Event-based Subsurface Utility Data Collection Framework

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Abstract -

Underground utility information is frequently incomplete, inconsistent, or of uncertain confidence, leading to safety risks, rework, and inefficiencies during construction and maintenance activities. Although existing standards, sensing technologies, and digital platforms define data quality concepts and investigation methods, their application within construction workflows remains fragmented and largely project-specific. In particular, limited guidance exists on when utility data should be collected across the construction lifecycle and how confidence in existing information should inform construction decisions. This paper proposes an event-based utility data collection approach that aligns subsurface information acquisition with recurring construction and maintenance events. It integrates lifecycle events, utility data categories, technology classes, and confidence considerations to support transparent, confidence-aware decisions on investigation, escalation, and opportunistic data capture. A visual representation and supporting tables illustrate how construction methods and access conditions influence achievable confidence and data availability, while highlighting construction and maintenance activities as high-value opportunities for reliable data capture. By providing an operational structure for applying existing standards in real construction contexts, the proposed approach supports coordinated decision-making, reduces reliance on ad-hoc investigations, and enables incremental improvement of utility information over time, contributing to safer construction practices and more reliable long-term subsurface asset management.

Keywords -

Underground utilities; Subsurface utility engineering; Construction lifecycle; Data collection framework; Utility data confidence; Event-based data capture; Infrastructure asset management; Utility mapping

1 Introduction

Underground utilities constitute a critical yet largely invisible component of the built environment. Utilities such as water, sewerage, gas, electricity, and telecommunication networks are routinely affected during construction and maintenance activities, resulting in service disruptions, safety hazards, schedule delays, and cost overruns [1]. Despite advances in sensing technologies and digital information systems, utility strikes and subsurface conflicts remain prevalent, particularly in dense urban corridors where multiple assets coexist within constrained space [2].

A key reason for these recurring issues is the misalignment between construction workflows and subsurface information practices [3]. Construction and asset management progress through interconnected stages, planning, design, installation, operation, maintenance, and decommissioning, yet underground utility information is commonly treated as static, captured once and reused irrespective of subsequent interventions [4]. As a result, critical construction decisions are often made using outdated or low-confidence information, while opportunities to improve data quality during direct interaction with the subsurface are frequently missed.

In practice, subsurface utility information is fragmented across organizations and project phases. Planning teams rely on legacy records and GIS databases; designers commission selective investigations; contractors expose utilities during construction; and maintenance crews uncover assets during routine and emergency maintenance works. These repeated encounters are rarely coordinated through a unified, lifecycle-oriented data logic, and records are infrequently updated after sites are reinstated, perpetuating uncertainty and rework across successive projects [1]. These challenges manifest differently across greenfield and brownfield contexts: while greenfield projects face uncertainty due to limited baseline records, brownfield environments are dominated by legacy utilities of unknown location, condition, and confidence, making coordinated construction particularly risk-prone.

At the same time, the construction sector has widely adopted detection, surveying, and documentation technologies such as ground-penetrating radar, electromagnetic locating, GNSS surveying, laser scanning, etc., [2, 5]. While these technologies have improved detection and documentation capabilities, their use remains largely project-driven and reactive rather than integrated across the asset lifecycle. Decisions regarding when to investigate, how far to escalate verification, and what information to capture are typically left to individual project teams, leading to inconsistent outcomes across projects and jurisdictions [4].

These observations indicate that subsurface utility challenges are not only technological but also procedural, highlighting the need to align utility data collection with construction and maintenance events while explicitly accounting for information confidence. This paper addresses this need by proposing an event-based utility data collection framework that operationalizes existing standards and technologies within real construction workflows. It focuses on defining when, how, and under what construction conditions subsurface utility data should be captured to maximize long-term data value, safety, and reliability.

2 Background and related works

2.1 Persistent challenges in subsurface utility data

A consistent finding across subsurface utility research is that existing utility records are frequently inaccurate, incomplete, outdated, or of unknown confidence. Comparative studies demonstrate that traditional utility records, including as-built drawings and One-call systems (Call before you dig), often significantly under-represent underground infrastructure and exhibit substantial positional inaccuracies when compared with Subsurface Utility Engineering (SUE) investigations [1]. Empirical evidence indicates that conventional records may represent up to 160% less utility infrastructure than identified through systematic investigation, and that only a minority of mapped utilities fall within acceptable positional tolerances [3].

