Integrated Modeling for Road Conditions Prediction: System User Guide

October 21, 2022

Final

U.S. Department of Transportation
Federal Highway Administration

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or “metric ton”)	Mg (or “t”)
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or “t”)	megagrams (or “metric ton”)	1.103	short tons (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ABBREVIATIONS

ADCIRC	Advanced Circulation model for oceanic, coastal, and estuarine waters
AHPS	Advanced Hydrologic Prediction Service
ASOS	Automated Surface Observing System
CAP	Common Alerting Protocol
ConOps	Concept of operations
CV	Connected vehicle
DMS	Dynamic message sign
EOC	Emergency operations center
FHWA	Federal Highway Administration
GFS	Global Forecast System
IMRCP	Integrated Model for Road Condition Prediction
METRo	Model of the Environment and Temperature of Roads
NDFD	National Digital Forecast Database
NHC	National Hurricane Center
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
RAP	Rapid Refresh weather model
RTMA	Real-Time Mesoscale Analysis
SLOSH	Sea Lake and Overland Surges from Hurricanes model
TMC	Transportation management center
TSMO	Transportation systems management and operations
USDOT	United States Department of Transportation

CHAPTER 1. INTRODUCTION

BACKGROUND

Transportation agencies face many challenges when working toward effective transportation systems management and operations (TSMO). Weather, incidents, and events outside the knowledge and control of transportation agencies and travelers can reduce a free flow of traffic to a snarled mess in minutes or seconds. Whether the focus is on traffic incident management, work zones, active traffic management, or emergency evacuation routing, the intent of TSMO is to minimize and mitigate the impact of disruptions and to enable travelers to make better choices for safe and reliable travel.

The breadth of information available to support TSMO strategies fortunately has been expanding to meet the needs. Views of traffic conditions, road weather, incidents and work zones, and flooding and extreme events have been expanded by augmenting an agency's own data with other private and crowdsourced data. The views of conditions that might affect safety and mobility across the transportation network has grown both broader and more detailed.

These views have, however, still been somewhat limited by their lack of integration and by being limited to current and past conditions. The next level of decision support for TSMO needs to be integrated across the technical disciplines and provide a view into likely future conditions. With this background and research experience, FHWA embarked on efforts in 2015 to develop Integrated Modeling for Road Condition Prediction (IMRCP). The resulting IMRCP tool incorporates real-time and archived data with results from an ensemble of forecast and probabilistic models, fusing them together in order to predict the current and future overall road/travel conditions for travelers, transportation operators, and maintenance providers.

The foundational elements needed to characterize Integrated Modeling for Road Condition Prediction (IMRCP) were developed in the Phase 1 development of a Concept of Operations and Requirements. The IMRCP Phase 2 work specified, implemented, tested, and evaluated the IMRCP concept in a demonstration deployment with local agencies in the Kansas City metropolitan area. Phase 3 expanded the IMRCP deployment across the entire Kansas City metro area, implemented a machine-learning based traffic model, operated the system for two winter seasons, evaluated the operational results, and updated the system documentation.

PURPOSE

The objectives of IMPCP Phase 4 are to improve and deploy the system for applications with two State agencies not previously involved in IMRCP development, expanding system capabilities and applicability to extreme events, addressing some functional gaps identified in Phase 3; deploy to a metropolitan area for planning, monitoring, and post-event assessment of traffic management during adverse weather conditions; deploy to a metro/region/state transportation management center to assess improvements to public safety, evacuation and emergency response to severe/extreme weather conditions; and update the system documentation to support future deployments.

The purpose of this System User Guide is to provide a description of the IMRCP system user interface, its functions, and features. This document includes instructions for using the interface, a sample set of practical use cases, and definitions of the map interface layers, data types, and alerts.

DOCUMENT OVERVIEW

Chapter 1 provides background information as context for the rest of the document.

Chapter 2 describes the system architecture to provide context for the user instructions.

Chapter 3 presents information on using the IMRCP user interface, including the map interface, scenario creation and viewing, and creating and accessing reports and subscriptions.

Chapter 4 outlines possible uses of the IMRCP system and provides example applications for actual events.

Appendix A describes the layers on the map interface.

Appendix B describes the observation types available in the system.

Appendix C describes alerts provided by the system.

CHAPTER 2. SYSTEM OVERVIEW

The IMRCP system provides a framework for the integration of road condition monitoring and forecast data to support tactical and strategic decisions by travelers, transportation operators, and maintenance providers. The system collects and integrates environmental observations and transportation operations data; collects forecast environmental and operations data when available; initiates road weather and traffic forecasts based on the collected data; generates travel and operational advisories and warnings from the collected real-time and forecast data; and provides the road condition data, forecasts, advisories, and warnings to other applications and systems. Road condition and operations data and forecasts to be integrated into the prediction include atmospheric weather; road (surface) weather; small stream, river, and coastal water levels; road network capacity; road network demand; traffic conditions and forecasts; traffic control states; work zones; maintenance activities and plans; and emergency preparedness and operations.

The IMRCP system performs six major functions:

- Collecting weather, traffic, operations, and hydrological data for use in predicting road and weather conditions.
- Storing the collected and system-generated data.
- Generating forecasts of traffic and road conditions.
- Mapping the forecasts, current conditions, alert notifications, and archive data for system users;
- Reporting on forecasts, current conditions, alerts, and archive data.
- Enabling "what-if" analyses of operational and maintenance strategies for traffic and road weather conditions.

Data sources and the road network model are specific to particular geographic areas. Observations from these data sources are stored in the IMRCP data store as sets of specific observation types. These data types are classed according to the model objects—like roadways, sensors, or atmospheric weather—to which they apply. All observation types and their sources are described in Appendix D.

The IMRCP system forecasts road weather, traffic, and hydrological conditions using data from the data store. The forecasted data is then written to the data store as additional sets of observation types, also described in Appendix D.

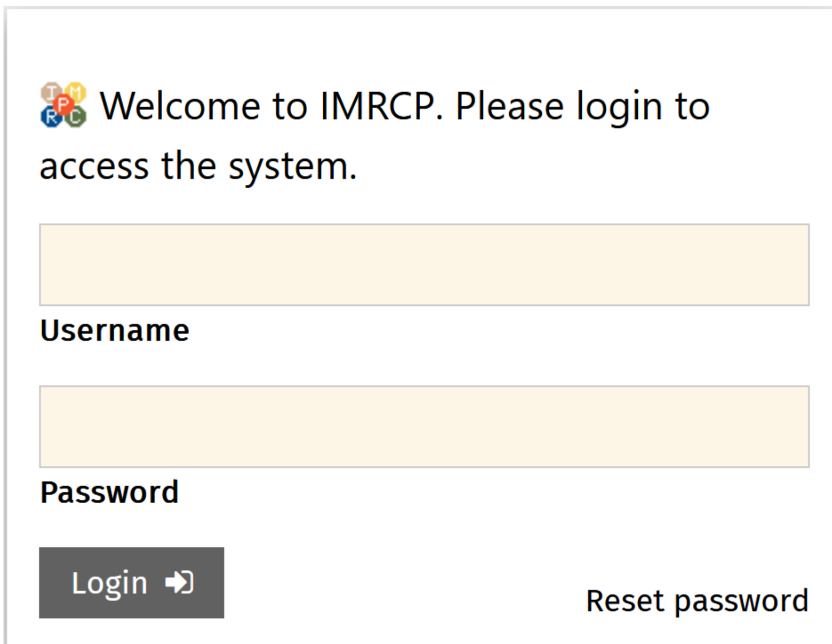
Data from the data store is presented to the user through the IMRCP user interface. The data populates layers on the map interface and is used to create alerts. Users may also view the data through reports and subscriptions. The user interface functionalities are described in 0.

CHAPTER 3. USER INSTRUCTIONS

LOGIN

The IMRCP user interface is accessed at https://imrcp.data-env.com/.[1] User accounts are set up by the system administrators. A prospective user provides a contact email address to the administrators, who assign a password for the account. Administrators then send the account name and password back to the prospective user.

As shown in Figure 1, users input their username and password and click "Login" on the IMRCP landing page to access the IMRCP user interface. Users who have previously been provided with passwords but have lost their password can get a new password by clicking the "Reset password" link.



Source: FHWA.

Figure 1. Screen capture. IMRCP login dialog.

