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(Research Article)

Integrated geophysical and geomatics site assessment for building extension planning at Clarkson university, Potsdam, New York

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Abstract

This project addresses the critical need for a comprehensive, multi-method site assessment prior to the proposed extension of a Center for Advanced Material Testing campus building, mitigating significant geotechnical and utility risks inherent in complex urban environments. Because only a limited number of boreholes can be utilized in projects due to financial constraints, there are undoubtedly dangers and a fair amount of uncertainty associated with geotechnical exploration. Depending on the experiences of the geotechnical engineers, these risks can be further raised or lowered.

This research employs an integrated process of using advanced Geophysical and Geomatics techniques to map both the surface and subsurface conditions of the area of interest. Subsurface investigations utilized Ground Penetrating radar (GPR) at 450 MHz, which one was a Malar single channel and the other was an 18-channel 3D Raptor GPR antenna, supplemented by Frequency Domain Electromagnetic (FDEM), and Electromagnetic (EM) methods. This combination was essential for accurately locating ghosts and active utilities. Surface mapping incorporated UAV for aerial photogrammetry to generate precise Surface models and digital terrain Models, complemented by high resolution LiDAR and conventional topographical and As-built surveys. This model not only confirms the site's geotechnical constraints and provides actionable data for foundation design but also establishes a reliable, risk-reducing protocol for future campus construction projects.

Keywords: Ground Penetrating Radar; Geomatics Engineering; Utility Mapping; Electromagnetic Survey; UAV Photogrammetry; Pre-Construction Assessment; GIS; Campus Infrastructure

1. Introduction

Major building extensions on existing campuses require more than conventional design control, they require reliable knowledge of both the visible surface environment and the hidden subsurface setting. In practice, limited borehole coverage, incomplete utility records and the density of legacy infrastructure can leave project teams with substantial uncertainty during design and excavation.

The proposed extension of the Solinsky Camp building at Clarkson University provided a representative case of this challenge. University campuses commonly contain overlapping networks of electrical, drainage, irrigation, communication, and abandoned service lines. When such utilities are not accurately located before excavation, the consequences can include worker safety hazards, design changes, service interruptions, environmental damage, schedule delays, and significant additional cost.

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This study therefore adopted an integrated site characterization workflow that combined geophysical surveying, conventional geomatics, remote sensing and GIS-based data integration. The main purpose was to generate a comprehensive, spatially referenced site model capable of informing engineering design and reducing risk before construction. The specific objectives were to:(1) map active and abandoned underground utilities within the area of interest, (2) georeferenced all findings to campus coordinates using topographic and as built survey control, (3) generate a high resolution surface products from UAV photogrammetry, and (4) integrate the resulting datasets within a GIS framework for engineering interpretation and future infrastructure management

The study contributes to the growing use of non-destructive subsurface investigation in civil engineering by showing how multiple complementary methods can be combined to improve reliability. Rather than treating each survey as a stand-alone deliverable, the workflow emphasizes integrated interpretation, cross-validation among sensors, and translation of results into a form directly usable by designers, construction managers, and campus planners.

2. Background and relevant literature

Ground Penetrating Radar" (GPR) is a non-destructive geophysical method that uses electromagnetic energy, typically within the radio-wave portion of the spectrum. It detects contrasts in dielectric properties beneath the ground surface. Since its early development, GPR has become a mature tool with broad application in archeology, pavement evaluation, environmental investigation, utility detection, concrete inspection, and geotechnical exploration (Annan, 2001; Daniels, 2004; Yelf, 2006).

A typical GPR system consists of three main components. As illustrated in Figure 2 below, a control unit (used to record, store and display reflected signals and position in real time), a power supply system and antennas (consisting of transmitter (Tx) and receiver (Rx). The control unit consists of electrical components used to trigger multiple short pulses of radar energy into the subsurface by transmitting antenna, and collecting, storing and displaying the reflected energy from the receiving antenna. Antenna frequency ranges from 10 to 1000 MHz for GPR systems, a single GPR system can be configured to be used with different frequency antennas. Application, size of target, and depth of target, all play an important role in selecting the correct frequency antenna.