Similar challenges are reported across transportation projects, airports, and dense urban developments, where the depth information is missing, reference systems are inconsistent, and records reflect as-designed rather than as-built conditions [6, 2]. These shortcomings result in increased project costs, repeated site investigations, and heightened safety risks during excavation [7, 8]. The literature consistently identifies fragmented data capture practices and the absence of systematic updating mechanisms as key contributors to poor data quality [4].

2.2 Quality-based approaches and SUE

Subsurface Utility Engineering (SUE), formalized through standards such as ASCE 38 and complemented by ASCE 75 and PAS 128 with PAS 256, is widely recognized as a structured engineering approach for improving subsurface utility data quality using defined quality or confidence levels. Higher SUE quality levels are associated with increased positional accuracy, improved completeness, and reduced risk of utility conflicts during construction [9].

A key strength of these standards lies in its explicit linkage between investigation methods and achievable confidence, enabling informed engineering decisions during planning and design. However, prior studies note that such standards are predominantly applied during pre-design and design stages as a project-specific investigation and provides limited guidance on systematically capturing and updating utility data during installation, repair, diversion, or replacement activities [1].

2.3 Utility investigation technologies

A wide range of technologies and methods has been investigated for subsurface utility detection and documentation. Non-destructive geophysical methods, including ground-penetrating radar and electromagnetic locating, are widely used to detect buried utilities under varying site and soil conditions [5]. Geospatial surveying technologies such as GNSS, total stations, and terrestrial laser scanning enable accurate spatial referencing of exposed utilities and support integration with digital records [2].

Intrusive verification methods, including trial trenches and vacuum excavation, remain the most reliable means of achieving high-confidence positional and depth information, particularly where non-destructive methods are constrained. While the technical performance of investigation technologies is well documented, studies consistently note that achievable accuracy is limited by soil conditions, congestion, and utility material, and that investigation methods are rarely sequenced or escalated within construction workflows [5, 2]. Consequently, technology selection remains reactive and project-specific rather than embedded within a lifecycle-oriented strategy.

2.4 Data uncertainty and digital integration

Prior studies emphasize that uncertainty is an inherent characteristic of subsurface utility data and must be explicitly represented to support risk-informed decision-making [10]. Probabilistic mapping and uncertainty-aware visualization approaches acknowledge that complete information is rarely achievable and instead aim to represent confidence envelopes around detected utilities [11].

Parallel work on BIM–GIS, CAD-GIS integrations, digital twins, and augmented reality seeks to improve coordination and situational awareness for utility management [12, 13]. While these platforms offer substantial potential, their effectiveness is highly dependent on the quality and confidence of input data. Many such approaches implicitly assume the availability of reliable baseline utility data or the feasibility of systematic data collection independent of construction activities. In practice, this assumption is rarely valid for legacy infrastructure, limiting their effectiveness in real construction contexts.

2.5 Lifecycle and event-based data capture

A smaller but critical body of literature explicitly argues that subsurface utility data quality should be improved incrementally across the asset lifecycle, rather than through large-scale resurveying efforts [14, 1]. These studies highlight the impracticality of repeated full exposure and advocate leveraging recurring construction and maintenance events, such as installation, diversion, repair, and replacement, as high-value data capture opportunities. While this work establishes the importance of lifecycle-based improvement, it does not provide a detailed operational structure defining event priorities, data requirements, technology applicability, or confidence management over time.

3 Research gap and objectives

Despite advances in underground utility data standards, sensing technologies, and digital platforms, construction practice still lacks a clear operational structure for aligning utility data collection with recurring construction and maintenance events. Existing approaches define data quality concepts, investigation methods, and uncertainty representation; however, their application across the construction lifecycle remains fragmented and largely project-specific. In practice, decisions regarding when to undertake additional investigation, which methods are appropriate under given access conditions, and how confidence in existing information should influence construction activities are often left to individual judgement. As a result, high-confidence data capture opportunities during routine construction and maintenance activities are frequently missed, perpetuating uncertainty and repeated investigations.