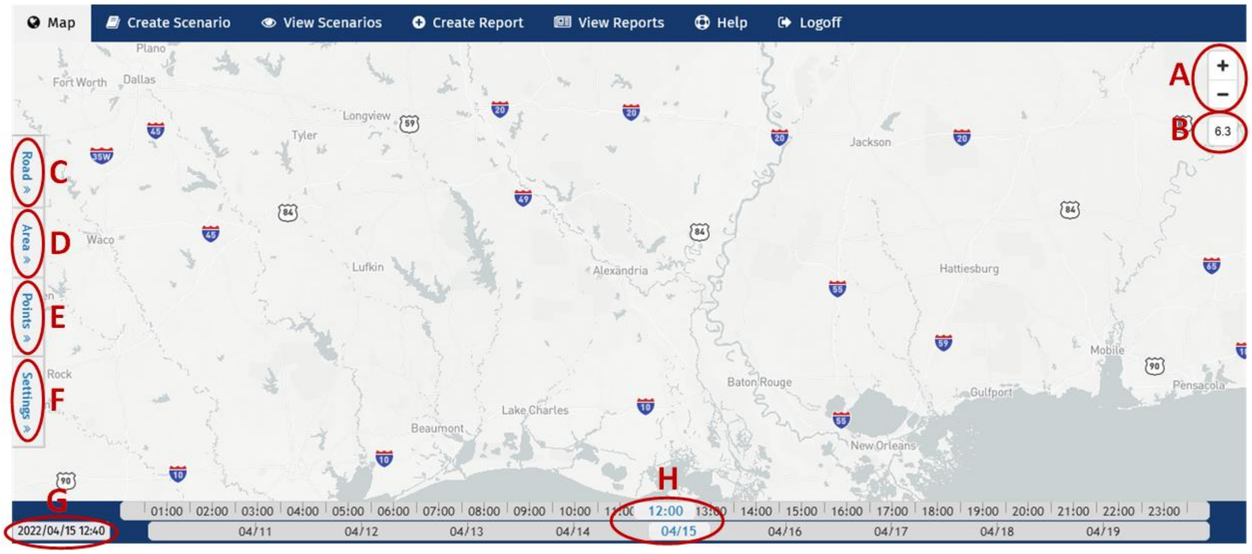
A successful login presents the IMRCP map user interface.

MAP

The IMRCP map is the default view when logging into the system. It provides views of road conditions, weather conditions, and alerts in the immediate past, present, and near future.

The map view is available from the leftmost tab at the top of the IMRCP window. Map controls as shown in figure 2 are described in the following sections.

[1] The instructions and examples in this manual presume that the user is accessing the system with a typical personal computer browser.



Source: FHWA.

Figure 2. Screen capture. Map User Controls.

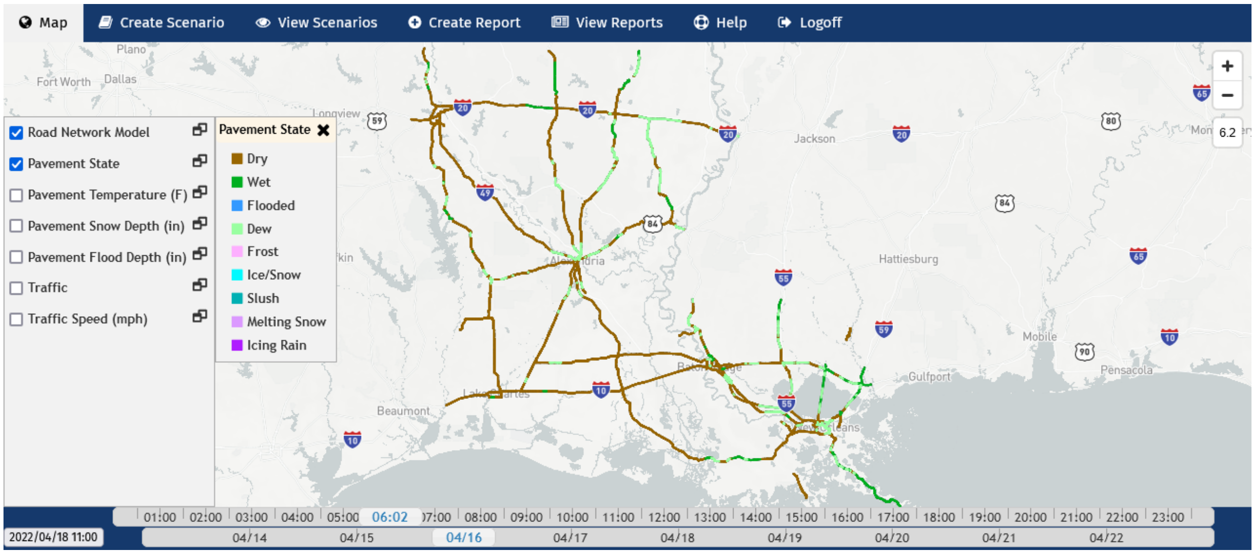
Using Map Tools

1. To zoom into and out of the map, use the zoom controls (A in figure 2) in the top right corner of the map or use the mouse's scroll wheel while the cursor is positioned over the map. Some map layers (for example, roads) may appear only when zoomed in to sufficient detail. The zoom level indicator (B) provides a reference.

2. To move the map, left-click on the map and drag the cursor.

Viewing Road Condition Data

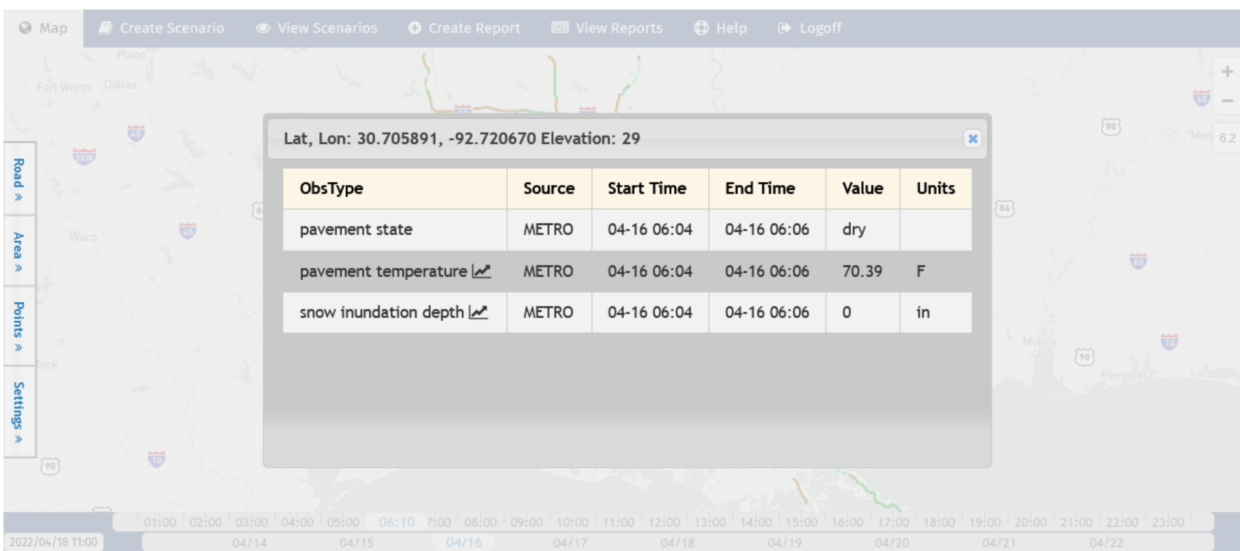
3. As shown in figure 3, users select a road data layer from the "Road" tab and panel (C in figure 2) on the left side of the page. Left-click the tab to open the panel. Select the type of data to be displayed by left-clicking the checkbox to the left of the layer label. Users can select multiple layers to be displayed, with the last layer selected on top. Left-clicking the icon to the right of a layer label opens the map legend for that layer. Left-click the ✖ icon on the legend or the icon to the right of the layer label to close the legend panel. Left-click the "Road" tab to close list of layers. The layer definitions can be found in appendix B.



Source: FHWA.

Figure 3. Screen capture. Viewing road condition data.

4. Left-click on a road segment on the map to view detailed data (figure 4) for that road segment at the date and time indicated on the time controls (H in Figure 2). Left-click the icon to close the details dialog.



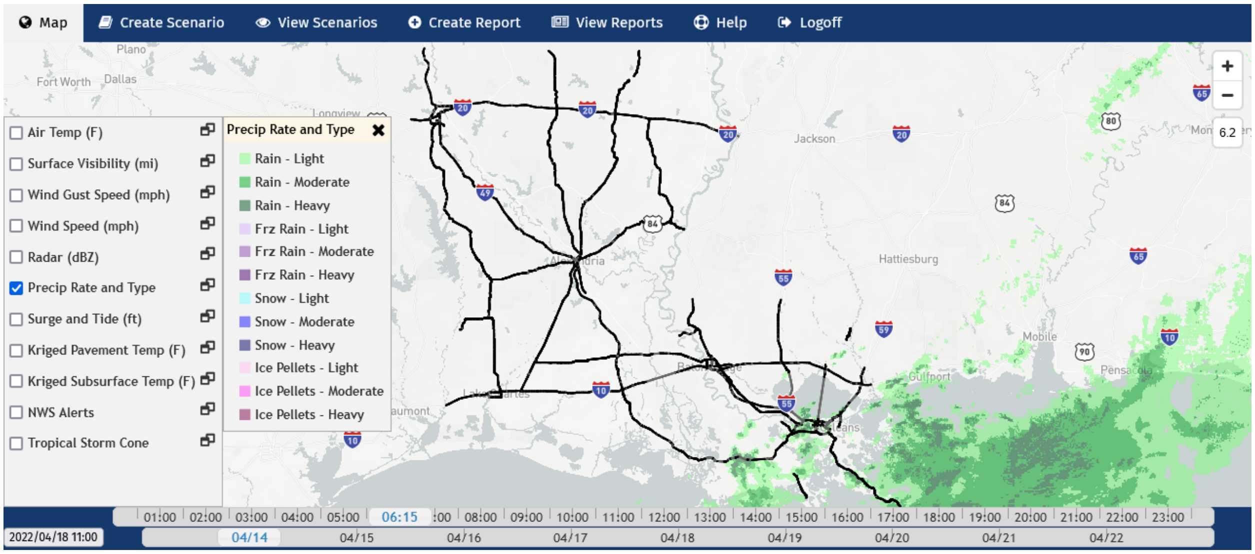
Source: FHWA.

