Minnesota Department of Transportation Metro Barrier Extraction and LiDAR Project

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June 2014

Research Project
Final Report 2014-22

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Technical Report Documentation Page

1. Report No.	2.	3. Recipients Accession No.
MN/RC 2014-22		

4. Title and Subtitle	5. Report Date
Minnesota Department of Transportation Metro Barrier Extraction and LiDAR Project	June 2014
	6.
7. Author(s)	8. Performing Organization Report No.
Trisha Stefanksi	
9. Performing Organization Name and Address	10. Project/Task/Work Unit No.
Minnesota Department of Transportation 1500 W. County Road B2 Roseville, MN 55113-3174	11. Contract (C) or Grant (G) No. (c) 01191 (wo)
12. Sponsoring Organization Name and Address	13. Type of Report and Period Covered
Minnesota Department of Transportation Research Services & Library 395 John Ireland Boulevard, MS 330 St. Paul, MN 55155	Final Report 14. Sponsoring Agency Code

15. Supplementary Notes

http://www.lrrb.org/PDF/201422.pdf

16. Abstract (Limit: 250 words)

By using a relatively new technology, mobile Light Detection and Ranging (LiDAR) and imagery, MnDOT obtained accurate roadway data in a safe and efficient manner. Using a manual extraction technique, MnDOT created a Geographic Information System (GIS) inventory of geospatial coordinate locations, asset attributes, and condition data for plate beam guardrails and concrete barriers. The LiDAR data was utilized for internal communication and visual rendering and will be used in the future to assist with roadway design. The project challenges were mostly technical in nature and highlight the importance of having a clear quality assurance/quality control process. The benefits of the project include, but are not limited to: calculating barrier replacement costs, scoping and budgeting future projects based on condition and future fed/state standard changes, allowing for better planning of maintenance activities, utilizing the imagery to extract other assets, and construction cost savings due to increased design accuracy.

17. Document Analysis/Descriptors	18. Availability Statement
Laser radar, geographic information systems, quality control, quality assurance, asset management, guardrails, barriers (roads)	No restrictions. Document available from: National Technical Information Services, Alexandria, Virginia 22312

19. Security Class (this report)	20. Security Class (this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	13	

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Published by:

Minnesota Department of Transportation
Research Services & Library
395 John Ireland Boulevard, MS 330
Saint Paul, MN 55155

Minnesota Department of Transportation
Metro Barrier Extraction and LiDAR Project

1. Background

Mobile mapping technology offers a new method to rapidly collect immense amounts of very accurate geospatial data in a safe and efficient manner. A vehicle traveling at posted speeds equipped with a laser scanner, high-resolution cameras, and GPS technology captures Light Detection and Ranging (LiDAR) data and geo-referenced images that are processed in the office using special software programs. The data captured can be used to support a wide variety of transportation activities, including: design, construction, operations and maintenance, and capital improvement planning.

2. Introduction

2.1 Project Summary

The Minnesota Department of Transportation (MnDOT) Metro District operates roughly 1,100 centerline miles of roadway within the cities of Minneapolis/St. Paul and surrounding communities. Part of MnDOTs responsibility is to maintain transportation infrastructure. In order to budget, plan, and maintain roadway infrastructure, accurate field data must be captured.

Prior to this project, MnDOT did not have an accurate inventory of plate beam guardrail and concrete barrier (referred to as barrier). In addition, MnDOT had not fully utilized LiDAR data for construction project design.

The project budget for hardware, software, and contract work was $280,000. The goals of the project were to:

1. Obtain filtered and classified mobile LiDAR data on several road segments within the Metro.
2. Obtain a metro-wide data set of imagery compatible with Trimble Trident 3-D Analyst (referred to as Extraction Software through the remainder of the document).
3. Utilize part of the processed LiDAR data for a 2016 design project.
4. Utilize part of the LiDAR for visual rendering and internal presentations to MnDOT staff.
5. Extract barrier attribute and condition data from images creating a GIS based inventory.
6. Create a management plan for the barrier.