Antenna frequency is a very important factor in GPR surveying. The functions thereof are to find a balance between image resolution and depth to the required target for the specific application. Higher frequency antennas like 500-1000MHz can penetrate to shallow depths of 1 to 3ft and are used for (concrete scanning and pavement evaluation. This can produce very clear and accurate resolution of target features. As such, lower frequency antennas like 50 - 200 MHz can penetrate to very deep targets with lower resolutions and are used for both geological and geotechnical investigation. The table below shows typical GPR frequencies, depths and applications for various antenna frequencies.

In campus environments, GPR is often more effective when paired with electromagnetic locating methods. EM based tools can directly trace conductive services and are useful for confining active utilities, whereas GPR can also reveal nondestructive and abandoned alignments when they produce clear radar signatures. This complementary relationship aligns with utility engineering guidance that recommends using multiple sources of evidence when documenting subsurface infrastructure (ASCE, 2002).

Geomatics methods are equally important because subsurface results gain engineering value only when they are accurately tied to a project coordinate system. RTK GNSS, topographic and as-built survey, UAV photogrammetry, and GIS integration make it possible to place utility findings in direct spatial relationship to buildings, pavements, drainage features, and design control. The literature therefore supports a multimethod workflow in which geophysical data acquisition, survey control, and geospatial integration are treated as parts of one site assessment system rather than isolated tasks.