Figure 4. Screen capture. Viewing road condition data details.

Viewing Area and Weather Condition Data

5. Users select an area data layer from the "Area" tab and panel (D on figure 2) on the left side of the page. Left-click the tab to open the panel. Select the type of data to be displayed by left-clicking the checkbox to the left of the layer label (figure 5). Users can select

multiple layers to be displayed, with the last layer selected on top. Left-clicking the icon to the right of a layer label opens the map legend for that layer. Left-click the ✖ icon on the legend or the icon to the right of the layer label to close the legend panel. Left-click the “Area” tab to close list of layers. The layer definitions can be found in appendix B.



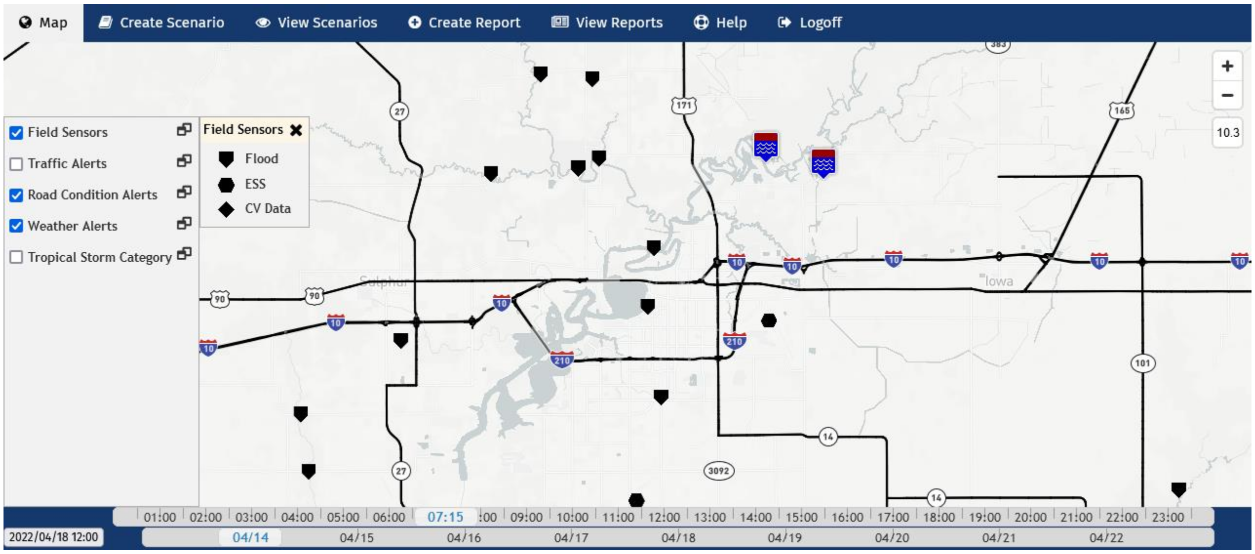
Source: FHWA.

Figure 5. Screen capture. Viewing area and weather condition data.

6. Left-click on a location with data for the selected layer on the map to view detailed data for that location at the date and time indicated on the time controls (H on figure 2). Left-click the icon to close the details dialog.

Viewing Alerts and Field Sensor (Points) Data

1. Users select a points data layer from the “Points” tab and panel (E on figure 2) on the left side of the page. Left-click the tab to open the panel. Select the type of data to be displayed by left-clicking the checkbox to the left of the layer label (figure 6). Users can select multiple layers to be displayed, with the last layer selected on top. Left-clicking the icon to the right of a layer label opens the map legend for that layer. Left-click the ✖ icon on the legend or the icon to the right of the layer label to close the legend panel. Left-click the “Points” tab to close list of layers. The layer definitions can be found in appendix B.



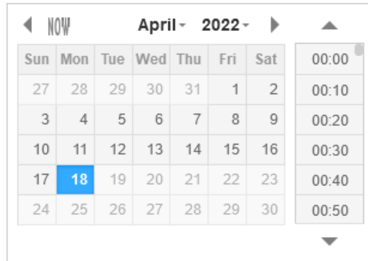
Source: FHWA.

Figure 6. Screen capture. Viewing alerts and field sensor data.

2. Left-click on a point layer icon on the map to view detailed data for that location at the date and time indicated on the time controls (H on figure 2). Left-click the icon to close the details dialog. Alert definitions can be found in appendix C.

Using the Time Selector

1. To view the map data layers for the immediate past, current, or future time frames, select a date and time on the time controls at the bottom of the map **(**H on figure 2).
2. The reference time frame can be set further into the past by left-clicking on the reference date-time display indicator (G in figure 2). A small calendar dialog will pop up over the map (figure 7). Select a date on the calendar using the year and month pulldown arrows or the left and right arrows at the top of the dialog to change the month and the calendar to select the day. Select the reference time on that day from the list on the right of the dialog. The dialog disappears when a time is selected. The date and time in the box and on the slider are changed to the new reference time for the view. Moving the time control sliders to the left will display data for that time. Moving the sliders to the right of the reference date and time will display forecasts as seen from that reference time.
3. To go back to the current time, click on the date display (G on figure 2) and then double-click on "NOW" in the upper left-hand corner of the pop-up dialog.



Source: FHWA.

Figure 7. Screen capture. Reference time selection control.

Changing Settings for the Map View

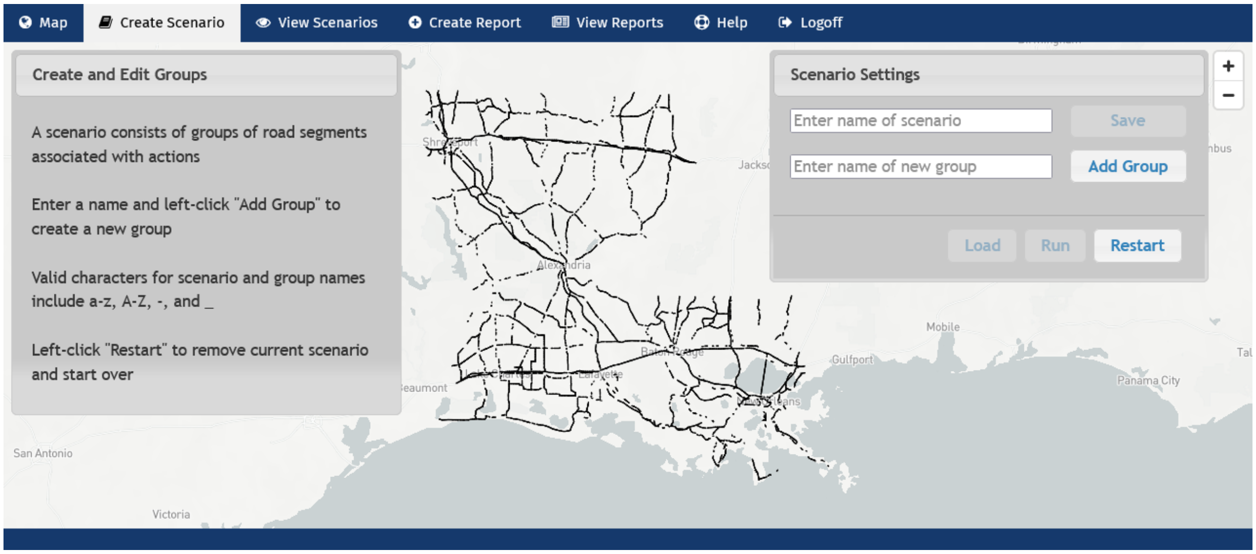
Users can change and save map view settings as account defaults using the “Settings” tab and panel (F on figure 2) on the left side of the page.

1. Set the map zoom level, location, and time frame.
2. Click on the “Settings” tab. Map Behaviors can refresh the map view once a minute by checking “Auto refresh.”
3. The current settings can be saved as defaults and will become active when the “Settings” tab is clicked to close the panel.

CREATING A SCENARIO

Scenario modeling enables IMRCP users to postulate and evaluate the impact of operations and maintenance strategies on road conditions during challenging environmental and incident conditions. Users create models of operations and maintenance interactions with specific road segments that are saved for execution and evaluation under at particular times and varying conditions.

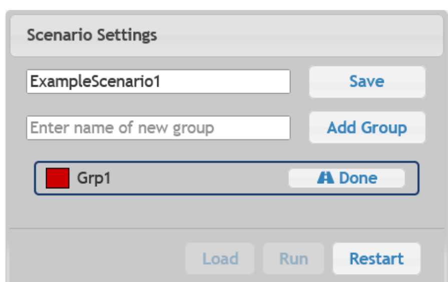
1. Select the “Create Scenario” tab at the top of the page. A map and dialogs for defining scenarios appears as shown in figure 8. The “Create and Edit Groups” dialog provides descriptions of the controls in the “Scenario Settings” dialog on the right.



Source: FHWA.

Figure 8. Screen capture. Dialogs for creating a scenario.

2. Enter a scenario name in the "Scenario Settings" dialog.
3. Enter a name for a new group of segments on which the scenario will take place and left-click "Add Group" to create a new group. The scenario and group names cannot contain spaces.
4. Use the map controls to zoom into an area for which the scenario is being created. Left-click the icon to add segments to the group. The "Scenario Settings" dialog appears as shown in the figure 9 example. A group of segments will share the same set of actions in the scenario. Some segment groups may be selected for evaluation of conditions upstream or downstream of a set of actions, even though there are no actions applied to those segments.



