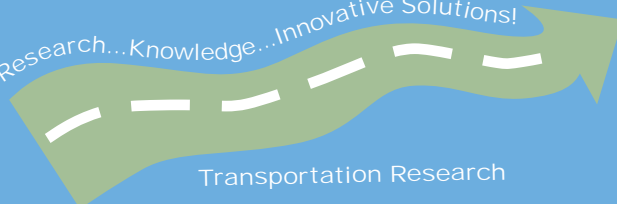# RESEARCH

2008-37

Developing and Implementing Enhanced Pavement Marking Management Tools for the Minnesota Department of Transportation: Phase I – Mapping Tool

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Technical Report Documentation Page

1. Report No. MN/RC 2008-37	2.	3. Recipients Accession No.	
4. Title and Subtitle Developing and Implementing Enhanced Pavement Marking Management Tools for the Minnesota Department of Transportation: Phase I – Mapping Tool		5. Report Date September 2008	
		6.	
7. Author(s) Neal Hawkins, P.E., Omar Smadi, PhD.		8. Performing Organization Report No.	
9. Performing Organization Name and Address Center for Transportation Research and Education (CTRE) Iowa State University ISU Research Park 2711 S. Loop Drive, Suite 4700 Ames, Iowa 50010		10. Project/Task/Work Unit No.	
		11. Contract (C) or Grant (G) No. (c) 89256 (wo) 3	
12. Sponsoring Organization Name and Address Minnesota Department of Transportation 395 John Ireland Boulevard, Mail Stop 330 St. Paul, Minnesota 55155		13. Type of Report and Period Covered Final Report	
		14. Sponsoring Agency Code	
15. Supplementary Notes http://www.lrrb.org/PDF/200837.pdf			
16. Abstract (Limit: 200 words) This document summarizes the development of a scalable, reliable, and practical process for viewing, querying, understanding, and making consistent, objective, and cost effective decisions regarding pavement marking needs, durability, and quality. The research team developed a Web-based pavement marking management system through the development environment of Microsoft Visual Studio 2005 ASP.NET in conjunction with ESRI's ArcGIS Sever Enterprise 9.2 SP4 functionalities to manage and produce the GIS map resources. The web site hosting itself was done on a Windows based server operating Internet Information Services (IIS). The resulting web based mapping tool provides Mn/DOT staff the ability to map and query pavement marking retroreflectivity information and serves as a significant resource to both district and central office staff in developing short and long-term pavement marking plans.			
17. Document Analysis/Descriptors Pavement Marking Management, Retroreflectivity, Geographic Information System (GIS), Management and Mapping Tools		18. Availability Statement No restrictions. Document available from: National Technical Information Services, Springfield, Virginia 22161	
19. Security Class (this report) Unclassified	20. Security Class (this page) Unclassified	21. No. of Pages 41	22. Price

Developing and Implementing Enhanced Pavement Marking Management Tools for the Minnesota Department of Transportation: Phase I – Mapping Tool

Final Report

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Center for Transportation Research and Education
Iowa State University

September 2008

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Executive Summary

The work described in this document, Phase I - Mapping Tools, is part of an overall project titled "Developing and Implementing Enhanced Pavement Marking Management Tools (PMMT) for the Minnesota DOT". This project developed a scalable, reliable, and practical process for viewing, querying, understanding, and making consistent, objective, and cost effective decisions regarding pavement marking needs, durability, and quality. The tool graphically displays pavement marking retroreflectivity data, collected by either mobile or handheld devices, using a web-based application which resides on Mn/DOT's GIS web server. Phase I – Mapping Tools provides Mn/DOT staff with the ability to map and query pavement marking retroreflectivity information and serves as a significant resource to both district and central office staff in developing short and long-term pavement marking plans.

The research team worked with Mn/DOT staff to retrieve, sort, and analyze various pavement marking data sources to be included within the mapping tool. Data items such as retroreflectivity, location (route and milepost), date, and line type were integrated with geographic location (as established by Mn/DOT staff). A standard format was developed for retroreflectivity and paint data which is compatible with the location component of Mn/DOT's GIS server.

Based upon the developed standard format, a prototype mapping tool, using ArcIMS/ArcServer as a platform, was developed. The prototype tool was demonstrated to the project task force consisting of Mn/DOT Office of Traffic, Security and Operations staff, Central Striping, District staff, and other interested parties. Feedback on functionality, practicality, ease of use, the graphical user interface (GUI), and other features was obtained from the group resulting in minor modifications to the tool.

For the PMMT to become fully operational, the additional steps which need to be completed by Mn/DOT staff were identified. These include establishing standard ORACLE data tables, developing retroreflectivity data flow requirements (central and district office), and determining web server and enterprise related needs.

Once the PMMT becomes fully operational, further enhancements to the PMMT include:

1. Paint Data - Incorporation of paint data from both Central Office and Contract Striping which will give staff the ability to match marking performance with installation information.

2. Standardize Handheld Data Collection - Developing data collection protocols for district staff to use when colleting retroreflectivity information using the handheld devices.

3. Standardize Mobile Data Collection – Identify opportunities to improve the Laserlux data in terms of data quality (less variability), location information (GPS), and incorporation of this information into the PMMT database.

Chapter 1: Introduction

The work described in this document, Phase I - Mapping Tools, is part of an overall project titled "Developing and Implementing Enhanced Pavement Marking Management Tools for the Minnesota DOT". The research focus is to develop a scalable, reliable, and practical process for viewing, querying, understanding, and making consistent, objective, and cost effective decisions regarding pavement marking needs, durability, and quality. Phase I – Mapping Tools will provide the Mn/DOT staff with the ability to map and query pavement marking retroreflectivity information (based on data availability) and will serve as a significant resource to both district and central office staff in developing short and long-term pavement marking plans. Phase I was divided into five tasks as described below.

> *Task 1.1 Data Sources* – This includes working with Mn/DOT staff to retrieve, sort, and analyze the various data sources needed and desired for display in the mapping tool. Data items such as retroreflectivity, location (route and milepost), date, and line type will be integrated with geographic location (as established by Mn/DOT staff). With an established reference system, the pavement marking information and performance will be referenced for inclusion in the GIS database used by the mapping tool.

> *Task 1.2 Other Data* - The research team will explore the availability of other pavement marking data such as the paint application databases and the possibility of making that data part of the GIS mapping tool.

> *Task 2. Prototype Tool* – This task will format the information from Task 1 to the mapping tool (focusing on the referencing component), will develop the data associations and relationships required for GIS based retrieval and display, and will develop the prototype mapping tool using ArcIMS/ArcServer as a platform. The tool (web based) will be developed utilizing tools that MN DOT can support and would not require additional licensing.

> *Task 3. Feedback* – This task will demonstrate the prototype tool to Mn/DOT Office of Traffic, Security and Operations staff and other interested parties. The demonstration will cover the basic functions and capabilities of the tool. Feedback on functionality, practicality, ease of use, the graphical user interface (GUI), and other features will be sought from the group. The information and perspective from this task will be used to finalize the development of the tool, user manual, and actual data queries and other examples to be included within the user manual.

> *Task 4. Training* – This task includes effort to provide a half-day training session on the mapping tool. The training is assumed to be at a Mn/DOT facility which can provide a computer work station for each participant. The training will cover mapping tool functionality, options, and other features and will provide participants the opportunity to use the tool to analyze and query the developed Mn/DOT database.

Task 5.1 Draft Final Report – Project deliverables include a technical memorandum on the project findings, the mapping tool which will be a web-based with a one-year product warranty and a brief user's manual. The technical memorandum will outline future phases of the project to enhance pavement marking decision making and performance. Future phases will discuss data maintenance and updates, potential enhancements to the mapping tool, calibration of mobile retroreflectivity, different material demonstration studies, and other issues deemed important by Mn/DOT staff.