2.2 Project Location

The Contractor collected imagery on all MnDOT mainline, overpasses, interchanges, weigh stations, rest areas, and historical sites. The contractor set targets, collected, and fully processed LiDAR data within the I35W bridge corridor from Washington Avenue to University Avenue, in Minneapolis, on US-61 beginning on Ramp on I94 to 7th Street in both directions, and on MN36 from just East of Edgerton St to East of US61 in both directions.

2.3 Project Tasks
In order to accomplish all project goals, the project was broken down by tasks with schedules and budgets for each task. Table 2.1 summarizes project tasks and completion dates:

TABLE 2.1: Project Tasks

Task	Description	Completion Date
1	Develop consultant contract	June 2012
2	Purchase extraction software	September 2012
3	Obtain contract data deliverables	June 2013
4	Populate asset database for mainline data	April 2014
5	Write management plan	March 2014
6	Post barrier data to internal web-based viewer (Georilla)	April 2014
7	Execute management plan	On-going

3. Results

3.1 Project Preparation
As described in the tasks, project preparation included writing a Request for Proposals, selecting a contractor and establishing a consultant contract, purchasing Extraction Software, receiving Extraction Software training, and establishing a geodatabase with defined attributes and business needs in order to store and edit all extracted imagery attribute data. Training included one day of software navigation/ software prep and one day of imagery extracting by a DTS consultant.

3.2 Project Deliverables

Data Transfer Solutions, LLC (Contractor) submitted project data on mobile storage devices in batches to MnDOT. The Contractor also kept back-up copies of all raw/processed data as part of the project contract. Quality control and safety plans were submitted by the Contractor. Quality assurance and quality control checks were performed by both the Contractor and MnDOT staff.

The project contract required an absolute survey- grade accuracy of ± 0.1 foot (or better) for the LiDAR data and ± 1 foot (or better) for the images. Other requirements for the LiDAR data included: 15 cm minimum density, root mean square error trajectory is less than 5 cm, random error must be ± 5 mm, systematic error must be ± 2 cm, relative precision must not exceed ± 5mm, filtering for any “noise”, and classifying and formatting according to American Society for Photogrammetry and Remote Sensing (ASPRS) LAS V1.8. Deliverables included Microstation TIN models of the three roadway surfaces with breaklines.

Additional image requirements included a minimum resolution of 5megapixels with negligible interference such as vehicles and sun glare. A 360-degree camera was not permissible. Image file format was Audio Video Interleave (AVI) format with the structure of the data meeting Extraction Software import requirements.

3.4 Microstation Model Results

The contractor submitted Microstation roadway tin files that were reviewed by Metro Surveys, Photogrammetrics, and Metro Design. The MN36 segment was used as a data validation model. The I35W and US61 roadway segments were visually represented during several internal presentations to MnDOT staff. The US61 segment was delivered to design and will be used for a fiscal year 2016 American with Disabilities (ADA) design project in which several sidewalks and pedestrian ramps are being retrofitted to existing topography. A depiction of the US61 roadway segment is shown in Figure 1.