Source: FHWA.

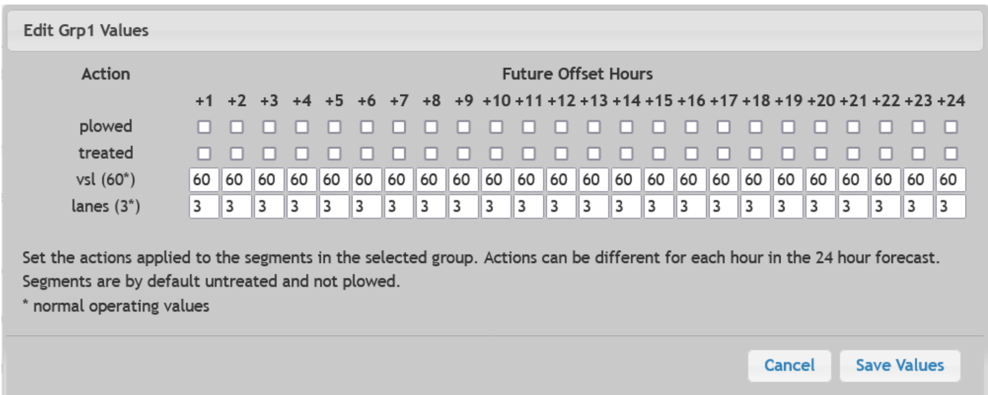
Figure 9. Screen capture. Scenario settings dialog.

5. Left-click to select the first segment for the first group. It may be necessary to zoom further in to distinguish segments that closely parallel each other on the map. The segment is highlighted as a thicker line than non-selected segments and in the group color. A green plus sign will be displayed when the mouse is hovered over a segment that can be selected. A red minus sign will be displayed when the mouse is hovered over a selected segment.
6. Left click to add/remove segments to/from the selection set. All segments in a group must

share the same number of lanes and speed limit. The cursor will change to a “null” icon if a segment with different properties is attempted for inclusion in a group. There is no hard limit on the number of segments that can be selected, but more segments will increase the time needed to process the report.

7. Left-click the Done button to save the set of segments. The segments selected for the group will be highlighted in the color shown in the corresponding row in the Scenario Settings dialog. The count of segments selected will appear next to the segment icon.

8. Left-click the icon to associate actions with the group. A group of segments will share the same set of actions in the scenario. An “Edit [group name] Values” dialog pops up (figure 10).



Source: FHWA.

Figure 10. Screen capture. Scenario actions dialog.

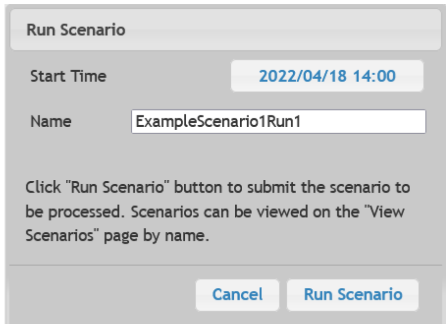
9. Set the actions applied to the segments in the selected group. Actions can be different for each hour in the 24-hour forecast. Segments are by default not plowed for snow and ice and not treated to prevent freezing of precipitation. Variable speed limits (“vsl”) model speed limit reductions that might be used to reduce the impacts of inclement weather or traffic congestion. Reducing the number of lanes can be used to simulate work zone or incident closure. Increasing the number of lanes models strategies like hard shoulder running or contraflow lanes. Normal operating values for are specific to the segments to which the actions are being applied. A value of “-1 for the vsl or lanes indicates that the normal operation value is unknown.

10. Left-click “Save Values” to save the action plan for the selected group. Left-clicking “Cancel” clears any changes. In either case, the dialog closes and the interface returns to the “Scenario Settings” dialog.

11. Add other groups as described in Steps 3 through 9 to complete the settings for the scenario. Left-click the “Save” button on the “Scenario Settings” dialog to save the segment groups and actions. A “Save Succeeded” dialog will appear. Left-click the icon to close the dialog. The “Scenario Settings” dialog reappears with “Load” and “Run” buttons enabled for selection.

12. If additional changes need to be made to a saved scenario model, click “Load” to return to the “Scenario Settings” with the saved groups and actions.

13. Left-click “Run” to submit a scenario for analysis. A “Run Scenario” dialog will appear as shown in figure 11. Left-click in the “Start Time” box to select a date and time at which the scenario forecast should start. Left-click in the “Name” box to provide a label for the scenario forecast results report. As instructed in the dialog, left-click the “Run Scenario” button to submit the scenario to be processed. The scenario may take an hour or more to process, depending on the number of road segments and actions included in the scenario. Scenario results are listed and accessed on the “View Scenarios” tab at the top of the IMRCP page.



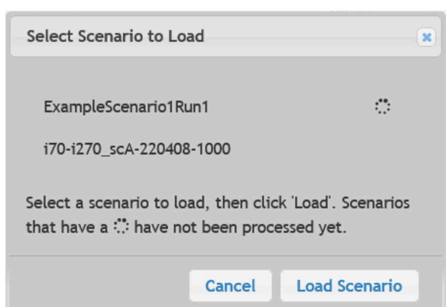
Source: FHWA.

Figure 11. Screen capture. Run Scenario dialog.

VIEWING SCENARIO RESULTS

Scenario modeling enables IMRCP users to postulate and evaluate the impact of operations and maintenance strategies on road conditions during challenging environmental and incident conditions. Users create models of operations and maintenance interactions with specific road segments that are saved for execution and evaluation under at particular times and varying conditions. Those scenario models are run to create result that are then viewed in IMRCP.

1. Select the “View Scenario” tab at the top of the IMRCP page. A “Select Scenario to Load” dialog appears as shown in figure 12. All scenarios that have been queued to run or completed for the logged-in user will appear in the list.

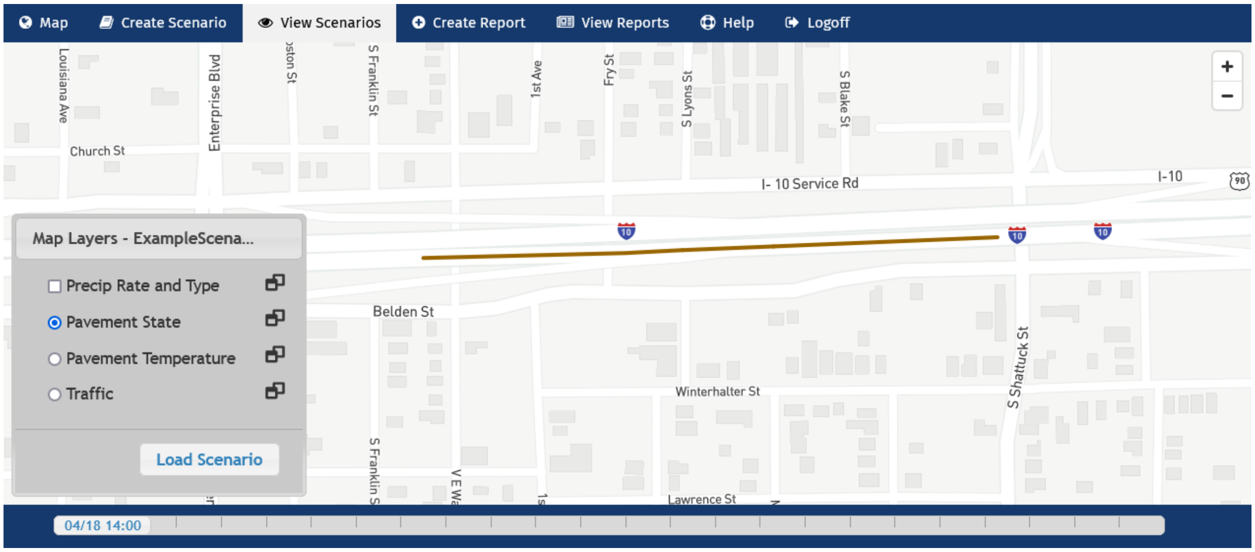


Source: FHWA.

Figure 12. Screen capture. Scenario selection dialog.

2. Find the scenario run name in which you are interested. If the scenario was just recently submitted to run, it may still be in process as indicated by a rotating icon to the right of the scenario name. If so, come back to this page later. Scenarios that are complete and

available for viewing have no icon to the right of the scenario name. When the run is complete, left click on the scenario run name to highlight that case. Left-click Load Scenario. The IMRCP window will show a map with the focus on the segment selections associated with the scenario that was run (figure 13). The specific time interval within the scenario time frame is selectable with the scale under the map.

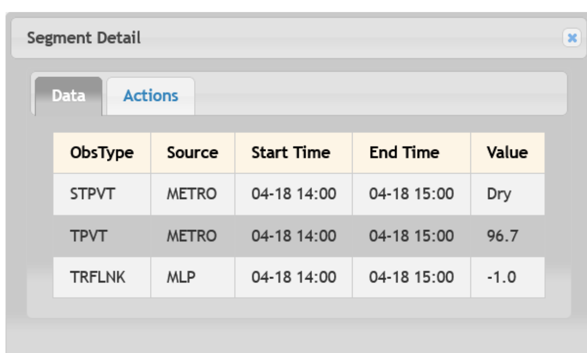


Source: FHWA.