Task 5.2 Final Report – Project final report edited by MN DOT staff.

This final report, along with the software tool, serves as documentation on project findings and tool development.

Chapter 2: Project Findings

Task 1.1 Data Sources

The research team worked with Mn/DOT staff to retrieve, sort, and analyze the various data sources needed and desired for display in the mapping tool. This included retroreflectivity measurement data, GIS format and platform information, and paint information.

Retroreflectivity – Mn/DOT collects pavement marking retroreflectivity with both the hand-held and mobile van equipment.

Mobile Van – Mn/DOT has operated the van for the last 6 years. Seasonal operations typically begin in May and continue through the first snowfall. The coverage includes all state roadways. District requests are completed first then the other state roadways are on an approximately 3 year rotation. The Van relies on floppy disks to transfer the data and there is no GPS unit on-board. The Van collects retroreflective data every 1/10th mile. Figure 2.1 provides an example of the raw Mobile Van data. Figure 2.2 shows the summarized information by roadway segment.

I494 22.6-‹75D01B00.3L0
White Calit   1
Yellow Cali   0.95
DMI Calibr 805.509 pulses/m (245.519 pulses/ft)
Hardware I   101
Software V   4.03
Date   13/05/107
Start Time   23:28
Stop Time   23:30
Start Chair   22.6 mi
End Chaina   20.6 mi
Station Inte 528 f
Lower Valic   50
Upper Valic   75
Rejection T   900
Sample Siz   200
Backgroun   101
Retroreflect   152   38.74
Crack Seal Bad Area Thru a Tow No Line He Dirt on Road
Intersec/Int Turn Lane Bridge Winter Hits Mixed Mater

Chain	Ave	Valid	Inv	Dval	LAve	RAve	Speed	RdAve	Event Code		Stdev	LStdev	RStdev	Hinv	Temp
22.5	106	17	35					0	0		0	55	235	4 WOC00V0	14.89	0
22.4	118	29	23					0	0		0	57	241	3 WOC00V0	26.31	0
22.3	133	40	12					0	0		0	59		3 WOC00V0	26.79	0

Figure 2.1 Raw Mobile Van Retroreflectivity Data

Date	District	Highway Number	Start RP	End RP	Road Name	Line	Material	Year Installed	MCD	Speed Limit	Standard Deviation	Road Surface	Memo	Product Name
5/3/2007	METRO	5	50.7	42.2	MN5-D	LL	T	06X	404	55	235	MIX		CONTRAST TAPE
5/3/2007	METRO	5	42.2	50.7	MN5-I	LL	T	06X	350	55	241	MIX		
5/3/2007	METRO	5	50.7	42.2	MN5-D	LEL	E	06X	110	55	44	MIX	LEL LOOKS LIKE SCRAPED HARD	
5/3/2007	METRO	5	42.2	50.7	MN5-I	LEL	E	06X	113	55	46	MIX	LEL LOOKS LIKE SCRAPED HARD	
5/4/2007	METRO	280	1.5	0	MN280-D	LEL	E	06X	95	55	30	CON		
5/8/2007	METRO	280	0	1.5	MN280-I	LEL	PL	06X	111	55	37	CON		
5/8/2007	METRO	280	1.5	0	MN280-D	LL	T	06X	449	55	251	CON		CONTRAST TAPE
5/8/2007	METRO	280	0	1.5	MN280-I	LL	T	06X	496	55	237	CON		CONTRAST TAPE

Figure 2.2 Summarized Mobile Van Retroreflectivity Data

Hand Held – Mn/DOT recently purchased 3 additional hand held units which will allow each district to have one machine. These units are used to verify marking retroreflectivity where mobile van information is not available or as part of contractor applied inspections. Figure 2.3 provides an example of the form used to summarize hand held information.

Minnesota Department of Transportation
Hand Held Pavement Marking
Retroreflective Data Colletion Form

Instp. Date	Markings Installed		HWY	Begin Ref. Pnt	End Ref. Pnt	SP Number	Material Type	LINE				Average (each 1/10 mile)	Subj. Rating	Color
	Month	Year						LEL	CL	LL	REL			
4/26/2007		2003	MN 68	96	99.01		PL				X	290	4	White
				97			PL				X	259	3	White
				98			PL				X	248	3	White
				99			PL				X	75	3	White
				99.01			PL				X		No line	

Note: Sampling shall conform to process outlined in the special provisions for each contracted installation. This requires a minimum of 25 individual readings per 1/10 mile interval.

Line :
LEL = Left Edge Line (Yellow)
CL = Center Line (Yellow)
LL = Lane Line (White)
REL = Right Edge Line (White)

Color: A = Acceptable (color meets specification)

Material Type:
T = Tape
E = Epoxy
PL = Paint Latex
TH = Thermoplastic

Subj. Rating:
5 = Outstanding
4 = Very good (markings in tack)
3 = Good (some damage to line)
2 = Bad (lots of damage to line)
1 = Failure (needs repair)

Figure 2.3 Form Used for Collecting Hand Held Pavement Marking Retroreflectivity Data

Database – Currently both the Mobile Van and Hand Held retroreflectivity data are summarized and stored on a project by project basis (there is no established central database for this information). The pavement marking management tool developed as part of this research effort will establish a database for both the Mobile Van and Handheld data. These data will then be accessible through a web based platform. Should Mn/DOT desire to integrate historic (past) retroreflectivity data into the new pavement marking management tool the research team will provide formatting guidelines to Mn/DOT staff.

Data Structure – Mn/DOT provided CTRE with their recommended format for retroreflectivity data storage (shown in Figure 2.4). The pavement marking management tool will utilize this recommended format as a basis for building the interface. CTRE will develop a similar format for paint data (trucks equipped with Skip Line controllers) using this same recommended location format.

Date_Measured	Const_District_Code	Road_Number	Directional_Roadway_Name	TIS_CODE	FROM_REF_POST_OFFSET	TO_REF_POST_OFFSET
6/21/2006	1	35E	I35E-I or Anoka CSAH-4-I	0401000035	000+00.220	415+01.987
DATE	VARCHAR2(2)	VARCHAR2(4)	VARCHAR2 (30 Byte)	VARCHAR2 (11 Byte)	VARCHAR2 (10 Byte)	VARCHAR2 (10 Byte)

Line_Code	Marking_Material_Code	Year Installed	MCD	Std_Dev	Speed_Limit	AADT	Presence_Code	Roadway_Material_Code
REL	PL	2006	0160		55	35000		
VARCHAR2 (3 Byte)	VARCHAR2 (6 Byte)	NUMBER (4)	VARCHAR2 (5 Byte)		NUMBER(2)	NUMBER (8)		

Contrast_Code	Product_Name	Longititude_DD	Latitude_DD	Comments
				Any text string
				VARCHAR2 (250 Byte)

Figure 2.4 Mn/DOT Recommended Data Structure Format

Task 1.2 Other Data

Paint Information – As part of the project the research team is going to assess the feasibility of incorporating other data (such as paint information) into the new tool. Pavement markings are currently applied by both Mn/DOT crews and by Contactors. All paint activities are reported manually in spreadsheet format. Additionally, two Mn/DOT trucks are equipped with Skip Line controllers which automatically record and format paint data along with location.

Spreadsheet Format – Figure 2.5 shows a portion of the spreadsheet format which provides date, location, company, paint material, and quantity information. In future tasks, the research team will assess the feasibility of including this paint data into the new tool.