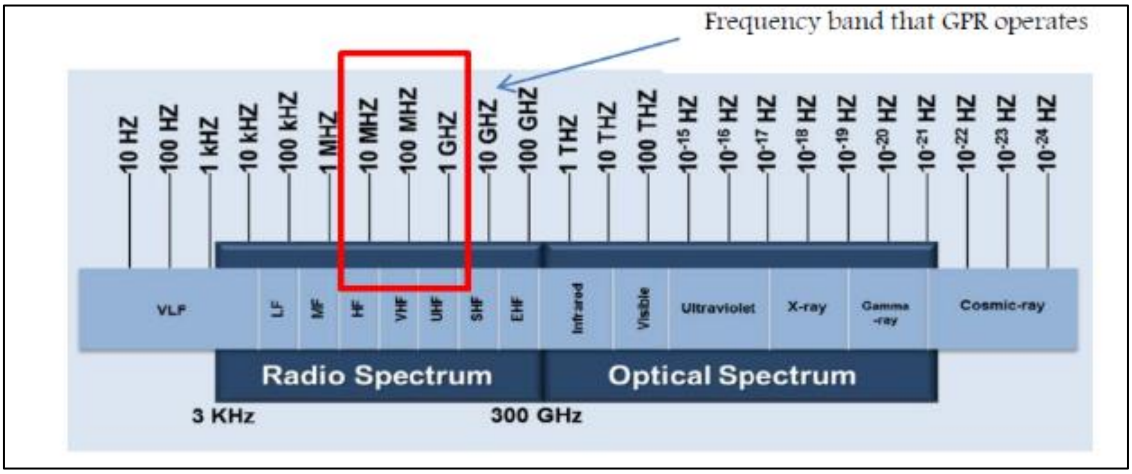

Figure 1 Radio Spectrum

Figure 2 Components of a GPR System

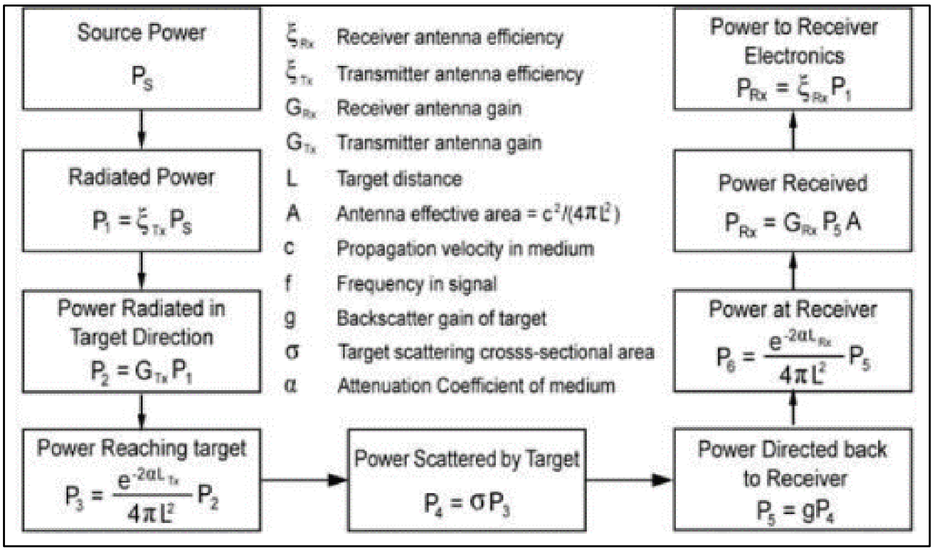

Figure 3 Flow Chart of the GPR System

Table 1 GPR Frequencies, Depths and Applications

Appropriate Application	Primary Antenna Choice	Secondary Antenna Choice	Depth Range (Approximate)
Structural Concrete, Roadway, Bridge Decks	2600 MHz	1600 MHz	0-0.3m (0 – 1.0 ft)
Shallow Geology, Utilities, Archeology	400 MHz	270 MHz	0.5 – 5m (0 – 12 ft)
Geological Profiling	100 MHz		0 – 30 m (0 – 90 ft)
Concrete, Shallow Soils, Archeology	900 MHz	400 MHz	0 -1m (0 – 3ft)

3. Materials and Methods

3.1. Study Area

The study area focused on the proposed extension area adjacent to the north side of the camp building on Clarkson University campus in Potsdam, New York. The survey area was centered approximately at coordinates 499900 E, 4945500 N, in state plane coordinate systems. The site was characterized by gentle surface relief, sparse vegetation and good physical access for ground-based surveying and UAV operations.

The practical significance of the area of interest lies in its location within an already developed campus setting. Existing buildings, hardscape, landscape zones, and utility corridors create environments in which both surface and subsurface data must be collected at high positional accuracy and interpreted together.