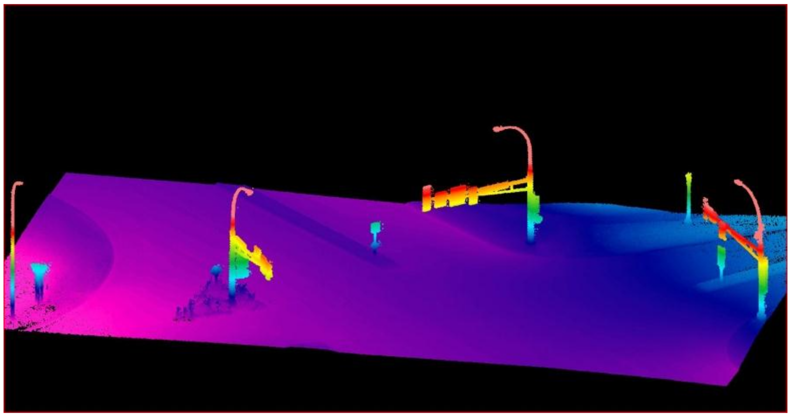


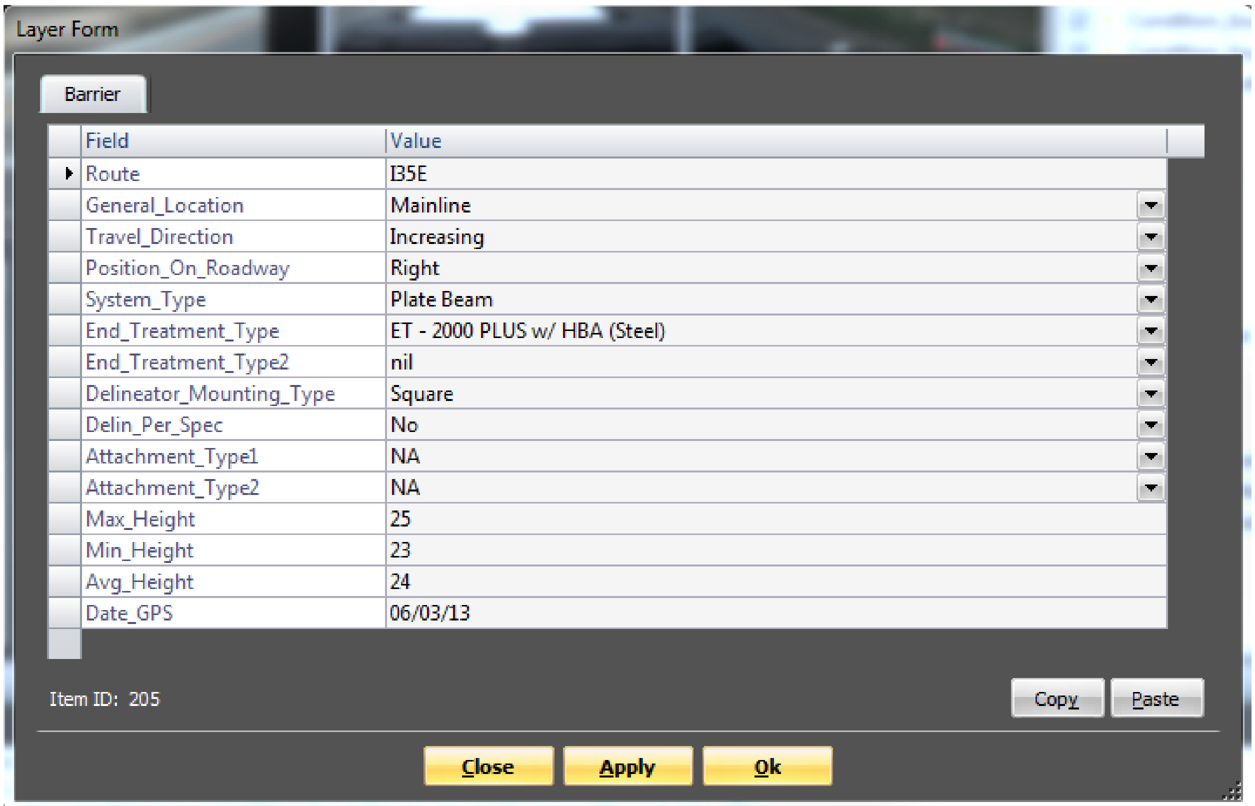
Figure 3.1: US61 TIN example

3.5 Image Extraction Results

Metro District staff reviewed over 1100 center lane miles of mainline and extracted location, attribute, and condition information for barrier. Barrier was extracted using a polyline with 15 attributes identified per segment. The attributes are described below, Figure 3.2 depicts the attribute table used within the extraction software, and Figure 3.3 shows extracted segments of both concrete and plate beam barriers.