District	Date Striped	Roadway	SP	Start R.P	End R.P.	County	City	Striper Foreman	Striper Company	Striper ID	Material Type	Material Stripe	Manufacturer Stripe	Material Bead	Manufacturer Bead
M	5/11/2007	TH96	8211-33			Washington	Stillwater	Josh Thompson	United Rentals	831974	Epoxy	LS60	Epoplex		Potters
M	5/9/2007	I494	2785-353			Hennepin	Bloomington	Josh Thompson	United Rentals	831974	Epoxy	LS60	Epoplex		Potters
M	5/8/2007	CSAH5	7008-52			Scott	Belle Plaine	Josh Thompson	United Rentals	831974	Epoxy	LS60	Epoplex	M247-1-MP	Potters
3	5/25/2007		86-605-23			Wright	Annandale	Josh Thompson	United Rentals	831974	Epoxy		Epoplex		Potters

White Bead (gal)	Yellow Bead (gal)	Total Beads (lb)	4" Broken White (ft)	4" Dotted White (ft)	4" Solid White (ft)	4" Broken Yellow (ft)	4" Double Solid Yellow (ft)	4" Solid Yellow (ft)	6" Solid White (ft)	8" Broken White (ft)	8" Dotted White (ft)	8" Solid White (ft)	8" Solid Yellow (ft)	12" Broken White (ft)	12" Solid White (ft)
18	9	810			4018	380	96	1451							
42	35	2300	3040		6960			7761	42						
54	12	2000	930		7326	40	592	724							
52	25	2500			8908	1040		5009							

Figure 2.5 Paint Spreadsheet Format

Skip Line Format - The research team visited the Metro paint crew and collected a sample of skip line paint data from the 2006 and 2007 seasons. Since some of the data included GPS readings (latitude, longitude) the data were plotted for review as shown in Figure 2.6.
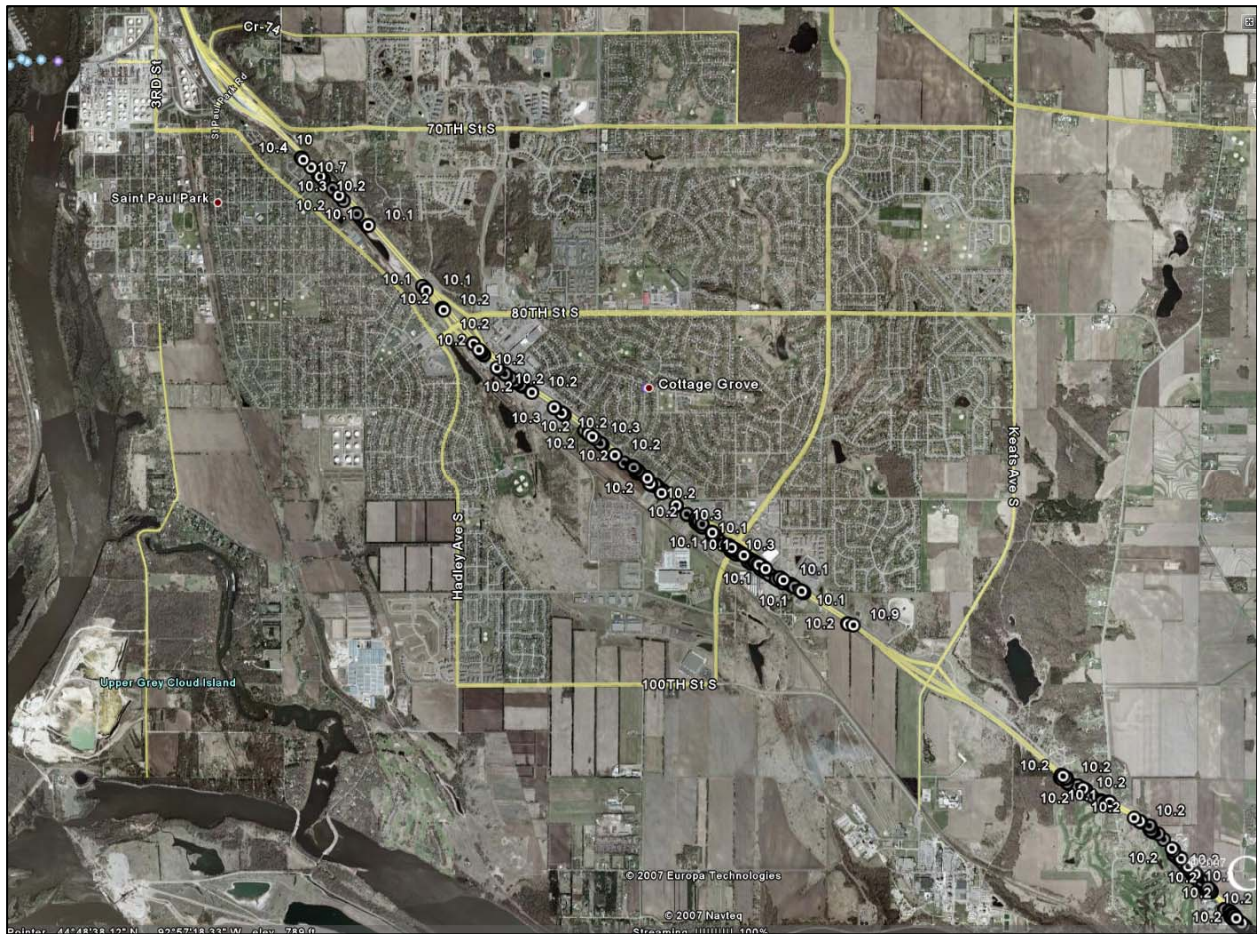

Figure 2.6 Example Plot From Skip Line Controller Data (Plotted by Truck Speed)

Task 2.0 Prototype Tool

The research team worked with Mn/DOT staff to develop the data associations and relationships required for GIS based retrieval and display, and developed the prototype mapping tool using ArcIMS/ArcServer as a platform.

Prototype Tool – The software design was based on the need to have a web-based graphical information system (GIS) for pavement marking evaluation that would allow Mn/DOT personnel to access specific information concerning pavement marking history without having to install additional client-side tools. These specifications directed development to use supported web authoring and database warehousing tools supported by Mn/DOT.

  The development environment used was Microsoft Visual Studio 2005 ASP.NET in conjunction with ESRI's ArcGIS Sever Enterprise 9.2 SP4 functionalities to manage and produce the GIS map resources. The web site hosting itself is done on a Windows based server operating Internet Information Services (IIS).   Web implementation was explicitly done by revising an ArcGIS Server Web Mapping Application template in Visual Studio 2005 using both C# and VB.NET programming languages.

The initial data used for testing and development was created in ArcGIS using shapefiles retrieved through the Mn/DOT Basemap website. An ESRI ArcMap Document, also known as a MXD file, was produced from these data and the initial GIS resources defined in ArcGIS Server point to this MXD file residing locally on the server. In the future a Mn/DOT enterprise database will replace the MXD file based GIS resource defined in ArcGIS Server and all map data and layer references will point to and be maintained on this enterprise level repository.

The prototype tool was presented to Mn/DOT staff for review and comment. Based upon feedback from these reviews and testing, the tool was finalized. Figures 2.7 through 2.12 below provide screenshots of the final Pavement Marking Management Tool (PMMT) developed.