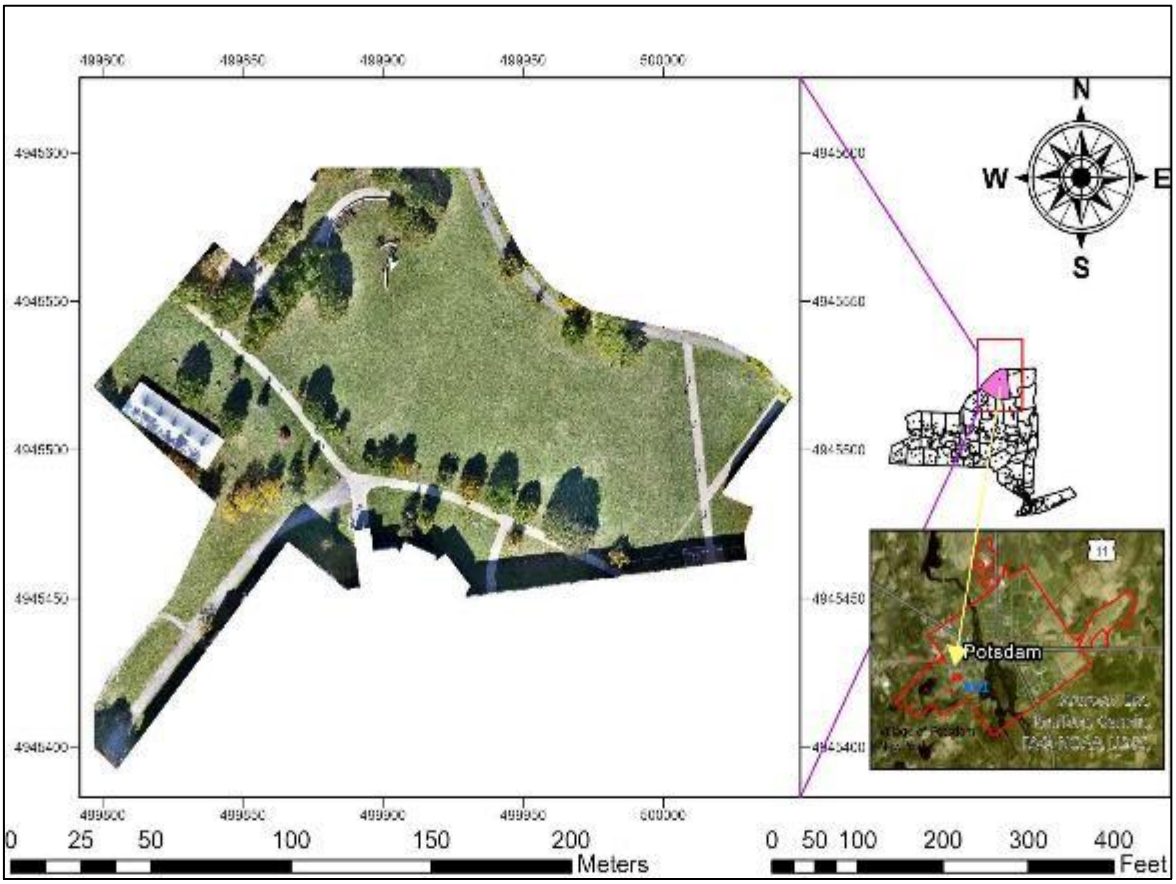

Figure 4 Study Area Map using Aerial imagery from UAV and State map from GIS Clearing house

3.2. Integrated survey design

The field program adopted a multi method design so that no important interpretation depended on a single sensor alone. Subsurface characterization relied on GPR, FDEM, and EM utility locating. Surface characterization relied on RTK topography and as built survey, UAV photogrammetry, GIS integration. This structure allowed the strengths of one method to compensate for the limitations of another.

Two 450 MHz GPR systems were used: an 18-channel 3D Raptor array for dense, high resolution utility imaging and a single-channel MALA GX system for target profiling along closely spaced lines. All GPR data were recorded in continuous mode and tied to the Emlid Reach RTK position for spatial control. Processing included time zero correction, background removal, band pass filtering, gain application, and migration to improve the interpretability of hyperbolic signatures and depth slices.

FDEM and EM methods were used to support targeted location of conductive services and to inform active utility alignments. Both active and passive modes were used where appropriate. The EM observations served as an important check on the geophysical interpretation, especially where GPR indicated linear features that could represent either active or abandoned infrastructure.

For surface characterization, RTK GNSS was used to collect topographic points and as built information for visible infrastructure such as manholes, curbs, building corners, and surface utilities. UAV photogrammetry was carried out using a 61 mega pixel camera with approximately 80% image overlapping at a flight altitude of 100 ft. 10 surveyed ground control points were distributed across the area of interest to strengthen georeferencing. LiDAR data were also acquired, but the processing needed for this report was delayed because corrected GPS data from the local reference framework were temporarily unavailable during a government shutdown.

Table 2 Summary of the principal survey methods used in the investigation.

Method	**Instrument / Configuration**	**Primary target**	**Main contribution to final site model**
3D GPR survey	18 channel 450 MHz Raptor	Shallow utilities and subsurface lineaments	High-density radar imaging of utility corridors
Single-channel GPR	450 MHz MALA GX, parallel lines at 1m spacing	Shallow utilities, localized depth slices, and soil-thickness patterns	Targeted proofing and support for depth-slice interpretation
FDEM locating	MALA mini 6L FDEM	Conductive Utilities	Confirmation of active and passive services and support for line tracing
EM locating	RD-series EM locators	Conductive Utilities	Confirmation of active services and support for line tracing
Topographic and as built survey	Emlid Reach RTK GNSS	Surface Features and visible infrastructure	Project control, georeferencing, and engineering base mapping
UAV photogrammetry	61 MP camera with ground control	Surface model and Ortho mosaic	High resolution mapping for grading and clearance review
GIS integration	ArcGIS Pro Workflow	All survey outputs	Unified spatial interpretation and final engineering visualization

3.3. Data integration and interpretation

All processed datasets were integrated in ArcGIS Pro. Utility centerlines interpreted from GPR and confirmed with EM observations were digitized and stored as linear features with associated depth or classification notes where available. Surface datasets from topographic survey and UAV photogrammetry were overlaid with subsurface interpretations to produce a unified engineering map of the site.

Interpretation focused on practical engineering outputs rather than purely geophysical description. The final deliverables were minted to identify potential excavation hazards, document the present state of visible and buried infrastructure, and provide an accurate base for foundation and utility planning.

4. Results

4.1. GPR depth slices and representatives radar interpretation

The single channel 450 MHz GPR survey produced depth slices that revealed several linear and localized anomalies consistent with shallow buried infrastructure. Depth-slice visualization was particularly helpful for following features laterally across the site and for identifying zones where multiple possible alignments intersected or clustered.