Route Name – The name of the MnDOT mainline route where barrier is located.
General Location – Choices include mainline, ramp, or local road.
Travel Direction – Increasing or decreasing according to MnDOT reference posts.
Position on the Roadway – Choices include right, median, left.
Barrier System Type – The system type; either plate beam or concrete barrier.
End Treatment Type 1 – The first end treatment type connected to the plate beam.
End Treatment Type 2 – The second end treatment type connected to the plate beam.
Delineator Mounting – If applicable, the type of delineator mounted to the barrier.
Delineation Per Spec – If applicable is the delineator mounted according to specification.
Attachments on Barriers – If applicable, identification (by type) of barrier attachments.
Max Height of Barrier – The maximum height along the segment of barrier, measured in inches from X to Y checking Z random locations along the barrier.

Max Height of Barrier – The maximum height along the segment of barrier, measured in inches from X to Y checking Z random locations along the barrier.
Min Height of Barrier – The minimum height along the segment of barrier, measured in inches from X to Y, checking Z random locations along the barrier.
Average Height of Barrier – The average height of the barrier, calculated by using the mean.
Date GPS'd – Date the images were captured.



Layer Form

Barrier

Field	Value
Route	I35E
General_Location	Mainline
Travel_Direction	Increasing
Position_On_Roadway	Right
System_Type	Plate Beam
End_Treatment_Type	ET - 2000 PLUS w/ HBA (Steel)
End_Treatment_Type2	nil
Delineator_Mounting_Type	Square
Delin_Per_Spec	No
Attachment_Type1	NA
Attachment_Type2	NA
Max_Height	25
Min_Height	23
Avg_Height	24
Date_GPS	06/03/13

Item ID: 205

Copy Paste

Close Apply Ok

Figure 3.2: Barrier attribute table

Figure 3.3: Extracted barrier in extraction software

Barrier condition was evaluated according to the guidelines in Table 3.1 and Table 3.2 with a point and associated image created at the location where the condition exists.

Table 3.1. Concrete Barrier Condition Issues

Condition State 1	Spalls w/ no steel exposure
Condition State 2	Spalls w/ steel exposure
Condition State 3	Severe Deterioration

Table 3.2 Plate Barrier Condition Issue

Functional	Hit that needs to be fixed
Non-functional	Open Guardrail
Cosmetic	Hit or rust that doesn't need to be fixed
End Treatment Broken	End treatment either hit or on the ground
Post Broken	Broken off post

Analyzing the barrier data that has been extracted (to-date) yields the statistics shown in Table 3.3. It should be noted that only mainline data has been extracted at this time, and since obtaining images from the project, several construction projects have occurred (i.e., addition of barrier on US10) that will be located and added to the data set in the near future. A map of the Metro area showing barrier locations is included in Appendix A.

Table 3.3: Metro Barrier Statistics (as of 4-1-2014)

Description	Statistic
Total mainline barrier	483 miles
Total mainline plate beam guardrail	227 miles
Total concrete barrier	256 miles
Overall rate of collection	5 miles/hour
Length of barrier extracted per hour	2.5 miles/hour
Most prevalent end treatment type	ET-2000 Plus/w HBA
Least prevalent end treatment type	SKT 8 (wood)
Highest density roadway	I35W at 0.98 barrier/cl mile
Minimum height	12"
Maximum height	96"

3.6 Asset Management Plan

A one-page plan has been written (Appendix A) identifying how the barrier inventory will be updated in the future and who is committed to keeping the data updated. In summary, all construction changes will be field verified and coordinates obtained, initially by internal MnDOT staff with handheld GPS devices, but eventually contractors will be required to collect as-built data as part of each construction contract. Maintenance updates are already being tracked by field crews using Daily Project Reports (DPR's) and mapped using a spatial data layer. This data layer will be used concurrently with the inventory data.