Figure 13. Screen capture. Scenario map view.

3. Users can select the layers available on the scenario results map in the dialog on the left. The precipitation rate and type can be displayed with any of the other roadway layers, only one of which can be displayed at a time.

4. Left-clicking on a segment brings up a dialog with the detailed results for that segment on a “Data” tab (figure 14). Left-clicking on the “Actions” tab displays the actions applied to the segment at the time being viewed on the scenario results map (figure 15). The rows in the table describe the actions for the selected segment at the time shown on the slide when the segment was selected for viewing.



ObsType	Source	Start Time	End Time	Value
STPVT	METRO	04-18 14:00	04-18 15:00	Dry
TPVT	METRO	04-18 14:00	04-18 15:00	96.7
TRFLNK	MLP	04-18 14:00	04-18 15:00	-1.0

Source: FHWA.

Figure 14. Screen capture. Data detail for segments in scenarios.

Segment Detail

Data | Actions

Action	Group	Start Time	End Time	Value	Normal Value
treated	1	04-18 14:00	04-18 15:00	false	
plowed	1	04-18 14:00	04-18 15:00	false	
lanes	1	04-18 14:00	04-18 15:00	3	3
label	1	04-18 14:00	04-18 15:00	Grp2	
vsl	1	04-18 14:00	04-18 15:00	45	60

Source: FHWA.

Figure 15. Screen capture. Action detail for segments in scenarios.

CREATING A REPORT OR SUBSCRIPTION

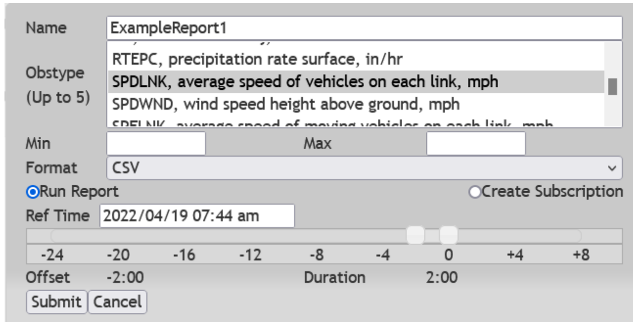
Reports provide extracts of road and weather conditions collected or forecast by the IMRCP system at locations within the road network for specific time periods. A subscription is a report run on a recurring basis, typically to provide a series of similar reports for further analysis or automation.

1. Select the “Create Report” at the top of the IMRCP interface. The system will display a map of the road network with an instruction dialog.

2. Use the map controls to locate a set of segments for which the report is to be run. It may be necessary to zoom further in to distinguish segments that closely parallel each other on the map. A green plus sign will be displayed when the mouse is hovered over a selectable segment. Left-click to select a segment for a report.

3. Left click to add/remove segments to/from the selection set. A red minus sign will be displayed when the mouse is hovered over a selected segment. Clicking on a selected segment removes it from the selection set. There is no hard limit on the number of segments that can be selected, but more segments will increase the time needed to process the report.

4. Press the enter key to finish the selection of segments for the report. A pop-up dialog for entering detailed report parameters will appear (figure 16).



Source: FHWA.

Figure 16. Screen capture. Report settings dialog.

5. Type a name in the name field.

6. Select the observation types (obstype) to be listed in the report/subscription. Observation type definitions and units are found in appendix A. Hold down the control key to select multiple individual types, or use the shift key to select a range of types.

7. If only selecting one observation type, optionally type a minimum and/or maximum value for that observation type in the "Min" and "Max" fields. Values less than the minimum or greater than the maximum constraints will be filtered from the report.

8. Select the format for the report/subscription from the dropdown menu. Comma-separated value (CSV) is the only option currently supported in IMRCP.

To run a report:

9. Select the "Run Report" radio button on the Report/Subscription wizard.

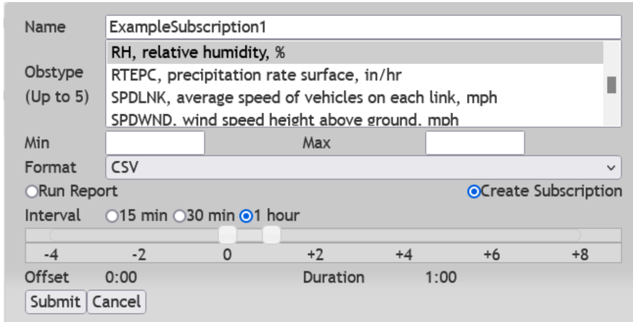
10. Select a reference date and time by clicking on the "Ref Time" input box.

11. Set the time range for the report relative to the reference time using the left and right slide controls. Note that time to the left of the reference time will yield measured and estimated values at those times; time to the right of the reference will yield values as they were forecast at that time.

12. Select the "Submit" button.

Creating a subscription involves defining the report parameters and a recurrence interval at which the report will be run. To create a subscription, complete the top part of the dialog and then:

13. Select the "Create Subscription" radio button on the Report/Subscription wizard (figure 17).



Source: FHWA.

Figure 17. Screen capture. Subscription Settings Dialog.

14. Select an interval radio button.

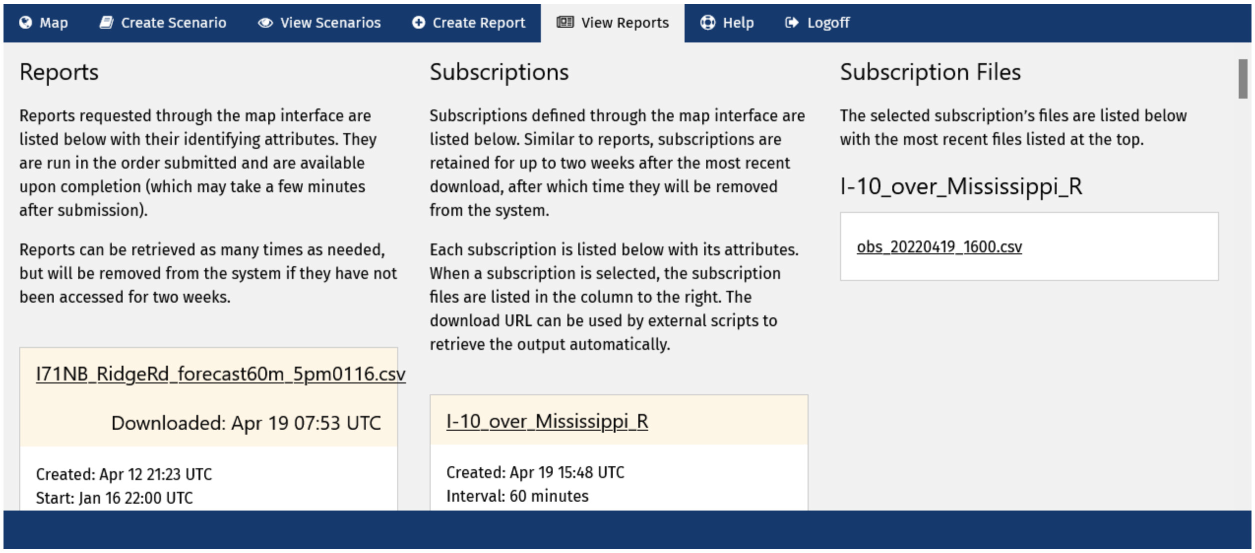
15. Set the time range for the report relative to the reference time using the left and right slide controls. Note that time to the left of the reference time will yield measured and estimated values at those times; time to the right of the reference will yield values as they were forecast at that time.

16. Select the “Submit” button.

VIEW REPORTS

Reports and subscriptions created are accessed through the “View Reports” tab at the top of the IMRCP page.

1. Select the “View Reports” tab at the top of the IMRCP page. Reports submitted by the user are listed in the left panel and the subscriptions submitted by the user are listed in the center panel (figure18). The creation date and filter criteria for each report and subscription is listed below its name. Each report and subscription is retained for two weeks after it has been downloaded and will then be removed from the system.



Source: FHWA.

Figure 18. Screen capture. Reports and Subscription Listings.

Viewing a Report

2. To view a report, click on the report name on the left panel of the page. The page may need to be refreshed if a report is pending fulfillment as reports may not be generated for several minutes after they have been requested.

Viewing a Subscription

3. To view a subscription, click on the subscription's name in the center panel of the page. The files generated for that subscription will appear in the right panel of the page.

4. Click on the subscription file you would like to open. The subscription files are named based on the time they are generated in a "YYYYMMDD_HHMM" format.

CHAPTER 4. EXAMPLE EVENTS

WINTER STORMS AND ROAD CONDITIONS

Winter weather conditions present complex operational challenges for the transportation system and its stakeholders. For example, travelers want information about conditions along their planned route and, as a group, create the aggregate traffic conditions as they drive along their routes. Winter maintenance crews plan for reducing the impact of storms on roadway conditions based on weather forecasts and may use a maintenance decision support system (MDSS), but also adapt to conditions on the roadway as they execute those plans. Operators in a transportation management center (TMC) monitor roadway conditions and implement weather responsive management strategies that may including using variable speed limits (VSL), limiting access to roadways through lane or road closures, and providing traveler information online, on roadside dynamic message signs, on smartphone apps, and through the media.

