

Road Doctor Memo No. 47

To: Metro District

Cc: Jesse Thorsen

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From: MnDOT Office of Materials & Research (OMRR) – Road Doctor Survey Unit

Date: 6/22/2023

Subject: Detection of buried street car tracks using 3DGPR on Arcade and 7th streets in St Paul, MN (SP6221-107)

This technical memorandum provides an overview of the 3D ground penetrating radar (3D-GPR) testing carried out on two roads in St. Paul. The Metro District (Jesse Thorsen) requested this testing for three road sections (Area 1, Area 2, and Area 3) located on Arcade and 7th streets (TH 5 and TH 61) in St. Paul, MN. These sections are part of the upcoming construction project SP 6221-107, which involves mill and overlay. However, the specified areas will undergo complete reconstruction due to the historical use of street cars in this part of the city. Our office was approached by the planner to utilize GPR technologies to investigate these areas and ensure the absence of any remaining street car trucks. The GPR survey covered the entire length of the roads, including driving, passing, parking (whenever feasible), and turn lanes.

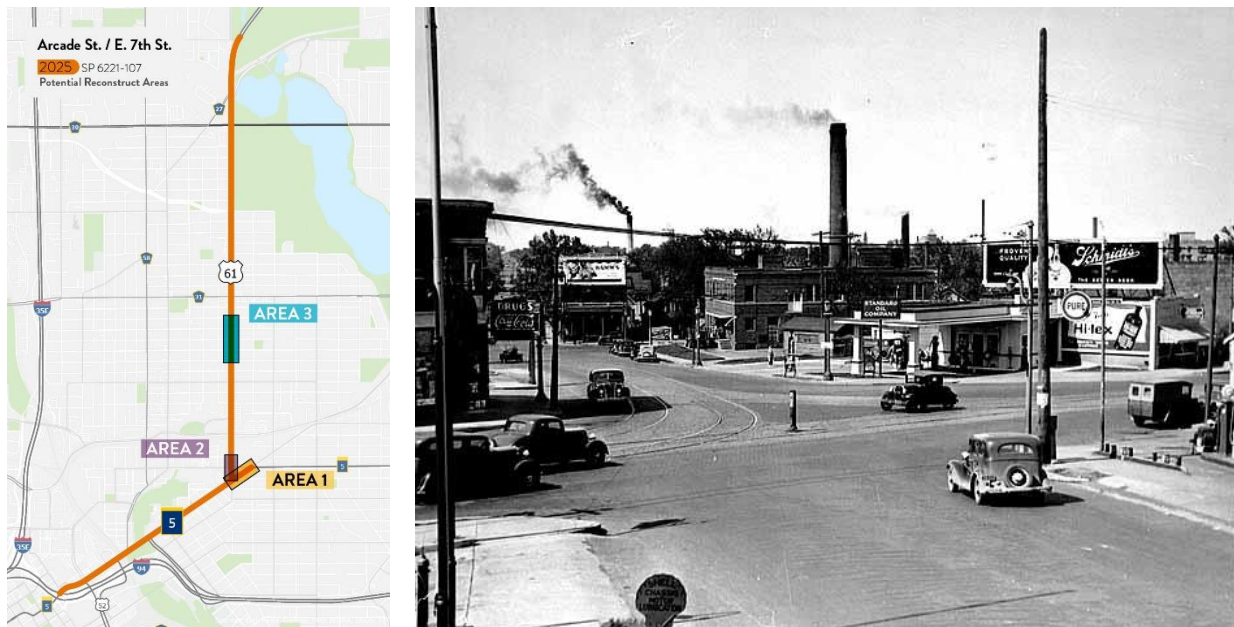


Figure 1. Map and historical picture of the testing site

Furthermore, an additional 4-mile section of 7th Street, spanning from Arcade St. to Erie St., was included in the survey beyond the areas initially proposed by the project planner. This decision was made based on our team's previous observation of buried tracks in this section through a pothole during winter. Collecting data from this road would prove the ground-penetrating radar's effectiveness in detecting buried street cars. The survey of this road segment was conducted solely in a single lane

Data collection and processing

Testing was conducted on May 22, 2023, using the Geoscope 3D-GPR radar unit. The unit (shown in Figure 2) employs an air-coupled antenna array composed of 21 channels. The width of the GPR unit is about 6 feet, and the spacing between the channels is approximately 3 inches. The survey conducted using this antenna configuration generates 21 GPR profiles. Each channel (antenna pair) emits GPR signals at frequencies ranging from 50 to 3000 MHz and records the reflected energy. The testing parameters and the speed at which the data was collected were tuned in such a manner as to probe efficiently (highest resolution possible) the top 1-foot layer of the pavement. The testing was conducted in the hours spanning from 10 AM to 1 PM with no traffic control.