To address this gap, this study proposes an event-based utility data collection framework that situates utility information acquisition within construction workflows. The framework integrates lifecycle events, utility data categories, technology classes, and confidence considerations into a single construction-oriented structure. Specifically, it aims to (i) align utility data categories and applicable technology classes with key lifecycle events, and (ii) support transparent, confidence-aware decisions related to verification, escalation, and opportunistic data capture during construction and maintenance activities.

4 Methodology and framework development

This section summarizes the methodological approach used to develop the event-based subsurface utility data collection framework. The framework is conceived as a structuring and decision-support artefact that synthesizes concepts from existing utility data standards (e.g., ASCE 38-22, ASCE 75-22, PAS 128, PAS 256), investigation methods, and construction practice into a coherent, construction-oriented logic suitable for application within real work zones.

The framework was developed based on the premise that physical access to underground utilities is governed primarily by construction and maintenance events rather than by continuous monitoring or isolated survey campaigns. Accordingly, methodology adopted an event-based perspective: recurring lifecycle events are treated as the primary opportunities for interaction with subsurface assets and for capturing durable data.

Framework design was guided by five principles: (i) construction-centricity, aligning with real workflows; (ii) lifecycle orientation, treating utility information as an evolving asset; (iii) spatial anchoring, applying the framework to defined work zones containing multiple utilities; (iv) confidence awareness, explicitly accounting for information reliability; and (v) technology neutrality, grouping methods by functional capability rather than specific tools. These principles ensure compatibility with existing standards while maintaining adaptability across project and regulatory contexts.

Eight representative lifecycle events (E1–E8) were identified through synthesis of typical planning, construction, and operational workflows in utility-dense environments. These events span records review, reconnaissance, non-intrusive investigation, intrusive verification, open-cut and trenchless installation, maintenance or repair, and decommissioning. Events are non-linear and non-mandatory, reflecting construction practice in which activities may recur, overlap, or be bypassed depending on project intent and risk.

To support standardized capture, utility information requirements were synthesized into six high-level categories: P (positional & geometric), M (material), F (functional), C (condition & performance), S (survey metadata), and L (lifecycle metadata). Investigation methods were abstracted into five technology classes (T1–T5) reflecting record sources, optical/visual methods, geospatial surveying, geophysical/NDT, and intrusive verification.

A key methodological distinction is made between *current confidence*, representing the reliability of existing information for a given utility within the spatial extent, and *achievable confidence*, representing the maximum reliability attainable during a given event using appropriate methods. This distinction underpins the framework's escalation logic: construction or maintenance activities should proceed only when current confidence is appropriate for the intended action; otherwise escalation to earlier or more invasive events is recommended.

Finally, events involving physical exposure of utilities, such as intrusive verification, open-cut installation, maintenance repairs, and decommissioning, are explicitly identified as high-value data capture opportunities. During these events, comprehensive utility information can be obtained with minimal additional effort relative to the construction activity itself. The framework therefore adopts an opportunity-based perspective that promotes systematic capture and recording whenever exposure occurs, supporting incremental improvement of utility records over time and reducing reliance on repeated standalone investigations.

5 Event-based utility data collection framework

This section presents the proposed event-based utility data collection framework and articulates its conceptual structure and decision logic. The framework integrates lifecycle events, utility data categories, technology classes, and confidence considerations into a construction-oriented model for subsurface utility data acquisition. The visual representation formalizes relationships between construction events, data availability, and achievable confidence, providing a structured basis for transparent and auditable decision-making across construction and maintenance contexts.

5.1 Framework overview and representation

Figure 1 illustrates the framework for a defined spatial extent (e.g., road segment, project corridor, or work zone), which constitutes the unit of application. Within this spatial extent, multiple underground utilities may coexist, each characterized by different levels of data availability and confidence. The framework is therefore spatially anchored rather than asset-isolated, reflecting real construction conditions in which decisions affect all subsurface assets within the work area.

The outer ring denotes eight recurring lifecycle events (E1–E8), derived from synthesis of construction workflows reported in literature, subsurface utility standards, and typical installation, maintenance, and diversion practices, and representing repeatable opportunities to consult, verify, or capture utility information. Events are nonlinear and may be entered, skipped or revisited depending on project intent, access and risk. The inner region groups utility information into six high-level categories (P, M, F, C, S, L); implementers should rely on Table 1 for attribute-level definitions and capture templates. The figure marks exposure-based events as high-value data capture opportunities (starred) where the highest achievable confidence is typically attainable.