In the future, a more robust asset management plan will be created for barrier that contains life-cycle cost analysis, performance measures, targets, and financial investment needs.

3.6 Project Challenges

In preparing to extract image data within the Extraction Software, MnDOT faced some challenges: a 64-bit computer was purchased; Microsoft Office 2010 (current standard) was removed from the computer because it wasn't compatible with the Extraction Software, and the set-up of the data within the Extraction Software was very complicated. Both the Contractor and software support staff were very helpful in answering questions and making sure MnDOT was set-up for extraction but the process was very time consuming.

The quality control portion of the contract was very important as some of the road segments submitted by the Contractor had sun glare and didn't contain all images, and other road segments were missing. Upon quality control checks, these issues were realized and all images were obtained.

Issues that occurred with the LiDAR data were as follows: MnDOT survey crews obtained point data, in addition to target data, in order to validate the Contractors work. This was not done at the same time as the Contractor set targets; therefore it was more time consuming and costly for MnDOT. **Also, horizontal and vertical control should be very tight, making the deliverables more accurate.**

3.7 Project Benefits

Recent applications of the barrier data have been used to help budget the replacements of the Breakaway Cable Terminal (BCT) and W-Beam Bullnose end treatments for guardrails. By being able to map out the location and the number of these two older styles of guardrail end treatments, the guardrail data provided a fairly accurate replacement/update budget need.

The barrier data has been quantified to determine a current day replacement value. Replacement value is helpful in comparing the worth of the asset to other assets within the agency as well as looking at maintenance costs relative to the asset value. Approximate replacement cost for the concrete barrier in the Metro District is $ 101,925,000 and plate beam is $37,563,000

Another project benefit is utilizing the plate beam inventory for planning/scoping of future Design projects and on-going Maintenance activities. All internal employees can view the inventory on "Georilla", an internal web-map. Thus allowing Planners to scope for future work, Designers to see attribute information in addition to location data, and Maintenance crews to determine what supplies are needed before going out to repair the plate beam. Along with identifying the type of end treatment, an image has been extracted at each end treatment so users can visually see each end treatment.

The project images have been utilized for other assets. Traffic sign GPS locations were extracted in locations where physically being on the roadway is very dangerous, such as a stretch of I-94 median in the downtown corridor. Noise wall locations were also extracted in several areas where data was needed.

This project facilitated the collaboration of several groups within MnDOT, including but not limited to: Design, Maintenance, Surveys, Photogrammetrics, Transportation Systems Management, and Traffic. It also raised an awareness of the applications of mobile LiDAR and since project completion several other mobile LiDAR projects have either been completed and/or are underway. Some of those projects include a stringless paving project on MN23 near Granite Falls, a concrete rehabilitation project on MN5 and TH8 in Metro District, and a 14-mile segment of roadways (I35W/694/US10) in Ramsey County that has both new roadway segments and future design work.