Figure 5 Points collected using the Mala mini 6L FDEM

Figure 6 FDEM Interpolated lines created in ArcGIS pro using Kriging operator

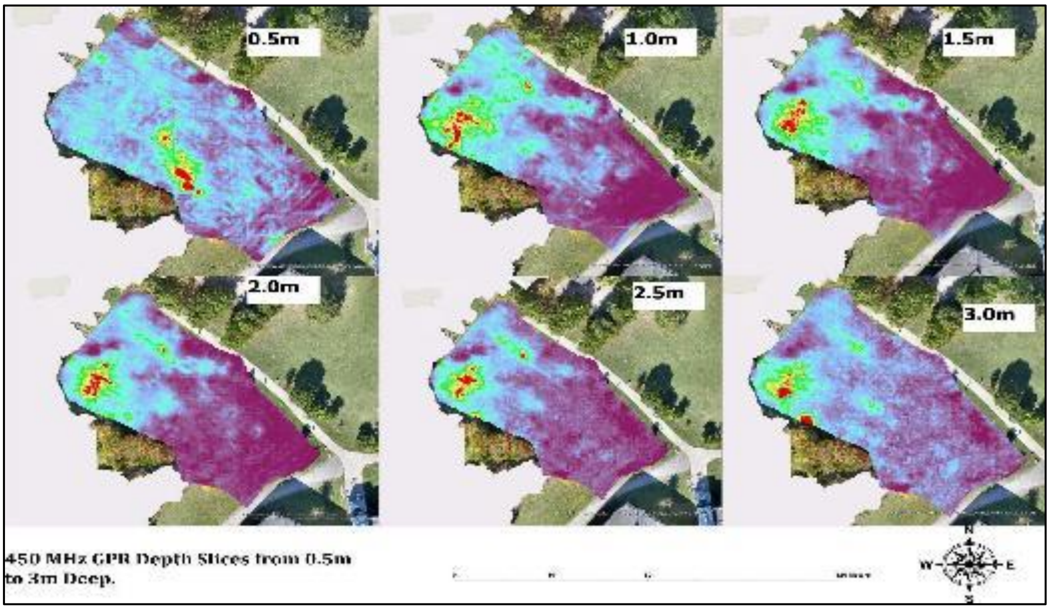

Figure 7 450 GPR Depth Slices created in geolitix from 450 single channel GPR

4.2. EM-confirmed utility mapping and integrated utility interpretation

Direct EM locating confirmed the position of active conductive services and provided a practical basis for distinguishing active lines from features that appeared only in radar data. The EM utility map identified electrical service and other conductive features that required clear protection during any future excavation.

When EM evidence was combined with GPR interpretation, the resulting integrated utility map showed a more complete subsurface network than either method could have provided alone. The combined interpretation captured both conductive active services and probable abandoned or nondestructive lines visible in the radar record. This distinction is especially important in developed campus settings where undocumented legacy infrastructure can pose excavation hazards even when it is no longer in service.

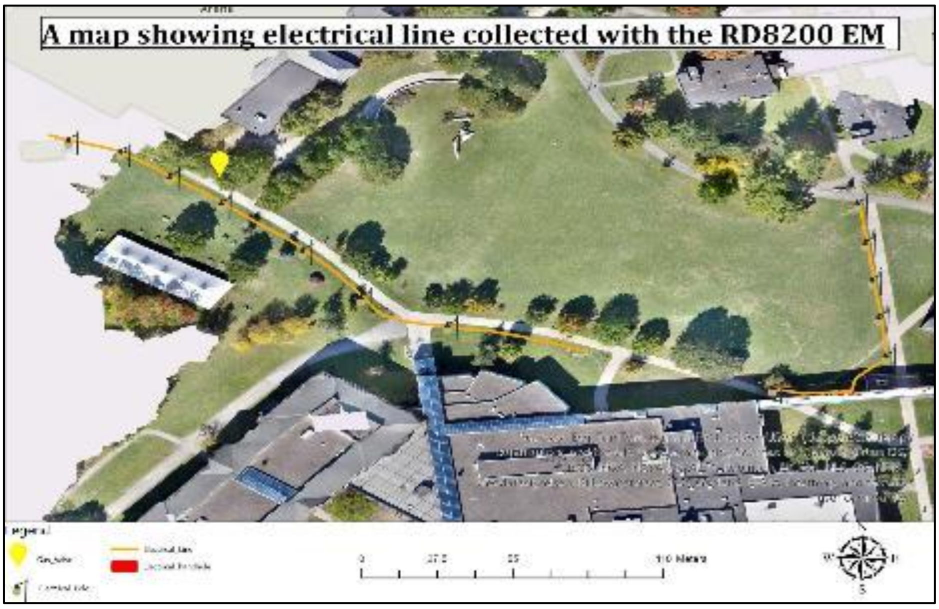

Figure 8 EM-derived map of a traced Electrical line collected using RD-series equipment