IMRCP Use Cases

IMRCP provides information and tools to support many of the needs driven by winter weather impacts on the transportation system. It enhances situational awareness by gathering, synthesizing, and integrating information about current and forecast traffic, weather, and hydrological conditions across the road network. It provides web interfaces, reports, and data subscriptions for operations stakeholders and for other systems that might benefit from the data integration. IMRCP can assist in planning and operations decision support with scenario analysis of weather-responsive management strategies like implementing VSL. Table 1 identifies potential operator uses for IMRCP in winter storms.

Table 1. Potential operator uses for IMRCP in winter storms.

Time relative to onset of storm	Operations/maintenance activities and potential uses for IMRCP
-5 days / -120 hours	Forecasts show approach of storm and extent of precipitation in IMRCP
-4 days / -96 hours	Continue to monitor storm forecast. Notify management and NWS office of intent to mobilize
-3 days / -72 hours	Continue to monitor storm forecast. IMRCP provides first look at pavement conditions during the storm, supplementing any other forecast resources. First response planning session for approaching storm with maintenance, operations, and NWS.
-2 days / -48 hours	Continue to monitor storm forecast. IMRCP updating pavement condition forecasts. Second planning session.
-1 day / -24 hours	Continue to monitor storm forecast. IMRCP updating pavement condition forecasts. Run IMRCP treatment/plowing scenario. Plan set and resources committed for storm response.
-18, -12, -6 hours	Continue to monitor storm forecast. IMRCP updating pavement condition forecasts. Update treatment and plowing scenarios.

Time relative to onset of storm	Operations/maintenance activities and potential uses for IMRCP
-3 hours	Continue to monitor storm forecast. IMRCP updating pavement condition forecasts. Update treatment and plowing scenarios. IMRCP forecasts traffic response to storm conditions. Run operations VSL/treatment/plowing scenarios. Maintenance and operations resources mobilized.
0 hours	Execute maintenance and operations plan. Collect AVL and mobile sensor data.
3, 6, 9, 12 hours	Continue to monitor storm, including pavement conditions updates from RWIS and maintenance operations. IMRCP updating pavement condition forecasts. Update operations scenarios to confirm ongoing operations plans.
12 hours	Storm passes.
24 hours	After action review. IMRCP event records used to review weather conditions and response. May perform scenario analysis of different treatment/plowing options or operational strategies.

Source: FHWA.

Agencies may already be using other winter weather and decision support tools. Many agencies, for example, have established relationships with local National Weather Service offices to exchange information on developing storms. Agencies may also have access to commercial weather information services, in some cases providing pavement condition information and forecasts similar to those provided by IMRCP. Agencies with access to a winter maintenance decision support system (MDSS) may use its treatment and plowing recommendations to guide maintenance planning and decisions. IMRCP can supplement those resources with additional information on traffic and operations, particularly traffic predictions.

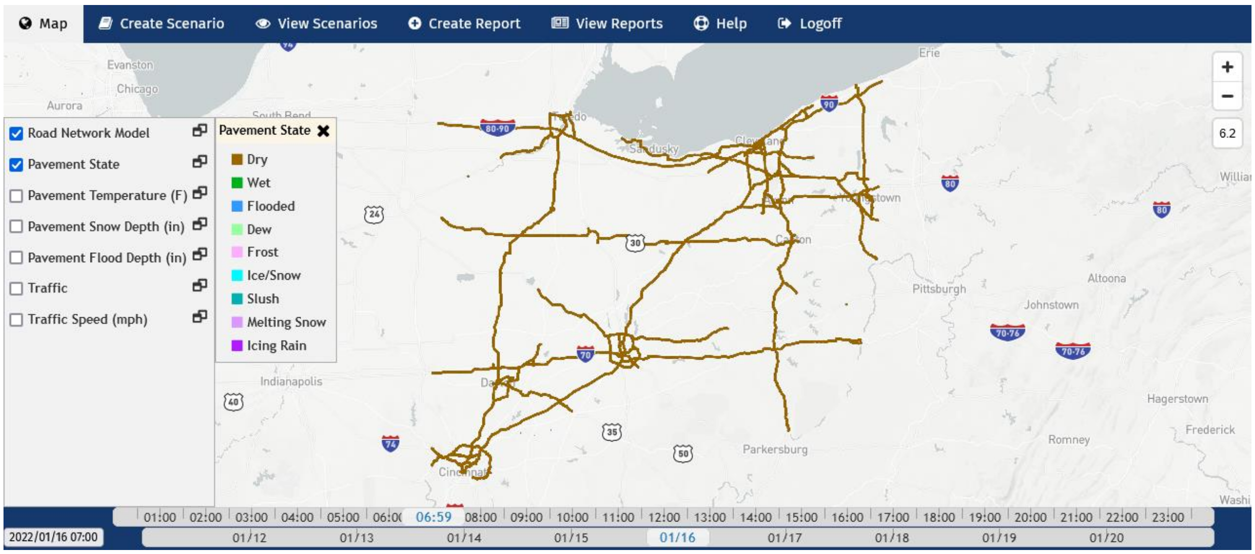
As a winter storm approaches, IMRCP will collect atmospheric weather condition information and forecasts. Those weather data will be used with data from road weather information systems (RWIS) to model current and forecast pavement conditions across the road network. IMRCP's scenario tools can be used to investigate the road condition impacts of pre-treatment and plowing, although it does not provide treatment or plowing plans that can be generated by an MDSS.

As winter storm conditions are affecting the road network, IMRCP integrates traffic and weather views of current road conditions. This enables operators and maintenance staff to see the network-wide impact of actual weather conditions as they develop. TMCs can get views of conditions beyond specific locations seen through traffic cameras. Maintenance supervisors can monitor conditions in real time beyond reports from plow vehicles or RWIS. Road weather condition forecasts reflect the accumulated real-time weather conditions. Traffic predictions include the impacts of road weather conditions and incidents that may have occurred as a result of those conditions.

After the storm has passed, IMRCP provides a record of weather and traffic conditions and forecasts throughout the storm. This record provides operations and maintenance staff with a richer and more integrated view of events for after-action reviews. The data might also be used to feed storm indices or performance measures.

Example Ohio Winter Storm – January 16-17, 2022

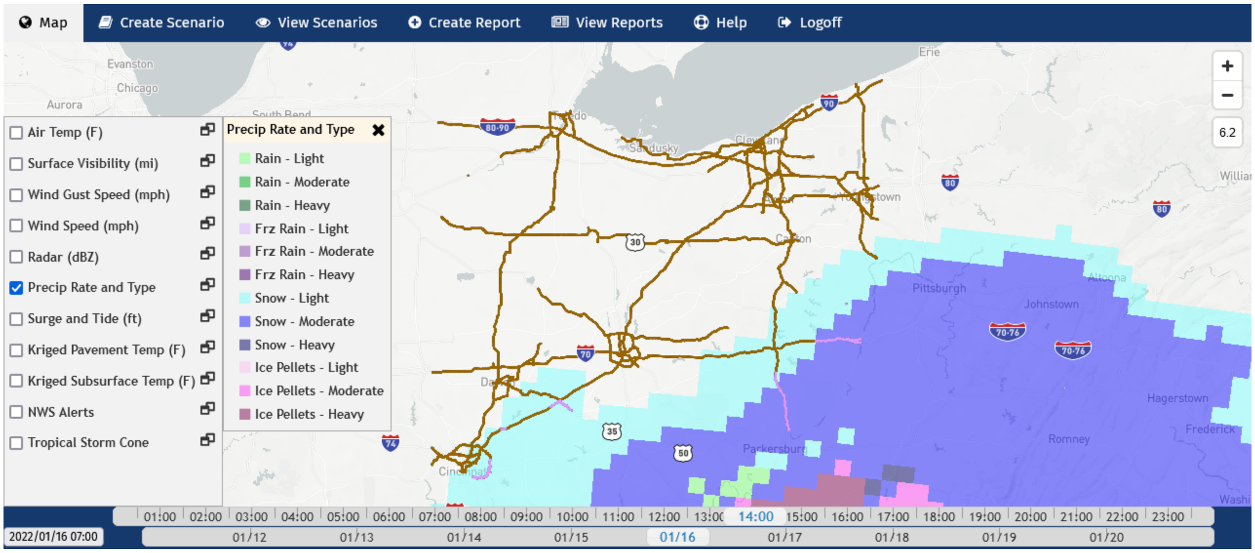
A winter storm was forecast to move (unusually) into Ohio from the southeast over Sunday and Monday, January 16 and 17, 2022. Conditions across the state were normal during the morning hours on the 16th, with dry roads across the state. (The times on the time controls in the figures are Central Time rather than Eastern Time.)



Source: FHWA.

Figure 19. Screen Capture. Ohio road conditions 1/16/2022 08:00 eastern time.