When used, the framework encodes a simple decision logic: practitioners populate a side-panel register with existing information and assign current confidence per utility; they define the planned activity and its required confidence; they consult Table 2 to identify technology classes and events that can raise achievable confidence; and they escalate to those events when current confidence is insufficient. This logic is intentionally generic and auditable and supports selective escalation rather than prescriptive sequencing.

5.2 Utility data categories

Table 1 formalizes the six data categories used throughout the framework. The attributes listed are representative and not intended to be exhaustive or restrictive. This consolidated category structure is intended for attribute dictionaries, data capture templates, contractual clauses and permit conditions, and provides a consistent lens for linking data requirements to construction events. These categories define what information may be captured; when and how it is captured depends on lifecycle events and access conditions.

5.3 Lifecycle events and data capture capability

Each lifecycle event (E1-E8) provides a different degree of physical or informational access to underground utilities and therefore supports different subsets of abovementioned data categories. Early events such as record review and reconnaissance primarily support baseline understanding and risk screening, with limited achievable confidence. Non-intrusive investigation events enable indicative detection and alignment estimation but remain constrained by site conditions and utility characteristics.

Events involving direct exposure, such as intrusive verification, open-cut installation, maintenance repairs, and decommissioning, offer the highest achievable confidence across multiple data categories. These events allow direct measurement and observation of geometry, material, condition, and installation context. The framework explicitly identifies such exposure-based events as high-value data capture opportunities, encouraging systematic recording rather than incidental documentation.

Open-cut and trenchless construction methods are treated distinctly. Open-cut installation inherently enables comprehensive data capture prior to backfilling, whereas trenchless installation significantly restricts post-installation verification. Consequently, the framework emphasizes achieving sufficient confidence through earlier events before undertaking trenchless works.

5.4 Confidence Assessment and Escalation

A core feature of the framework is the distinction between achievable confidence and current confidence. Achievable confidence represents the maximum reliability that can reasonably be attained during a given event using appropriate methods. Current confidence represents the reliability of existing information for a specific utility within the spatial extent, based on available records, prior investigations, and documented exposures. Current