4. Conclusions

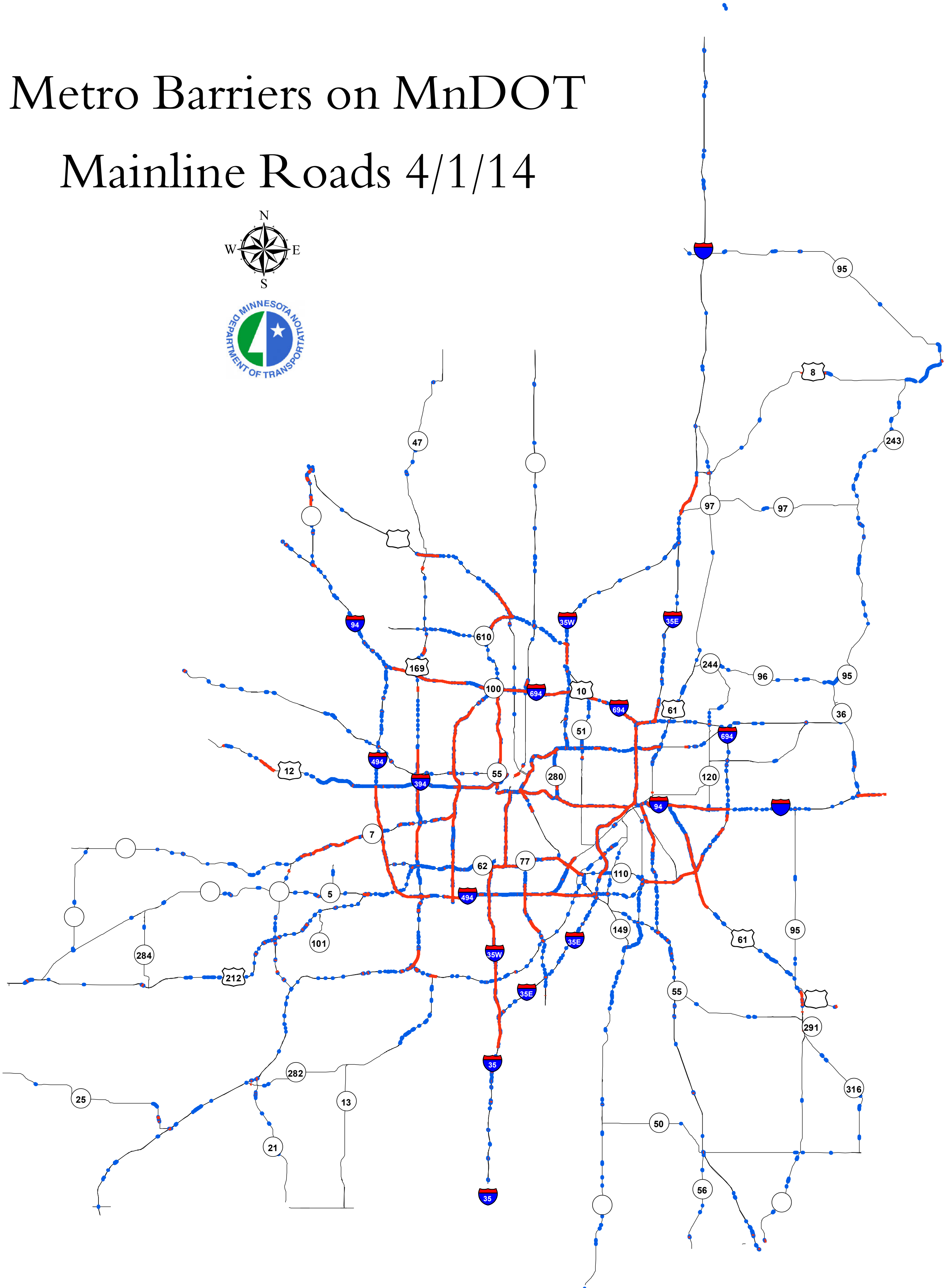
The project was a huge success, project goals were reached within the proposed budget and several other project benefits have been realized as explained within this document. Internal project extraction costs were $19,000 to collect guardrail and concrete barrier. The quoted cost of externally extracting barrier was relatively equal at $22,000. Thus, in the future, it is recommended to use external resources to extract asset data, as long as project attributes deliverables are clearly defined to meet MnDOT expectations.

Future project work will include obtaining feedback from design and construction on the US61 project and extracting the remaining interchange and overpass barrier data.

Appendix A

Metro Barriers on Mainline Roads

Metro Barriers on MnDOT Mainline Roads 4/1/14



Concrete Barrier	226.5 Miles	
Platebeam	227 Miles	A-1

*Does not include cable median barriers, or barriers on ramps and overpasses