Figure 2.7 shows the initial screen for the web based PMMT application. This will be accessed through the Mn/DOT web site using their GIS tools. Five menu items are displayed on the left side of the frame (Query, Results, Map Contents, Navigation, Overview, and Chart Query Attributes). Within the top menu bar, several standard GIS functions are available (Zoom-in/out, Pan, Zoom Extents, Info, etc.) and specific to the PMMT application an additional function is provided (Retroreflectivity Chart). The map shows the entire state with county borders, all state routes, and a map scale. Routes having retroreflectivity data are highlighted by color (based upon retroreflectivity values).
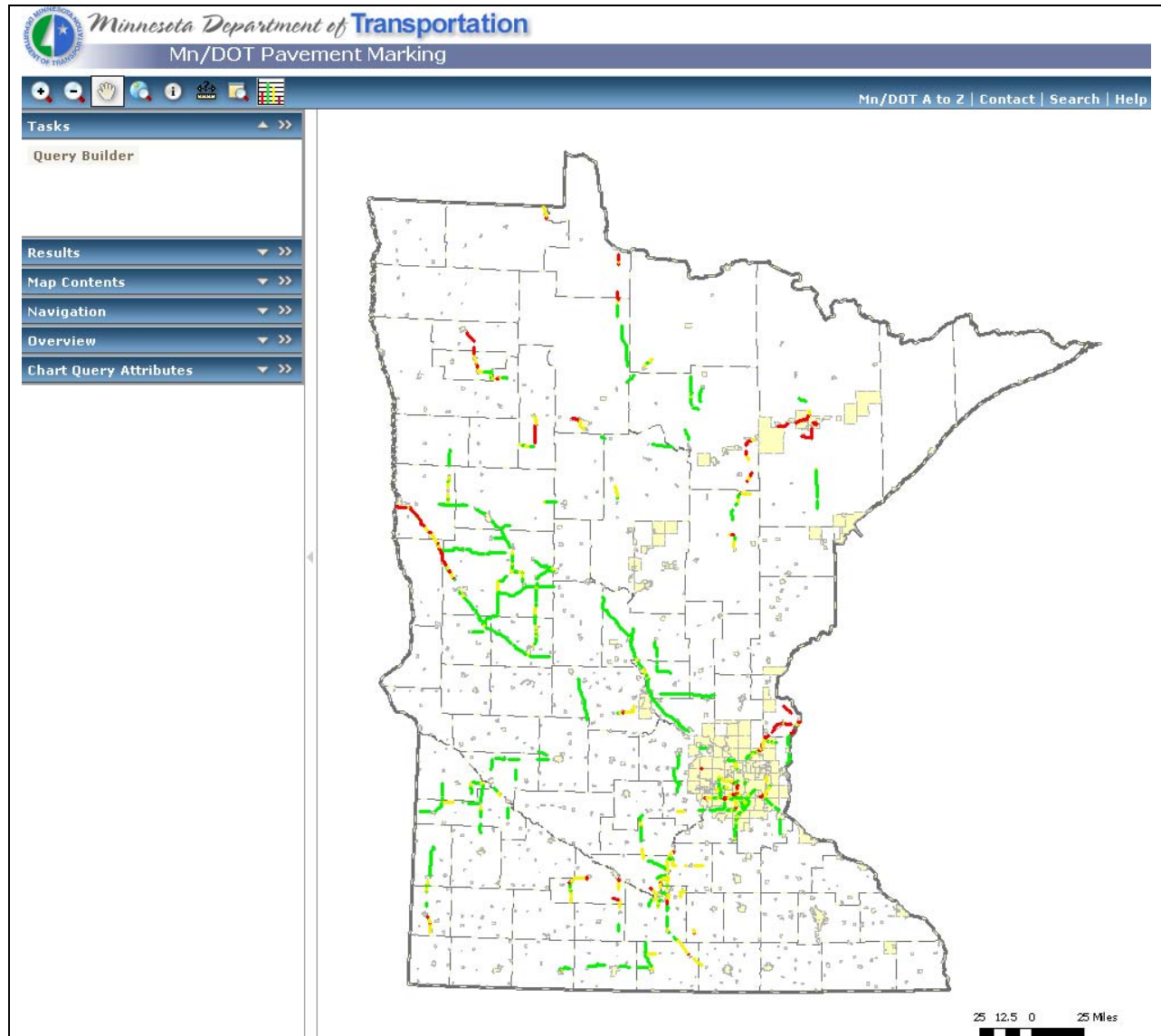

Figure 2.7 Initial Screen

Figure 2.8 shows a zoomed in view. The left frame provides the Chart Query Attributes which in this example are defined by:

Map Layer – White Lines *(user can select either white or yellow)*
Year – 2007 *(range of years based upon available data)*
Direction – All *(user can select all, increasing, or decreasing)*
Line Type – Right Edge Line *(user can select from a variety of types)*

The Chart Query Attribute window also displays a legend which defines retroreflectivity levels. As shown for white lines with green > 145 mcd, yellow between 100 and 145 mcd, and red being < 100 mcd. This also provides an estimate of the number of miles for each level. For example, the number of lane miles highlighted in red (retroreflectivity < 100 mcd) is equal to 255 miles.

Figure 2.8 Zoomed-In View with Legend Information

Figure 2.9 demonstrates the results when using the Info tool to show retroreflectivity data for a specific highway segment. The Results window shows available data from the PMMT database including location, pavement marking type, installation information, and retroreflectivity value measured. Data from the table can be exported into other programs such as Excel.

Additional information regarding state roads, rivers, trails, etc. can also be accessed through the Results window.
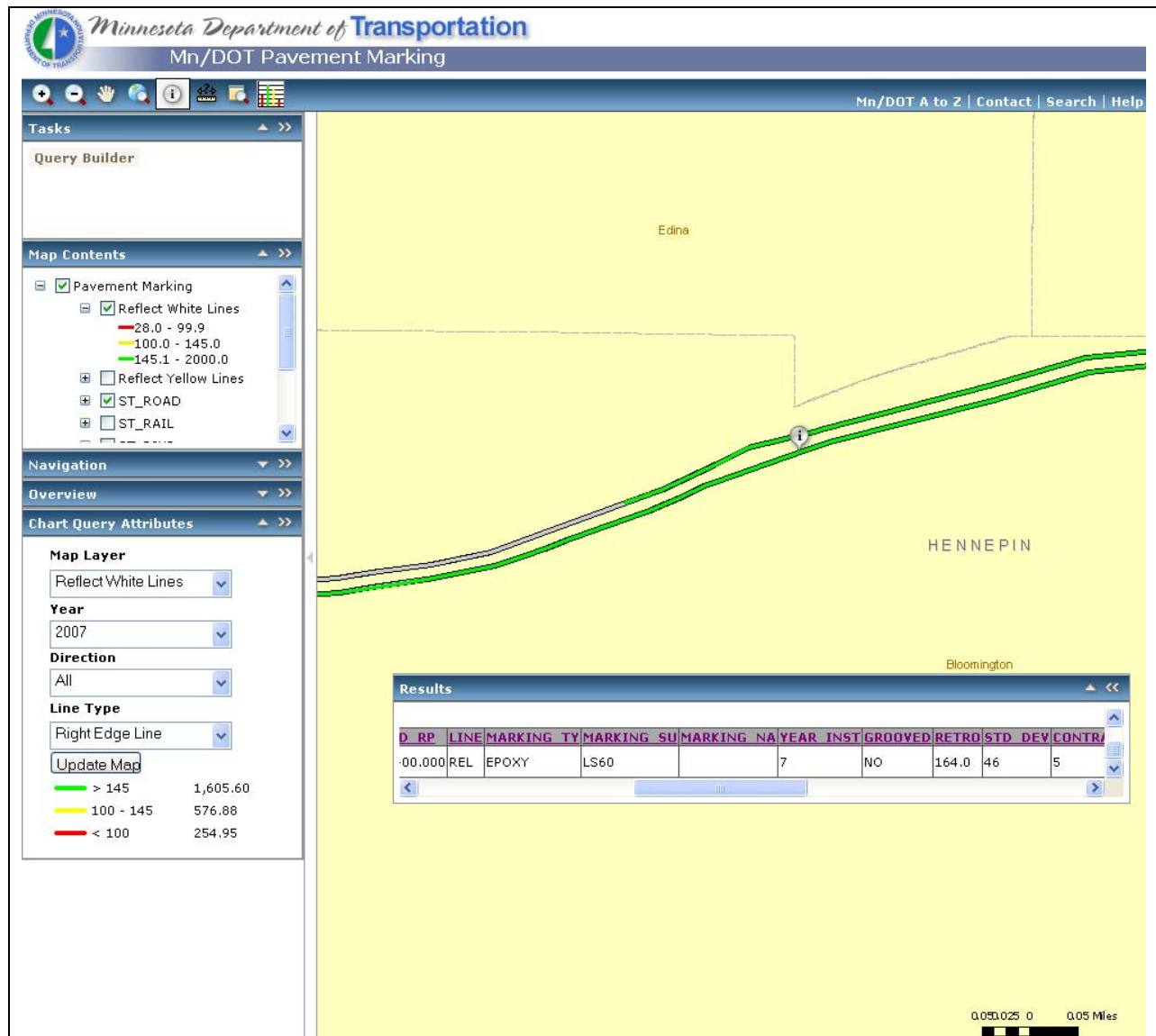