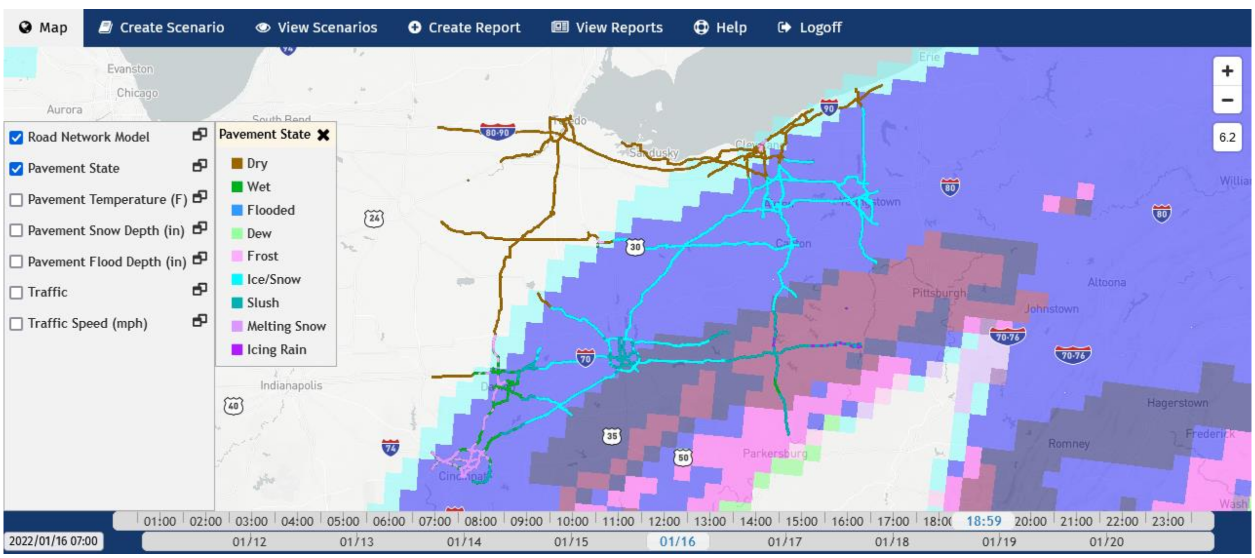
The forecast on the morning of the 16th shows snow beginning to fall in far southeastern Ohio in mid-afternoon.



Source: FHWA.

Figure 20. Screen Capture. Ohio forecast weather conditions 1/16/2022 15:00 eastern time.

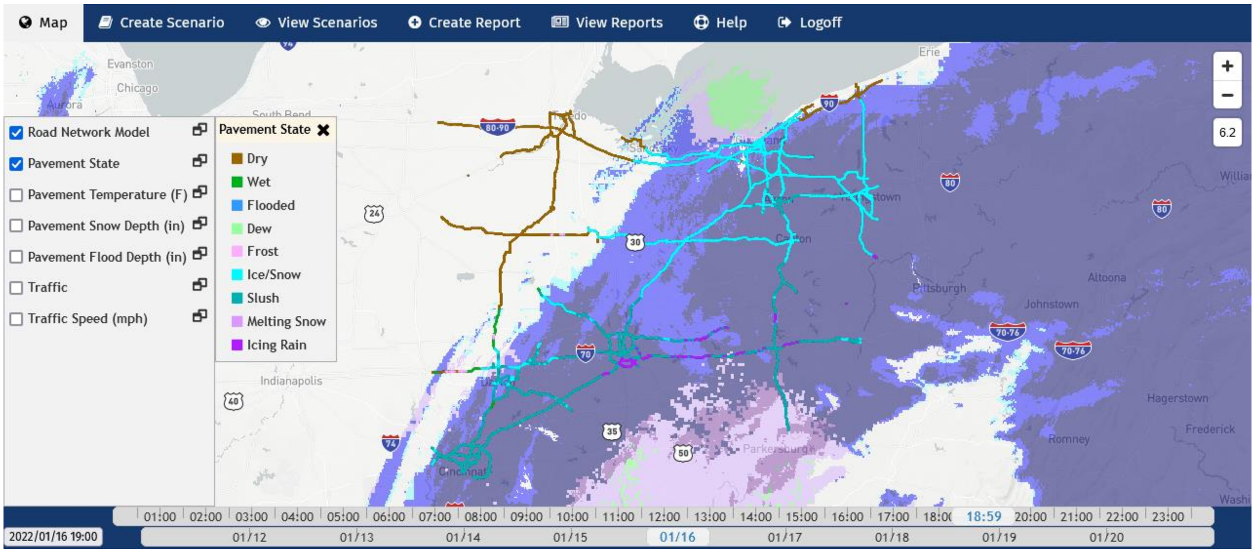
The morning 12-hour forecast on the 16th shows more widespread winter precipitation and worsening road conditions across the state in the mid-evening. The forecast pavement conditions do not in this case include the effects of any pre-treatment or plowing operations.



Source: FHWA.

Figure 21. Screen Capture. Ohio forecast road conditions 1/16/2022 20:00 eastern time.

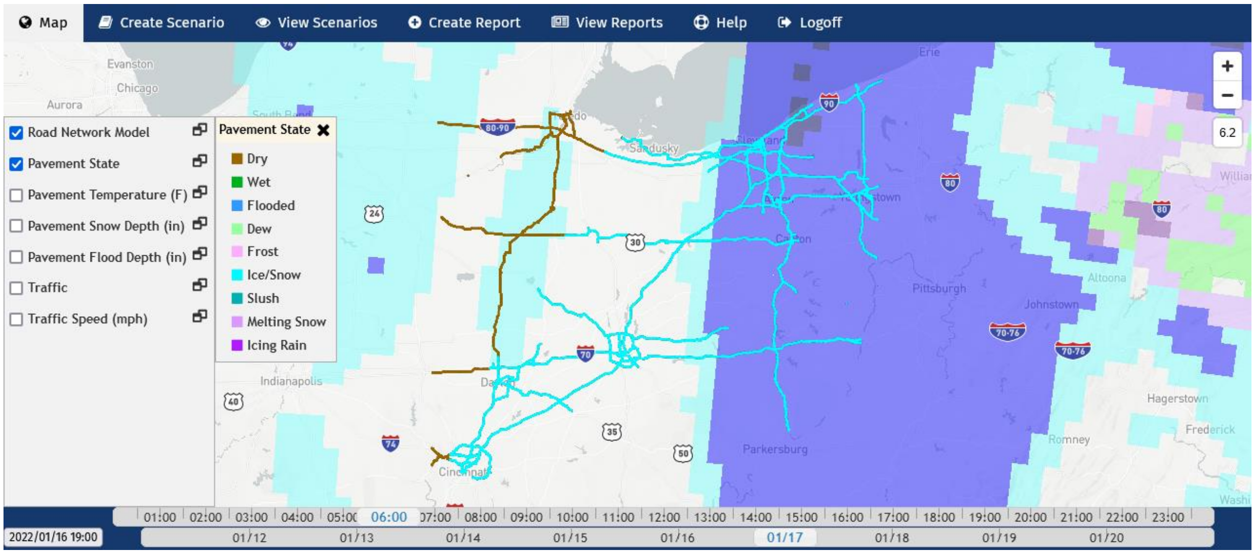
The 12-hour weather and road condition forecasts across the state are proven to be reliable as conditions in the evening closely resemble the earlier forecast. The road condition model shows the result of precipitation accumulations and melting and refreezing cycles, but does not include any pre-treatment or plowing operations that may have occurred during the day.



Source: FHWA.

Figure 22. Screen Capture. Ohio road conditions 1/16/2022 20:00 eastern time.

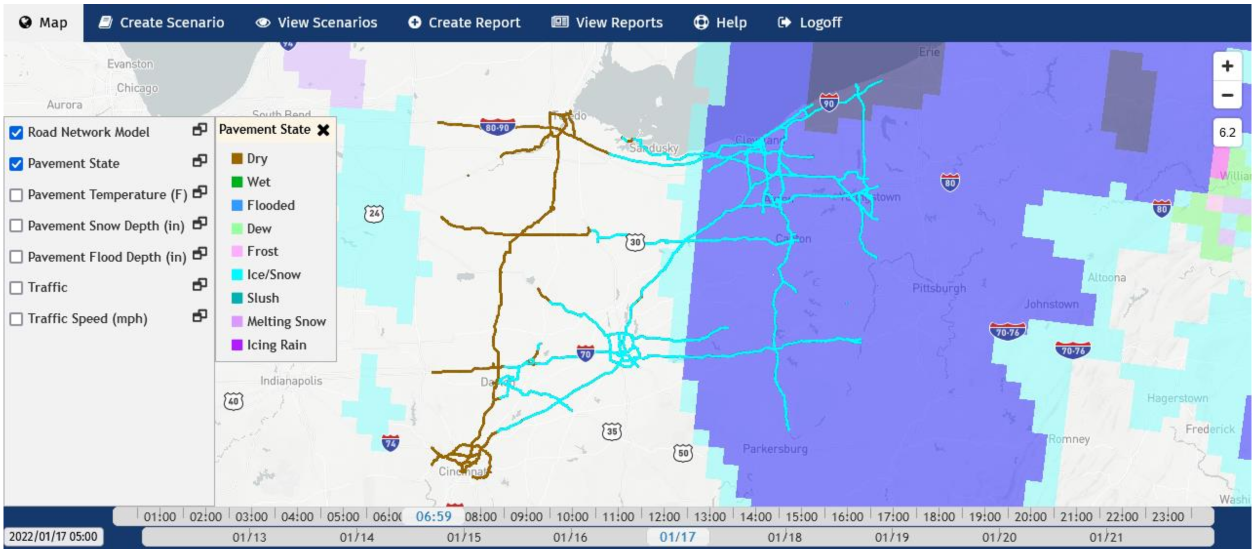
The Sunday evening forecast for the Monday morning commute indicates a potential for continued snow and icy conditions over the eastern half of the state.