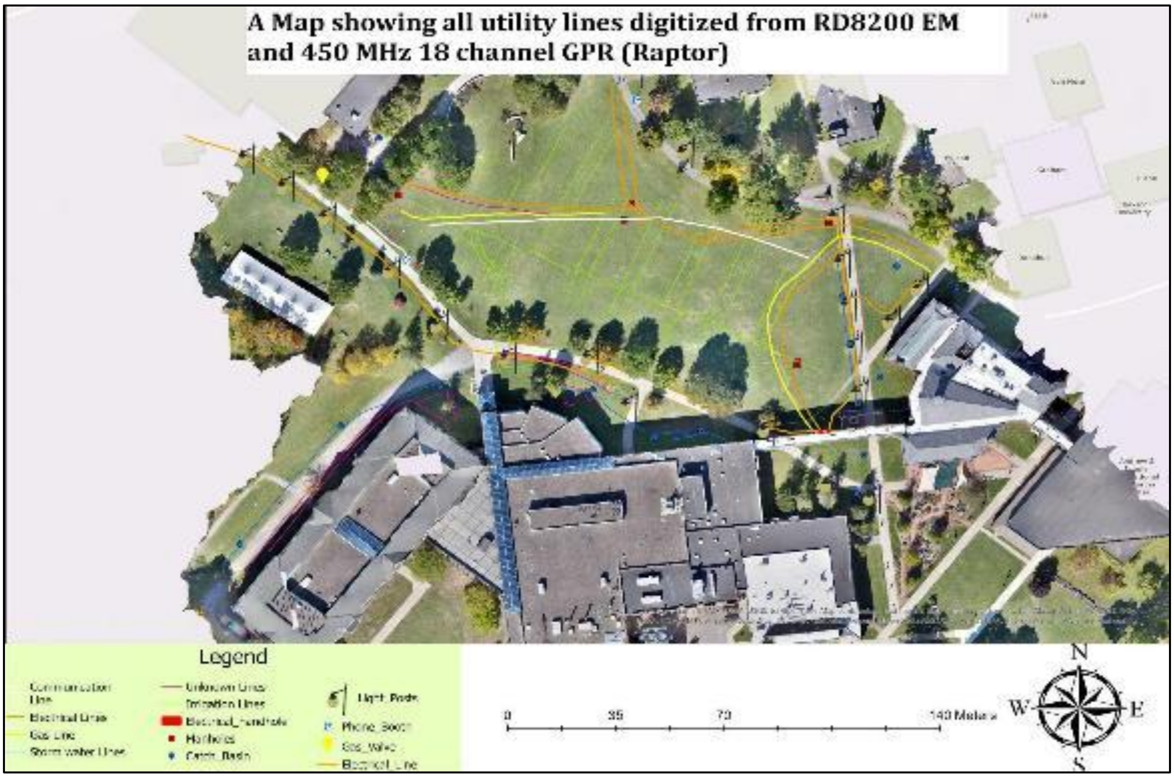

Figure 9 Integrated utility map derived from combined GPR & RD8200 EM

4.3. Summary Statistics

The compiled utility inventory showed meaningful variation in the mapped length of different line classes. The largest total mapped length corresponded to irrigation lines, followed by electrical lines, unknown lines, stormwater line, gas line and communication lines. Based on the original project summary graphic, the approximate totals were 926.33 meters for irrigation lines, 584.14 meters for electrical lines, 348.57 for unknown lines, 225.33 for stormwater lines, 179.77 for gas lines, and 144.48 for communication lines.