Figure 2.9 Info Tool Results

Figure 2.10 demonstrates the Retroreflectivity Status chart which is produced using the charting button on the upper menu bar. The table shows retroreflectivity data in a tabular and graphic format (using the same retroreflectivity color thresholds).
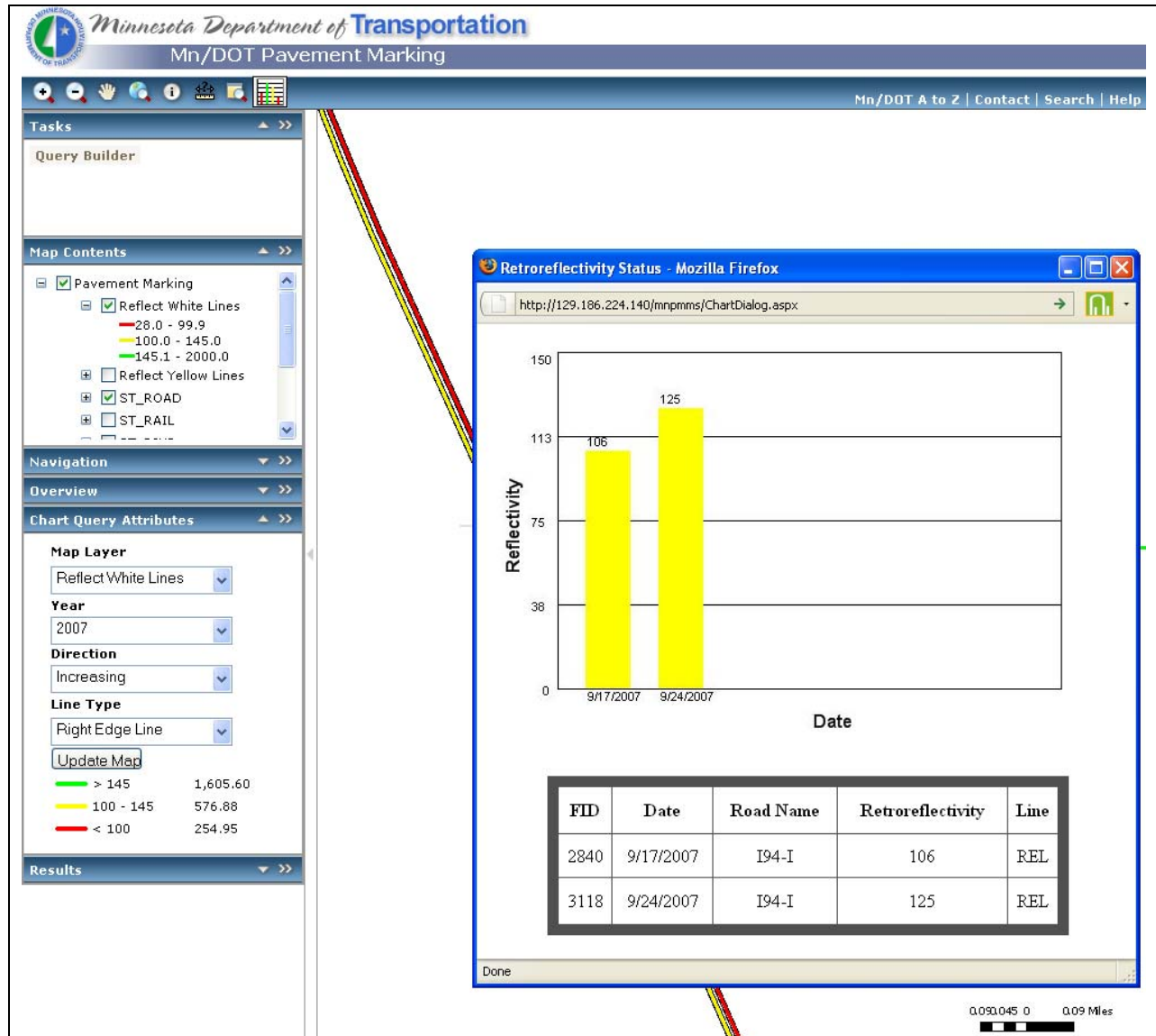

Figure 2.10 Retroreflectivity Status Window

Figure 2.11 demonstrates the Query Builder functionality where the user can identify the records of interest from any of the Map Content Layers. The example above is a query for all white lines on Interstate 94 in the decreasing direction (I-94-D) having a retroreflectivity value equal to or greater than 200 mcd. The results can be exported to other programs such as Excel.

Figure 2.11 Query Builder and Results

Figure 2.12 shows the items defined under the Help screen. These standard Mn/DOT web page menu items have been modified for the PMMT functions. The major help items related to the PMMT are included within the Appendix.
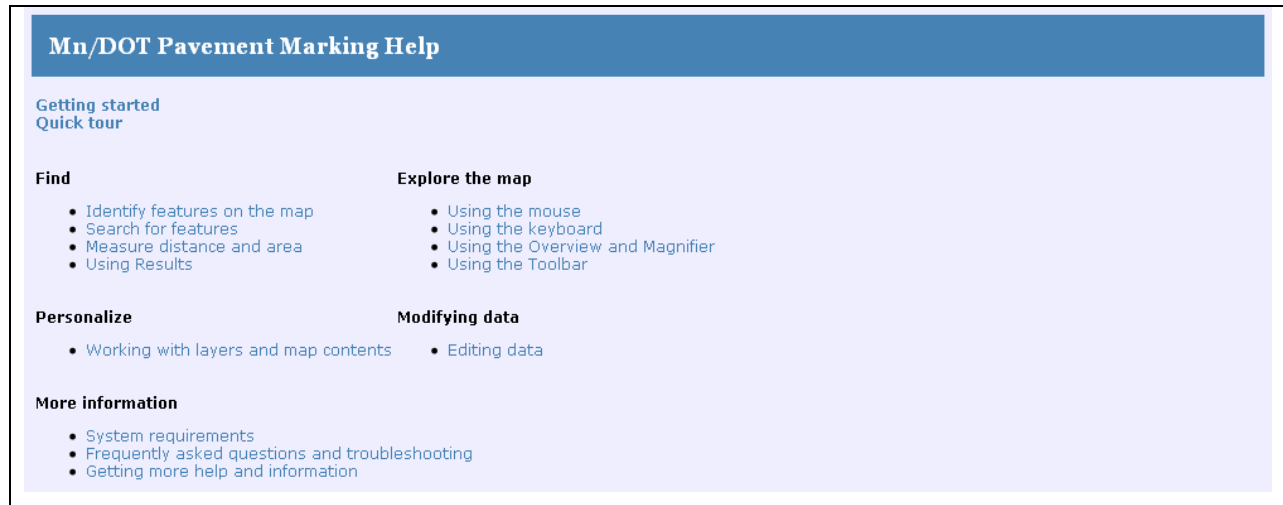

Mn/DOT Pavement Marking Help

Getting started
Quick tour

Find
- Identify features on the map
- Search for features
- Measure distance and area
- Using Results

Explore the map
- Using the mouse
- Using the keyboard
- Using the Overview and Magnifier
- Using the Toolbar

Personalize
- Working with layers and map contents

Modifying data
- Editing data

More information
- System requirements
- Frequently asked questions and troubleshooting
- Getting more help and information

Figure 2.12 Help Menu Items

Task 3.0 Feedback

The prototype tool (Task 2.0) was presented to Mn/DOT staff (April 16th, 2008) for comment and input on tool format, features, and integration. The group identified future enhancements to the tool and discussed the need to begin other work, not part of this contract, in automating the process for data (from the field to the database) viewed using the tool.