Figure 2. 3D-GPR antenna layout

Data processing was accomplished using the Examiner software. Standard filtering techniques were adopted to remove noises and interferences and to improve the GPR image quality at the depths beneath the concrete pavement layer (beneath 1 foot)

Interpretation of GPR results

Ground Penetrating Radar (GPR) is a geophysical technique that uses radar pulses to create subsurface images of the Earth's layers. GPR emits electromagnetic waves into the ground and measures the reflected signals. In the GPR data, buried metallic or distinct objects typically appear as hyperbolic signatures, similar to the one shown in Figure 3.

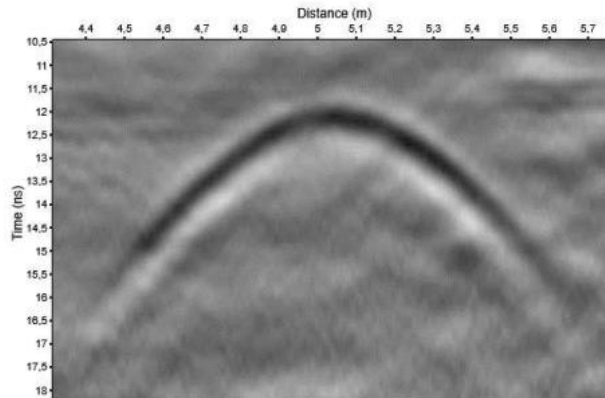


Figure 3 Example of GPR hyperbola from a buried object

Note that when:

- multiple hyperbolas appear in a GPR data set, it typically indicates the presence of multiple buried objects (see Figure 8 on intersection between arcade and 7th streets)
- Continuous lines of hyperbolas in GPR data typically indicate a linear or elongated buried object. Instead of individual isolated hyperbolas, the continuous hyperbolas form a distinct pattern that suggests a continuous target extending along a specific path or alignment.

Key findings

Based on the GPR data analysis, multiple segments of 7th Street, including the construction site labeled as Area 1, exhibited reflections resembling buried streetcar tracks. At the intersection of Arcade and 7th Streets, the GPR indicated the presence of two sets of streetcar tracks (four lines), as depicted in Figure 8.

Conversely, no significant findings were observed on Arcade Street. On 7th Street, only one set of tracks was observed, although the survey was limited to a single lane. The buried element appeared to originate at a depth of approximately 5 inches below the surface of the pavement. For further details and a summary of the sections displaying evidence of buried elements, please refer to the attached Excel spreadsheet. While the spreadsheet provides information regarding the location and length of the sections suspected to contain buried streetcars, it was not possible to provide precise quantities based on this interpretation. The following images depict examples of GPR data illustrating evidence of long-buried elements.