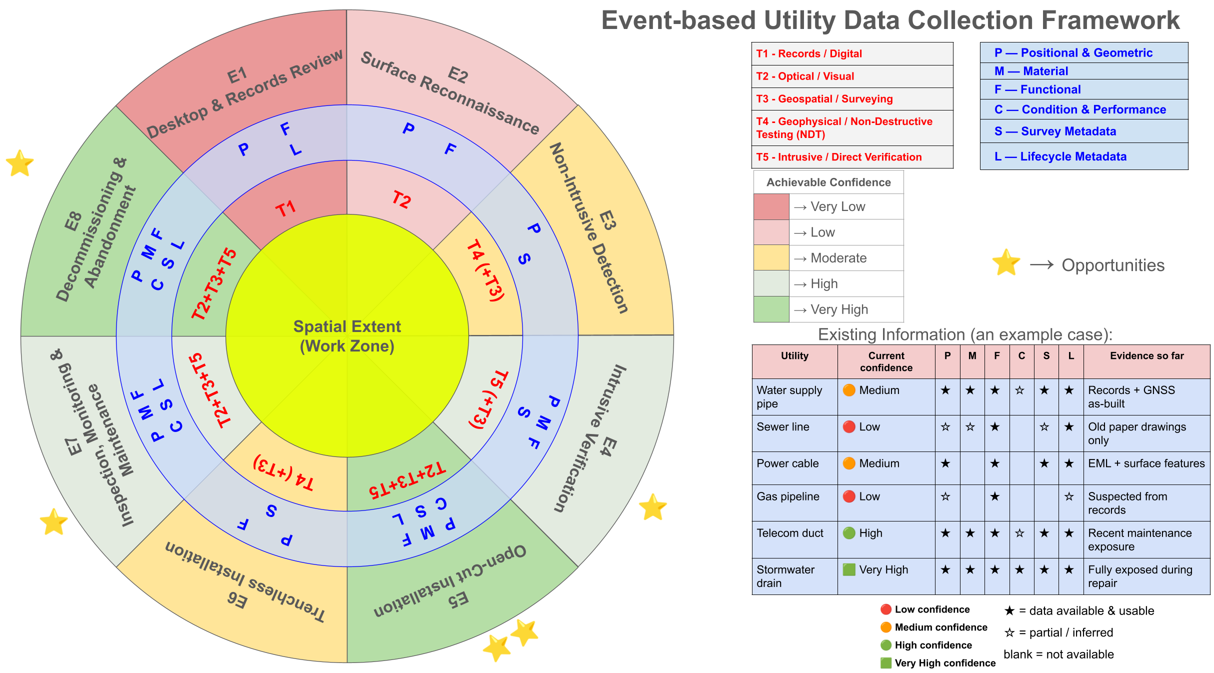

Figure 1. Event-based utility data collection framework

Table 1. Utility data categories and representative (non-exhaustive) attributes

Data Category	Example Attributes / Parameters
P - Positional & Geometric	Horizontal coordinates (X, Y), elevation/depth, spatial reference system, alignment, length, diameter, horizontal and vertical profile,burial depth, network connectivity, proximity to other utilities
M - Material	Material type (PVC, steel, concrete), wall thickness, grade/specification, lining/coating type, corrosion protection, backfill/bedding type, manufacturer, applicable material standards, installation age
F - Functional	Asset type (water pipe, gas pipe, duct, etc.,), service type, design capacity, pressure rating, flow direction, load class, operating limits, functional role in network, redundancy or criticality, control function (e.g., valve)
C - Condition & Performance	Condition rating, structural integrity score, corrosion level, deformation, leakage/blockage status, hydraulic/performance metrics, failure history, remaining useful life, inspection findings, inspection frequency/last inspection date
S - Survey Metadata	Survey method (e.g., GPR, GNSS, etc), instrument, survey date, surveyor/organization, accuracy, resolution, QA/QC status, detection limitations, standards compliance, data format/encoding
L - Lifecycle Metadata	Installation date, construction method (open-cut or trenchless), project/contract ID, ownership, operation start date, maintenance/repair/upgrade history, decommissioning date, regulatory compliance, replacement cost, asset status, risk/criticality score, warranty

confidence may be assessed using established quality classification systems such as SUE quality levels defined in ASCE 38-22, or equivalent local practices where available. Where formal classifications are not available, confidence may be assigned based on the data source, investigation method, and recency of verification.

Construction and maintenance decisions are informed by comparing these two measures. Where current confidence is sufficient for the intended activity, work may proceed. Where it is insufficient, the framework supports escalation to earlier investigation events until acceptable confidence is achieved. This logic is particularly critical for trenchless works and high-risk excavations, where post-construction verification is limited or impossible. Importantly, the framework does not mandate escalation through all events; it provides transparent guidance on when escalation is justified.

5.5 Technology classes and applicability constraints

Investigation and documentation methods are grouped into five functional classes (T1–T5). Table 2 lists representative methods as sub-rows, summarizes where each method typically performs well, and identifies known limitations (for example, material dependency of GPR and tracer-wire reliance for EML). This abstraction allows technology constraints to be considered at the decision level without embedding site-specific optimization into the framework.

Where different technology classes provide conflicting information, a simple precedence logic is applied. Geo-

Table 2. Technology tiers for subsurface utility data collection and applicability