Task 4.0 Training

The prototype tool (Task 2.0) was presented to a larger Mn/DOT staff group for both training and feedback purposes (May 7th, 2008). The group discussed use of the tool at multiple staff levels and implementation of the tool within Mn/DOT. Based upon the positive feedback from these discussions the tool was considered fully completed.

Next Steps

This report covered the effort under Phase I – Mapping Tools which provided Mn/DOT staff with the ability to map and query pavement marking retroreflectivity information. Future efforts are defined by two categories.

Mn/DOT Next Steps:

For the PMMT to become operational, the following steps need to be completed.

1. Build ORACLE Tables (this will be completed by CO – EGIS based upon the standard format and naming convention established for the PMMT.

2. Develop retroreflectivity data flow requirements.

    a. Data Sources:

        i. Laserlux data from central office (does not currently include GPS)

        ii. Handheld data from districts (some of this will not have GPS)

    b. Data Formatting – putting the above data within the standard PMMT format for location, pavement marking and installation information. This will be completed by CO-OTSO staff.

    c. Data Submittal – Development of the "handshake" for data transfer from CO-OTSO to the web server (CO-EGIS).

    d. Location Formatting – CO-EGIS will use the Route Location Converter (RLC) to convert location information into the Mn/DOT GIS web server format.

3. Implementation – Determine web server needs, number of users, and other features/business rules to support access to the PMMT.

Future Research:

Further enhancements to the PMMT will include:

1. Paint Data - Incorporation of paint data from both CO and Contract Striping which will give staff the ability to match marking performance with installation information.

2. Standardize Handheld Data Collection - Developing data collection protocols for district staff to use when colleting retroreflectivity information using the handheld devices.

3. Standardize Mobile Data Collection – Identify opportunities to improve the Laserlux data in terms of data quality (less variability), location information (GPS), and incorporation of this information into the PMMT database.

Appendix A: Help Menu Items

Help Menu Screen

Mn/DOT Pavement Marking Help

Getting started
Quick tour

Find

- Identify features on the map
- Search for features
- Measure distance and area
- Using Results

Explore the map

- Using the mouse
- Using the keyboard
- Using the Overview and Magnifier
- Using the Toolbar

Personalize

- Working with layers and map contents

Modifying data

- Editing data

More information

- System requirements
- Frequently asked questions and troubleshooting
- Getting more help and information

Find

Identify features on the map

If you want to know about a feature on the map, you can get more information about it.

To identify a feature

1. In the Toolbar, click the Identify button. ⓘ . The button changes to a pressed appearance ⓘ . (If no Identify button is visible, then the Identify function is not available in this application.)
2. Click on the feature you want to identify. An identify icon ⓘ will be placed on the map at the location clicked. After a few moments, an entry for the location should appear in the **Results** section of the Console. The results will display the active layers in a table format.
3. Expand the location by clicking on the double arrows to undock the Result console. This moves the Result console out of main console and allows you to expand it by stretching the edges.

4. See Using Results for more on using the Results window.

Find

Search for features

The Web mapping application may allow you to search and find features of interest to you. The searching tools that are available will depend on how your application is configured.

Search, find and query tasks

The website may enable you to search one or more layers for text that you enter, to find an address, or to search for places using a Web database. The administrator of the website determines the types of searches available.

For example, the query may ask you to enter a value for the name of a city. A more complex query may ask for two or more values, and search using these values. For example, a query may ask for a city name and country name. The query might use the values you enter to look for a city with the name and that is in the country you entered.

1. The search or find task can be displayed from the Tasks list in the Console. Click the down-arrow to expand the Tasks list. If an option to find features is not in the list of Tasks, it may not be available in this web application. Click on the task item to open it.
2. The search or find task opens in a new element window within the mapping application. Some examples of possible tasks are shown below. This element window may be moved, collapsed, and closed. See Getting Started for details on using moveable windows.

Query Builder ▲ ⊗

Select a layer:

Reflect White Lines ▾

Double click to select the column:

ROAD_NAME
TIS_CODE
START_RP
END_RP
LINE
MARKING_TY
MARKING_SU

=	<>	LIKE
>	>=	AND
<	<=	OR
%	_	Is	()	NOT

'LL'
'REL'
'1LL'
'2LL'

Values   **First values:** 10

Query:

"LINE" = 'REL'

Clear **Validate** **Run**

There were 2487 results returned by the query.

3. Select features you want to search for in the drop-down box of the Query Builder window. The task may require entering all of the value, or part of the value. The a hint about what you need to enter to find features is given by clicking the Values button for the selected column.
4. Click **Run** to start the search.
5. The Results section expands in the Console to display results of the search (if it does not expand automatically, click the down-arrow in the Results section to display it). The text searched for displays in the results item.
6. If features are found, a table appears next to the results item. The example below shows one possible result of a search using Query Builder.

Results ▲ ≪

ST_BORD
Select all ,Unselect all, Zoom to all, Export to Excel

		Selected	FID	AREA	PERIMETER	STATE_	STATE_ID	
🔍	✋	☐	0	218504303057.843	3152873.74341	2	1	2

ST_CNTY
Select all ,Unselect all, Zoom to all, Export to Excel

		Selected	FID	AREA	PERIMETER	COUNTY_	COUNTY_ID
🔍	✋	☐	10	2666178346.73383	257069.02414	12	12

Reflect White Lines
Select all ,Unselect all, Zoom to all, Export to Excel

		Selected	FID	DATE_MEASU	DIST	ROAD_NUMBE	ROAD_NAME	TIS_CODE
🔍	✋	☐	708	39271.79167	D2	MN92	MN92-I	0
🔍	✋	☐	709	39271.79167	D2	MN92	MN92-I	0

7. The results display one or more layers where features are found. For more details on using the Results window, see UsingResults.htm.

A-5

Find

Measure distance and area

You can use the Measure tool to measure distances and areas. To use one of these tools, open the Measure dialog and then use the appropriate tool.

- To open the Measure dialog
- To measure a line
- To measure a polygon
- To find X,Y coordinates

To open the Measure dialog

1. In the Toolbar, click the **Measure** icon ⊞. If the Measure icon is not visible, then the Measure tool is not available for this application.
2. This opens the Measure element dialog.
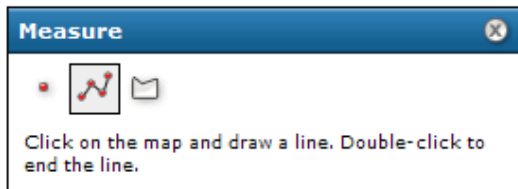
See the instructions below depending on whether you want to measure a line or to measure area. You can also use the point option to find the x,y coordinates of a location on the map.
3. After measuring, you can close the Measure dialog by clicking on its Close icon in the upper right, or by clicking any other tool in the Tools element (Zoom in, Zoom out, Pan, etc.)