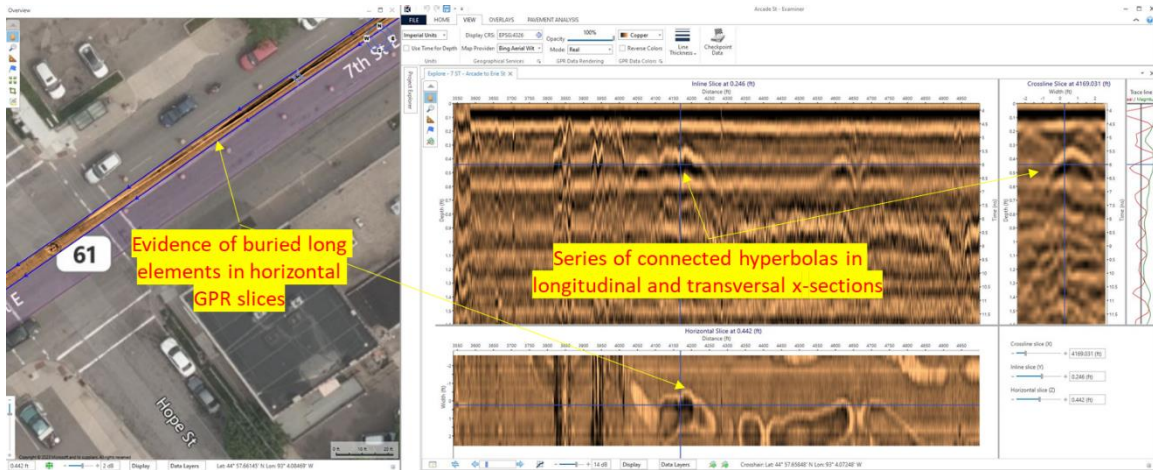


Figure 4 : Section on 7th Street from Arcade to Maple St

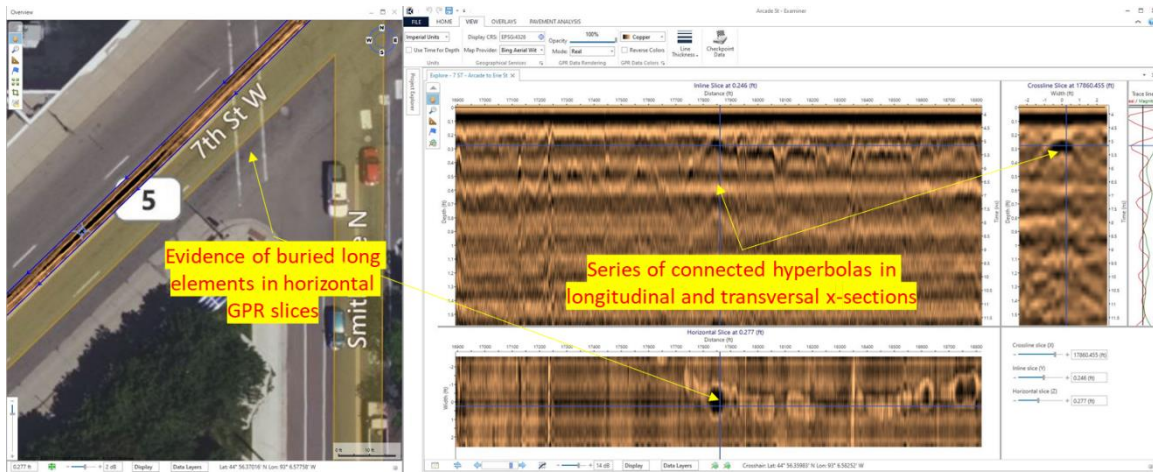


Figure 5 : Section on 7th Street from Grande Ave to Dousman St

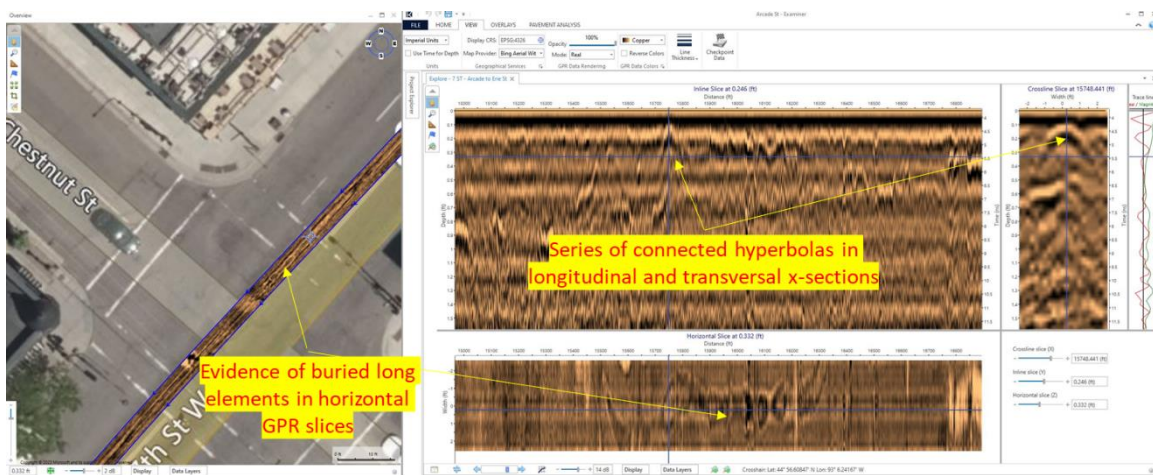


Figure 6 : Section on 7th Street from Kellogg Ave to Grande Ave

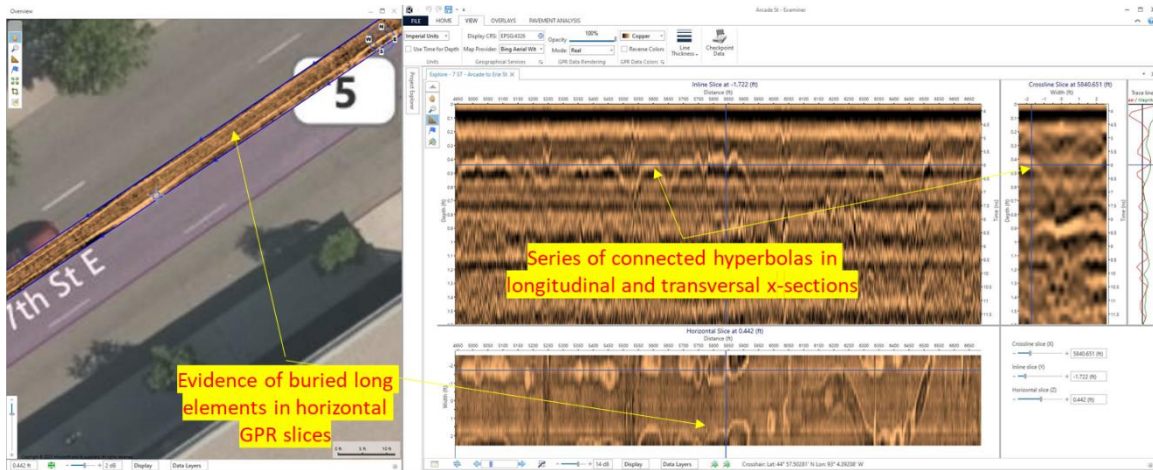


Figure 7 : Section on 7th Street from Maple Ave to Payne Ave

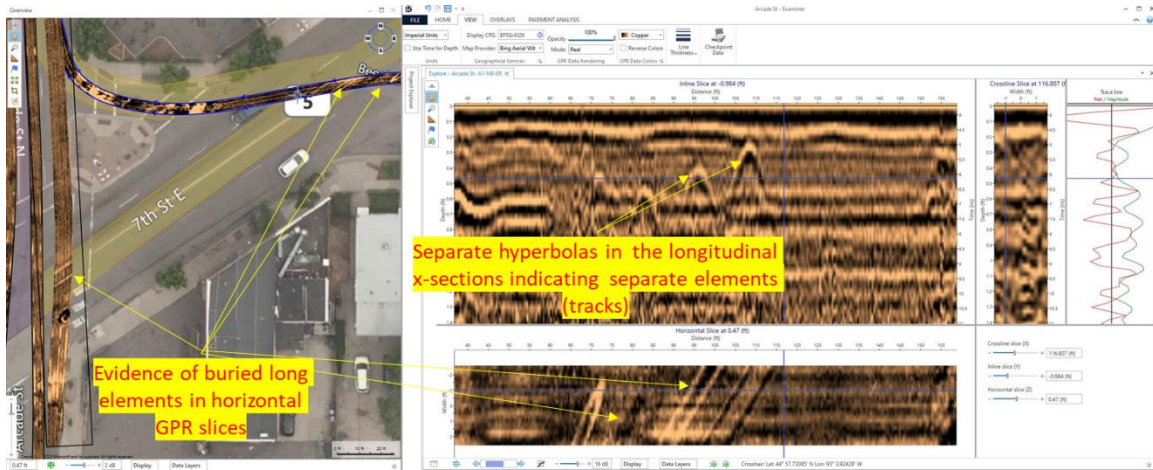


Figure 8 : Intersection between Arcade and 7th streets

The interpretation regarding the presence or absence of streetcars was solely based on the analysis of the GPR data, in consultation with various GPR practitioners from MnROAD and external sources such as Kontur and road scanners. It is important to note that we did not have access to ground truth data that could definitively validate the observations made using the GPR data. However, based on our analysis, we are confident that the highlighted sections may contain unremoved streetcars. We encourage the project engineers to share any future information or observations during the construction process that could either support or refute the GPR findings.

We hope that this report and the information presented within it will assist you in formulating the most suitable rehabilitation strategies for the project. We also welcome your feedback to help us enhance the utilization of 3D-GPR for the detection of buried objects on pavements.