Tier	Typical Methods / Data Sources	Works Well For	Known Limitations
T1 – Records	GIS databases & utility atlases	Baseline topology, planned layouts, design intent, ownership context	Often incomplete or outdated; may represent design not as-built
	As-built drawings & owner records	Approximate alignment, Material specifications, installation dates, and historical context	Fragmented across agencies; inconsistent georeferencing; unknown coordinate datums
	Historical maps & archived plans	Identifying legacy or abandoned utilities	Poor accuracy; unknown reference systems; unverified current existence
T2 – Optical / Visual	Photos, video logs, & field documentation	Chronological record of exposed assets, materials, and construction activities	Unstructured; lacks spatial reference; no subsurface detection
	UAV & aerial imagery	Surface context, obstructions, site topography, and progress monitoring	Cannot detect buried utilities; weather/lighting dependent; requires airspace clearance
	CCTV & pipeline inspection	Internal condition (corrosion, cracks, blockages) of accessible pipelines	Limited to pipe interiors; lacks external positional data
T3 – Geospatial / Surveying	GNSS (RTK / PPK)	Centimeter-level positioning of exposed utilities and survey control	GNSS-denied environments; multipath errors; requires clear sky view
	Total station survey	Millimeter-level precision for exposed utility geometry	Line-of-sight constraints; limited range
	Laser scanning (TLS/MLS)	High-density 3D capture of exposed infrastructure (TLS) or rapid corridor mapping (MLS)	Requires exposure; setup effort (TLS); reduced accuracy in cluttered environments (MLS)
T4 – Geophysical / NDT	Ground penetrating radar (GPR)	Detection of shallow utilities; non-metallic pipes	Performance dependent on soil conditions; interpretation uncertainty
	Electromagnetic locating (EML)	Tracing metallic utilities and plastic pipes with tracer wire	Ineffective without intact tracer
	Acoustic leak detection	Identifying pressurized leaks in utility networks	Ineffective for gravity or low-pressure systems
	Fiber-optic & strain sensing	Distributed monitoring of instrumented pipelines	Requires pre-installed sensors; does not locate unmapped utilities
T5 – Intrusive / Verification	Vacuum excavation (hydrovac)	Non-destructive exposure for verification and safe clearance	Cost and access constraints
	Test pits & trenches	Direct confirmation of position, depth & material	High disruption; reinstatement required
	Boreholes	Stratigraphy and groundwater assessment for design planning	Risk of utility strikes; limited lateral information
	Manhole & chamber surveys	Direct measurement of invert elevations, pipe sizes, and connectivity	Limited to existing access points; confined space hazards

physical survey results (T4) are treated as the primary source for positional attributes (P) within the surveyed area, as they reflect physical detection rather than historical records (T1). Record-based sources (T1) remain relevant for material (M) and functional (F) attributes not directly inferred from geophysical methods. Such discrepancies are recorded in survey metadata (S) and act as a trigger for escalation to intrusive verification (E4/T5) where conflicts occur within the planned work zone.

5.6 Framework use and interpretation

The framework is intended to be applied iteratively. For a given spatial extent, users first assess existing information and current confidence, define the intended construction or maintenance activity, and identify the required confidence level. The framework then guides whether existing information is sufficient, whether escalation is warranted, and which events represent high-value opportunities for durable data capture.

By structuring utility data collection around construction and maintenance events, the framework supports incremental improvement of subsurface information over time. It enables authorities, designers, and contractors to move beyond static records and ad-hoc investigations toward a coordinated, confidence-aware approach aligned with real construction workflows.

5.7 Illustrative application scenarios

To illustrate how the framework supports decision-making, Table 3 summarizes representative, illustrative scenarios. These scenarios demonstrate how the framework guides escalation, technology classes, and opportunistic data capture under different construction intents and site conditions. These examples provide operational clarity without prescribing rigid procedures.

6 Discussion and Implications

This study proposes an event-based utility data collection framework that reframes subsurface information management as a construction- and maintenance-driven process, rather than a one-time or pre-design activity. The primary contribution lies not in introducing new sensing technologies or data standards, but in operationalising when, under what construction conditions, and with what confidence utility data should be acquired within real construction workflows.

Existing standards and guidance have established data quality concepts, investigation methods, and documentation requirements, significantly improving awareness of subsurface uncertainty. The proposed framework complements these efforts by providing an explicit operational layer that links such guidance to recurring lifecycle events. By distinguishing between current confidence and

