and site stewardship teams seeking to reduce offsite legacy risk while strengthening long-term stakeholder confidence.

Use of artificial intelligence disclosure statement

In the preparation of this work, the authors used Copilot and internal documentation to support the initial draft. The authors have reviewed the content and edited it where required and take full responsibility for said content.

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