To measure a line

1. In the Measure dialog, click the Line icon ⟋. The Line icon is outlined to show it is the active type.
2. Move the cursor to the first point of the line you want to measure, and click the left mouse button. As you move the mouse from this location, you will see the line stretching to the current position. The measure dialog will also begin to display distance.
3. Move the cursor to the second point of the line. If you only want to measure one straight-line segment, double-click at this location. Otherwise click once with the left mouse button.
4. If measuring a line with multiple segments (polyline), continue clicking at vertices to add segments. The length of the previous segment is shown in the **Segment** display in the Measure dialog. The **Total Length** displays the sum of segments added so far.

Measure ⊗

Segment: 184.56 Miles
Total Length: 429.332 | Miles ▾ |
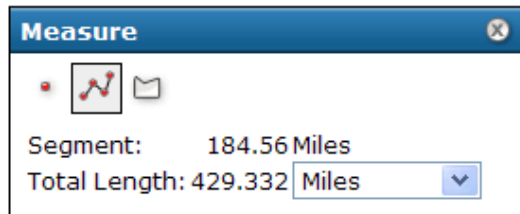
5. At any point during the measuring, you can change the units for measuring distance by using the drop-down list in the measure dialog. You can also change units after completing the measurement.
6. At the last vertex, double-click to end the line. The **Total Length** displays the length of the line, including all segments if multiple ones were drawn. You can change the units drop-down list to see the same line expressed with different units.
7. To draw a new line, simply click on the map to start the new line. This erases the previous line.
8. To erase the line from the map, click any of the measure type icons in the Measure dialog. If you click any other tool in the Tools element, this will close the Measure dialog, and any line or polygon will also be erased.

To measure area

1. In the Measure dialog, click the Polygon icon ⬡ . The Polygon icon is outlined to show it is the active type, and the dialog changes to show information on measuring polygons.
2. Set the units for measuring distance. For polygons, the measured area displays in the Area Units, and the perimeter displays in the Distance Units.
3. Click the left mouse button at the first point in the polygon. As you move the mouse from this location, you will see the line stretching to the current position.
4. Click the second point of the polygon. The first segment draws, and the polygon now stretches to the current position from the last point as well as to the initial point. When you click the third point, the measure dialog displays the perimeter and area of the polygon based on the vertices added. The total is updated as you add more vertices.

Measure ⊗

Perimeter: 97.508 | Miles ▾ |
Area: 360.403 | Sq_Miles ▾ |
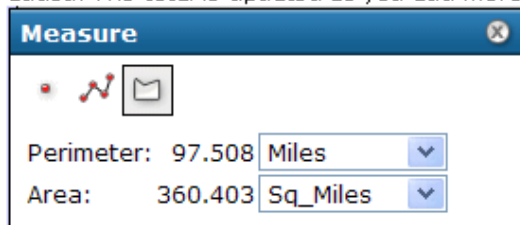
5. Continue adding points (vertices) of the polygon. New vertices add segments connecting to the previous vertex.
6. At the last vertex in the polygon, double-click the mouse. You do not need to click at the original point again. Read the Area and Perimeter from the Measure dialog. You can change the Distance Units to see the same polygon expressed with different units.
7. To draw a new polygon, simply click on the map to start the new polygon. This erases the previous polygon.
8. To erase the polygon from the map, click any of the measure type icons in the Measure dialog. If you click any other tool in the Tools element, this will close the Measure dialog, and any line or polygon will also be erased.

To find X,Y coordinates

The Measure dialog also allows finding the X,Y coordinates at a point where you click on the map.

1. In the Measure dialog, click on the point symbol   .
2. Click on the map. The coordinates at the location you clicked will be displayed in the Measure dialog.
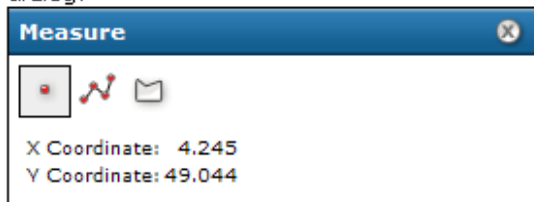
The units and projection (spatial reference) of the coordinates will be based on the map used in the web application.
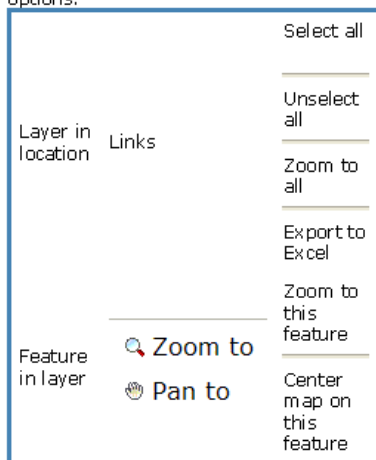
Find

Using Results

The Results panel displays the output from using the Identify tool, from a search using Find, or from other operations that output information.

To open the Results window

- Results panel expands automatically after using Find or the Identify tool.
- You can also expand Results by clicking its down-arrow in the Console. If you open Results before doing any Find or Identify, the Results panel will be blank.
- You can collapse the Results panel to its title bar by clicking the collapse icon.
- You can resize the height of Results by clicking and dragging the bottom of the the Results section.
- If Results is re-opened, previous results will still be visible, along with any new ones just found.

Navigating the Results window

- After doing a Query or Identify, one or more **Location** or **Find** items will be added to Results.
- If you do another Find or Identify, the new results items are added to the top of the list in Results. Previous Locations remain in the list.
- When you expand a Location or Find item, you will see one or more **layer** names. Expand a layer to see the features found within that layer at the location. This displays attribute **field names and values** for the feature.
- Right-click on an item in Results for options:

Selecting with the Results window

Features may be selected (highlighted) by clicking the check-box next to feature names. This causes the feature(s) to be highlighted on the map. By default the highlighting has a cyan (blue-green) outline or fill, but this may be set to a different color by the creator of the map service.

Zooming to Features

You can zoom to one or more features in the Results window. See the table above for illustrations of the right-click menus.

- To zoom to a single feature, click the feature's Zoom icon.
- To zoom to all the features in a layer, click the "Zoom to all" link of the features.
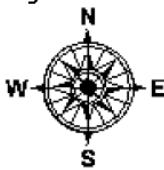
Export Features to Excel

You can export table features of a selected layer in the Results window to an Excel spreadsheet.

- To export a table to Excel, click the "Export to Excel" link located above the desired table.
- A new window will be generated and a File Download prompt will be displayed requesting you to Open, Save, or Cancel the spreadsheet export.
- Open will immediately generate the Excel spreasheet and display it in a new browser window.
- Save will allow you to export the Excel spreadsheet to a local drive location that you specific.

Explore the map

Using the mouse

You can use a mouse or pointing device to move around and explore the map.
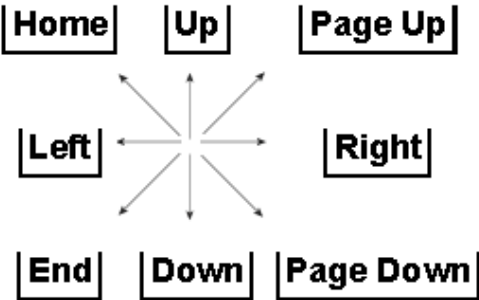
Map action	Use this tool...	...and do this
	Navigation element (image may vary)	Display the Navigation image, if necessary by clicking its down-arrow in the Console. Click and hold on the Navigation image in the direction you want to re-center the map. You can click on any spot on the Navigation image to fine-tune the movement.
Re-center the map	**Pan tool**	Click on the Pan tool in the Toolbar, then click and drag the map to move it.
	Overview map	In the Console, make the **Overview** map visible. The red rectangle shows the current map extent. Click inside this rectangle and drag to move the main map's extent.
	Mouse wheel	Scroll the mouse wheel forward or up to zoom in. Each wheel click will zoom the map by about 50 percent in width and height.
Zoom in	**Shift+Left mouse**	Hold the Shift key down, then hold the left mouse button down and drag to draw a rectangle. The map will zoom in to the area of the rectangle.
	Fixed zoom in	If available, click on the fixed-zoom-in icon in the Toolbar. The map will zoom in on the center of the map.
	Zoom in tool	Click on the zoom-in tool in the Toolbar, then • Click once on the map: the map will zoom in and