Table 3. Illustrative application scenarios

Scenario	Context	Framework Application	Expected outcome
Baseline understanding and risk screening for planned works	Planned surface works (e.g., resurfacing) in a utility-dense corridor using primarily GIS and legacy as-builts	Framework applied at corridor level. Assessment begins at E1 with current confidence assigned per utility. Low-confidence utilities are flagged, and escalation to E2 or E3 is triggered only where construction risk or congestion justifies it.	Selective escalation improves confidence where needed, avoiding unnecessary investigations and supporting construction safety.
New utility installation - open-cut	Open excavation for new line installation	Baseline from E1; open-cut treated as opportunistic high-value capture event (E5). Comprehensive as-built data captured using T2, T3, T5 during exposure before backfilling	High-confidence as-built update eliminates need for future E2–E4 investigations in this zone
New utility installation - trenchless (HDD)	New HDD installation beneath a road where post-installation verification is limited	Trenchless installation (E6) require pre-construction escalation to E3/E4 to verify existing utility positions, as post-installation correction is not feasible	Prevents utility strikes and alignment errors that cannot be rectified after drilling
Maintenance and repair as opportunistic capture	Routine or emergency maintenance requiring temporary exposure of utilities	Maintenance (E7) treated as opportunistic capture event. Exposed utility attributes systematically recorded using T2, T3, T5 and integrated into authoritative records to update confidence	Maintenance events incrementally improve authoritative records at marginal cost.
Multi-utility coordination in brownfield corridors	Fragmented ownership, inconsistent records, conflicting stakeholder data	Framework applied at spatial-extent level. Current confidence is assessed per utility; missing or conflicting records are treated as low confidence, triggering selective escalation to E3/E4. Confidence is updated per utility to support coordinated decision-making across stakeholders.	Improved coordination, reduced disputes, and increased corridor-level confidence.
Incremental information improvement over time	Authority lacks resources for comprehensive resurveying	Framework is institutionalized to require data capture at high-value events such as E4, E5, and E7. Each intervention incrementally updates records and confidence without dedicated survey campaigns	Progressive update of utility information supports long-term asset management & reduces repeated investigations.

achievable confidence, the framework supports transparent and defensible escalation decisions without assuming that higher investigation levels are always necessary.

Importantly, the framework does not prescribe rigid sequences or mandatory investigations. Instead, it formalizes a decision logic that allows events to be skipped, revisited, or escalated based on construction intent, access conditions, and risk. This flexibility reflects real construction practice and avoids the inefficiencies associated with uniform or overly conservative investigation requirements.

From a construction perspective, the framework supports risk-informed decision-making by clarifying when existing information is sufficient and when escalation is justified, particularly for high-risk activities such as trenchless installations. For asset owners and authorities, it provides a consistent basis for defining permit conditions, inspection requirements, and data capture obligations without prescribing specific technologies or vendors.

A key practical implication is the explicit recognition of construction, maintenance, and decommissioning activities as high-value data capture opportunities. Systematic recording during these events enables incremental improvement of utility records over time, reducing reliance on repeated standalone investigations and supporting long-term asset information quality.

The use of technology classes rather than specific instruments is a deliberate design choice. Known applicability constraints, such as material dependency of geophysical methods or access limitations for surveying, are addressed through technology applicability tables and embedded escalation logic. The framework therefore guides how technology limitations should influence decisions, rather than attempting to optimize sensor selection.

This study does not claim to eliminate uncertainty or replace engineering judgement. Site-specific conditions, contractual constraints, and safety considerations remain critical and must be addressed by practitioners. The framework has been developed through synthesis of standards, prior research, and construction practice and illustrated through representative scenarios. Large-scale field validation and quantitative assessment are identified as important areas for future work.

7 Conclusion

This paper presented an event-based utility data collection framework that aligns subsurface utility information acquisition with construction and maintenance workflows. By structuring utility data collection around lifecycle events, data categories, technology classes, and confidence considerations, the framework provides practical guidance on when data should be collected, when escalation is warranted, and when construction activities should be leveraged as durable data capture opportunities.

The proposed approach shifts utility data management from a predominantly record- or survey-driven paradigm toward a workflow-integrated, confidence-aware process. Rather than requiring comprehensive resurveying, the framework enables incremental improvement of utility information through routine construction and maintenance activities, supporting safer construction, improved coordination among stakeholders, and more reliable long-term asset records.

Future work may focus on implementing the framework within digital platforms, evaluating its application across diverse project types, and exploring automated or semi-automated support for confidence assessment and escalation decisions. Nevertheless, the framework provides a structured foundation for operationalising existing standards and technologies within real construction contexts.

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