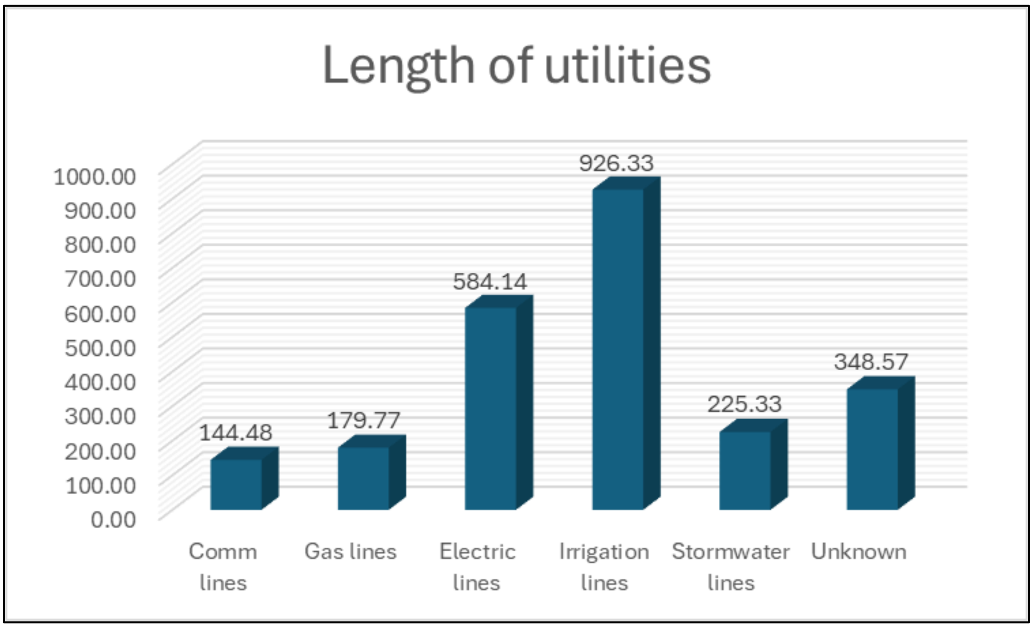

Figure 10 Summary chart of total mapped utility length by interpreted line class

5. Discussion

The most important outcome of the study was not a single map or geophysical image, but the reliability gained by combining methods. GPR offered broad sensitivity to buried contrasts, including probable abandoned or non-metallic utilities. EM locating provides higher confidence for active conductive services. RTK survey and UAV photogrammetry ensured that the results could be used directly in engineering space. In this sense, the value of the workflow was cumulative, each method made others more useful.

The results also demonstrated the importance of documenting ghost utilities in developed sites. These features may not appear in current records and may not carry an active EM signal, yet they still matter for excavation planning and safety. Their identification through radar signatures, coupled with the absence of corroborating active utility evidence, gave the design team a stronger basis for deciding where to avoid, expose, protect, or remove buried infrastructure.

The high-resolution surface products added a second dimension of engineering value. Because the site model integrated ground features, building edges, visible utility access points, and orthophotography, the final interpretation could support grading review, clearance checks, and coordination among design disciplines. This makes the dataset useful not only during pre-construction assessments but also as a foundation for future campus infrastructure management.

One method that proved less successful in this setting was electrical resistivity tomography (ERT). As noted in the original project, dense buried infrastructure created substantial electrical noise, especially near buried water lines, which limited interpretability. This does not imply that ERT is inherently unsuitable for engineering site assessment, rather it highlights the need to match method selection to site conditions and project objectives.

6. Conclusion

This study showed that an alleged geophysical and geomatics workflow can substantially improve pre-construction understanding of complex campus sites. By combining GPR, FDEM, EM locating, RTK topographic survey, UAV photogrammetry, and GIS integration. The investigation produced a spatially coherent site model capable of supporting design, excavation planning and infrastructure management.

The combined approach utility mapping confidence supported the identification of both active and abandoned underground lines and provided high resolution surface information relevant to grading and clearance assessment. In practical terms, the workflow reduced uncertainty at the planning stage and created a stronger technical basis for avoiding utility strikes, minimizing redesign, and supporting efficient construction sequencing.

For future work, targeted geotechnical verification at selected anomalies, completion of the LiDAR processing stream, and integration of the resulting data into a centralized campus GIS database would further strengthen the long-term value of the project. The study therefore supports the use of multimodal, survey-integrated assessment as a best-practice model for campus expansion and similar civil engineering projects in developed environments.

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