		recenter the map where you click; **OR** • Click and drag to draw a rectangle on the map: the map will zoom in to the area of the rectangle.
	Mouse wheel 	Scroll the mouse wheel backward or down to zoom out. Each wheel click will zoom the map by about 50 percent in width and height.
Zoom out	Fixed zoom out 	If available, click on the fixed-zoom-out icon in the Toolbar. The map will zoom out from the center of the map.
	Zoom out tool 	Click on the zoom-out tool in the Toolbar, then • Click once on the map: the map will zoom out and recenter the map where you click; **OR** • Click and drag to draw a rectangle on the map: the map will zoom out so that the current map area will fit into the rectangle drawn. The smaller the rectangle you draw, the more the map will zoom out.
Zoom out to full map	Zoom full extent 	Click on the full extent image in the Toolbar. The map will zoom all the way out to the full map extent.
Identify features	Ctrl + Left mouse 	Hold the Ctrl key down, then click with the left mouse button on a location. Features at the location will be found a shown in the Results window.

Explore the map

Using the keyboard

You can use keyboard to move around and explore the map.

Map action	Keyboard shortcut	Description
Zoom in	**Shift** + **+**	Each click of the plus key (on numeric keypad only) zooms in the map by a fixed amount. Hold the Shift key down and press the Plus key.
Zoom out	**Shift** + **-**	Each click of the minus key (on numeric keypad only) zooms out by a fixed amount. Hold the Shift key down and press the Minus key.
Recenter (pan) the map	**Home** **Up** **Page Up** **Left** **Right** **End** **Down** **Page Down**	These keys move the map a small amount with each click. Arrow keys move vertically or horizontally. Home/End/PageUp/PageDown move diagonally. To use these keys on a numeric keypad, turn off the number lock (Num Lock key).

Explore the map

## Using the Overview and Magnifier

Overview

The Overview window displays a small map with a larger extent than the current map. The current map's extent is shown in this window with a red rectangle.

- Display the Overview window by clicking its down-arrow in the Console.
- The map can be re-centered by moving the red extent rectangle. Click and drag on the red rectangle to re-center the map.
- As you zoom the map in or out, the Overview map's extent changes so it shows an area somewhat larger than the main map.
- The Overview map may look different from the main map. Layers may be visible at different map scales (zoom levels). Also, if the website uses multiple map services, only one will display in the Overview map.

Magnifier

The Magnifier window allows a close-up view of a small portion of the main map.
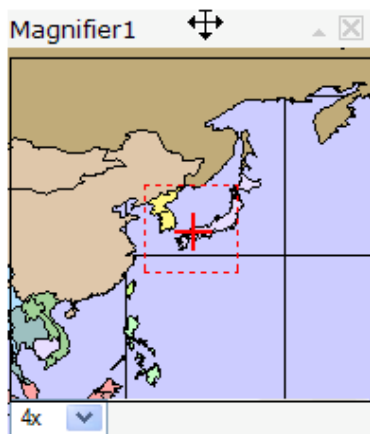
Magnifier moving to new location | Magnifier displaying zoomed view

- To display the Magnifier window, click the Magnifier icon ⊡ on the Toolbar.
- The Magnifier window can be moved, collapsed and closed as desired. See Getting Started for details.
- To magnify an area of the map, move the Magnifier window over the area by dragging on its title bar. A small red rectangle shows the area that will be magnified. Once you drop the Magnifier on a location, a zoomed-in view of the area will display within the Magnifier window.
- The amount of magnification can be changed with the drop-down list in the lower left of the Magnifier window.

If the website uses multiple map services, only one of them will display in the Magnifier window. The administrator can set the map service to be used.

Explore the map

Using the Toolbar

The toolbar allows you to interact with the map by clicking on the map with a tool. For example, if you click in the toolbar on the Zoom In tool, then click on the map, the map will zoom in around where you click.

You can also interact with the map using the keyboard. Also see Using the mouse for tips on using the mouse to interact with the map.

To use a tool

Note: Some tools do an action immediately. These include the Full-extent tool and the Magnifier tool.

- In the toolbar, click on the tool you want to use.
- Move the cursor over the map. The cursor may change to indicate the tool you are using.
- Click on the map with the left mouse button. *Note:* Some tools work by depressing the mouse and dragging the cursor to draw a rectangle, line or polygon, then releasing the mouse button.
- The results depend on the tool. The map appearance may change, such as zooming in or out. Or the results may appear in the Console's Results section, such as with the Identify tool.

Tools

Tools in your website depend on the purpose and use of the application. Some or all of these may be available:

Name	Icon	Description
Zoom in	🔍+	**Click and drag a rectangle**: Click and hold the left mouse button down on the map at one corner of the rectangle to zoom in to. Drag the mouse to the other corner of the rectangle, and release the mouse button. The map will zoom in to the area of the rectangle.
Zoom out	🔍−	**Click and drag a rectangle**: the map will zoom out so that the current map area will fit into the rectangle drawn. The smaller the rectangle you draw, the more the map will zoom out.
Pan (recenter)	✋	**Click and drag the map**: Click and hold the left mouse button on the map, and drag the map. The map will be recentered, with the location dragged at the location you dropped it.
Full extent	🔍	**Full extent**: Immediately zooms the map out to the area of all features and layers. The active tool does not change.
Identify	ⓘ	**Click to identify**: Click with the left mouse button on the map. A small icon is added to the map and the Location is added to the section in the Console. See Results for how to use the identification information.

Measure		**Measure distance or area**: See Measuring for usage.
Magnifier		**Magnify a section of the map**: See Magnifier for usage.
Chart		**Chart pavement marking retroreflectivity**: See Charting for usage.

Personalize

Working with layers and map contents

A mapping application can use one or more content sources. Each content item corresponds to a service, such as an ArcGIS Server service or ArcIMS service. Each source contains one or more map layers. A map layer is a type of data shown on the map, such as roads, cities or a satellite image.

If the mapping application allows it, you can view the list of the contents of the map, turn on and off layers, and examine the symbols for layers.

To examine the map contents:

- In the Console, display the **Map Contents** item, if necessary, by clicking the down arrow for Contents ▼ . If Contents is not present, then this mapping application does not allow viewing the contents list.
- When Map Contents opens, only the top-level content items are visible. Your content item(s) will probably differ from this graphic.

Map Contents ▲

⊞ ☑ World

- Click the plus button ⊞ next to a content item to display the **layers** within it.
- The **check-box** next to the layer indicates whether the layer is currently turned on.
- If enabled, you can click the check-box next to the layer name to **turn the layer on or off**. The map automatically redraws to reflect the changes in layer visibility.
- Some layers may not be visible at the current map scale (zoom level). These layers are called **scale dependent**. You may need to zoom the map in or out to see a particular layer displayed, even if its check-box is checked to draw.

- If layers have a plus button ⊞ next to the name, you can expand the layer to display a **legend** for the layer. The legend may display a single symbol or multiple symbols for the layer.

Map Contents ▲

- ☑ World
  - ☑ Cities
    - • Less than 4723921
    - ● 4723921 - 944794:
    - ■ 9447941 - 141719(
    - ■ 14171961 - 18895!
    - ■ 18895981 - 236200
  - ☑ Rivers
  - ☑ Lakes
    - ■
  - ☐ 5 Degree Grid
  - ☐ World Image
  - ☑ Countries
  - ☑ 30 Degree Grid