Source: FHWA.

Figure 23. Screen Capture. Ohio 12-hour forecast road conditions 1/17/2022 07:00 eastern time.

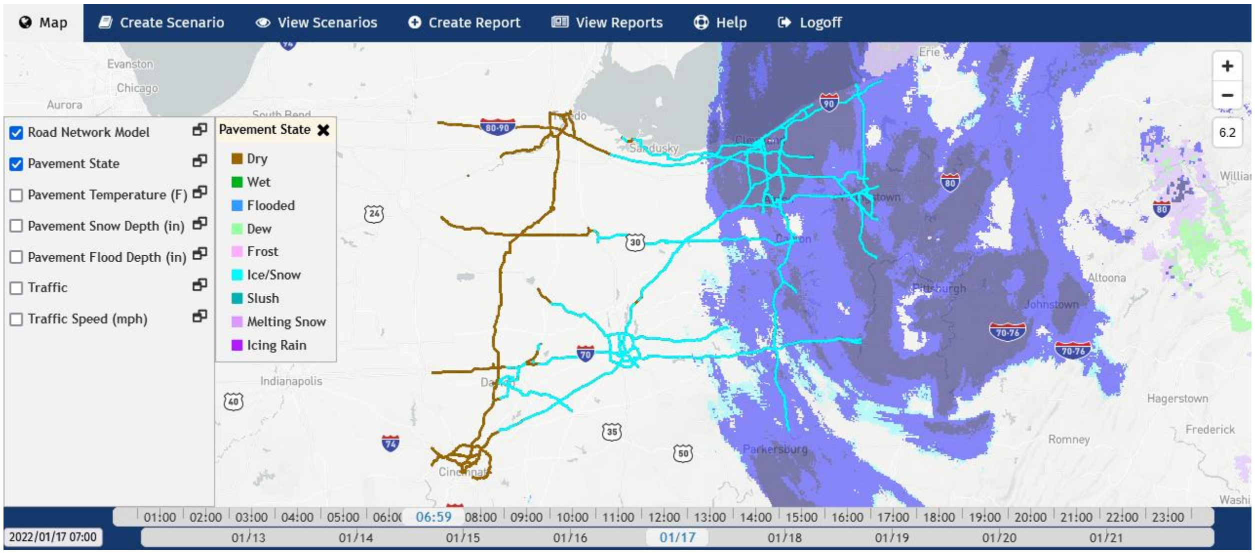
The forecast has not changed significantly overnight. The early morning 2-hour forecast on the 17th is still predicting widespread snow through the commute hours.



Source: FHWA.

Figure 24. Screen Capture. Ohio 2-hour forecast road conditions 1/17/2022 08:00 eastern time.

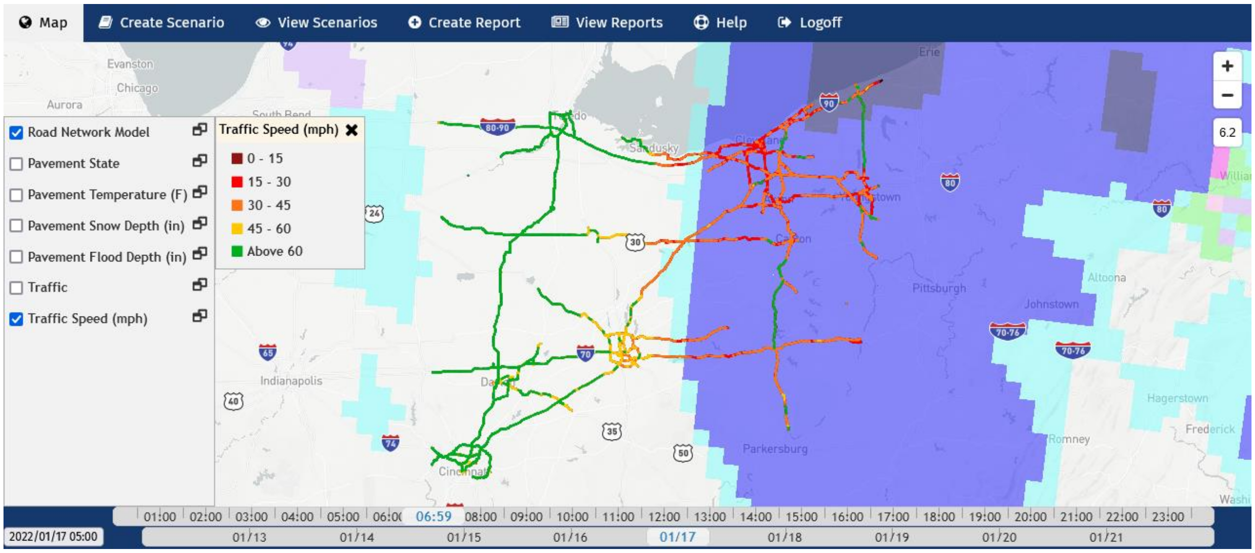
Weather and conditions on the roads during the commute again demonstrate the relative accuracy of the forecasts. Indicated pavement conditions do not include effects of any plowing operations.



Source: FHWA.

Figure 25. Screen Capture. Ohio road conditions 1/17/2022 08:00 eastern time.

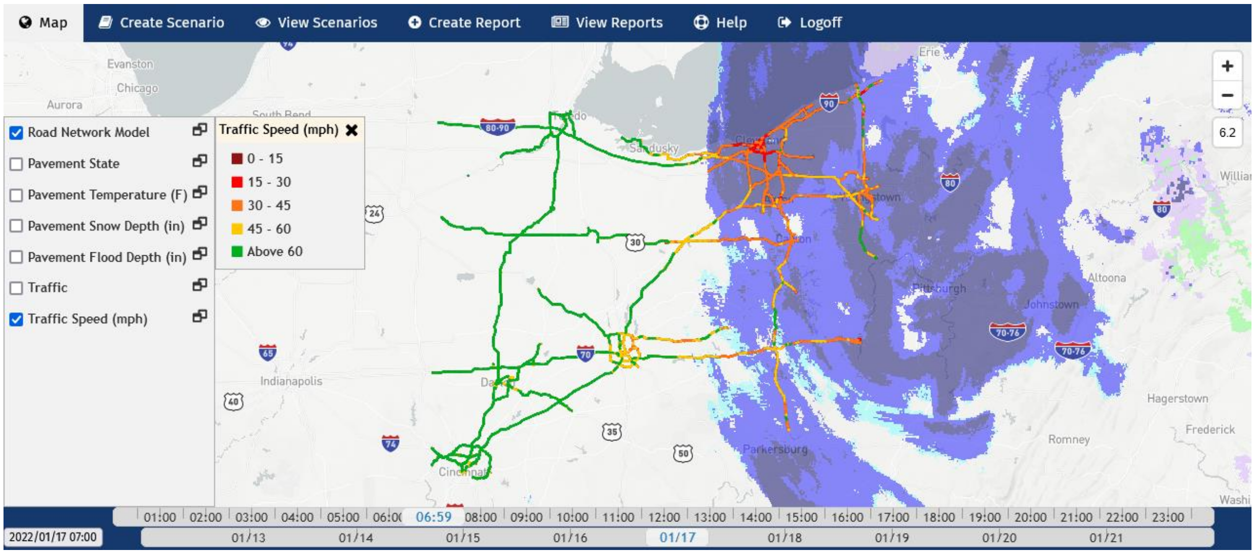
The 2-hour early morning traffic condition forecasts predict very slow speeds almost everywhere on the modeled road network during the commute hours.



Source: FHWA.

Figure 26. Screen Capture. Ohio 2-hour forecast traffic conditions 1/17/2022 08:00 eastern time.

Monitored conditions during the commute show a stark slowdown in traffic conditions under the storm. Actual traffic conditions demonstrate the accuracy of the traffic forecast consistent with the underlying relative accuracy of the weather forecast.



Source: FHWA.

Figure 27. Screen Capture. Ohio traffic conditions 1/17/2022 08:00 eastern time.

TROPICAL STORMS

Tropical storms create an ongoing series of threats to transportation system operations, as well as to life and property, as they approach land and move onshore. Emergency guidelines focus on planning for evacuation and preparedness for the storm's landfall and are dependent on the increasingly more precise forecasts of expected storm conditions and potential consequences. Operations as the storm moves onshore are somewhat limited to monitoring conditions and receiving damage reports. The post-storm recovery stage focuses on assessing damages and moving as quickly as possible to restore access and essential services to affected areas.

Transportation agencies play a support role throughout the storm planning, event, and response phases. While roadways are essential to preparing for and responding to tropical storms, emergency operations and public safety agencies manage most of the storm-related activities on the road network. The transportation agencies continue to maintain normal operations throughout, participate in emergency operations center (EOC) decisions and public information dissemination, support evacuations and contraflow, and provide resources to extraordinary operations in flood control, response, and service restoration.

IMRCP use cases

IMRCP provides information and tools to support transportation agencies in tropical storm conditions. It enhances situational awareness by gathering, synthesizing, and integrating information about current and forecast traffic, weather, and hydrological conditions across the road network. It provides web interfaces, reports, and data subscriptions for operations stakeholders and for other systems that might benefit from the data integration. IMRCP can assist in planning and operations decision support with scenario analysis of weather-responsive management strategies like implementing VSL. Table 2 identifies potential operator uses for IMRCP in tropical storms.

Table 2. Potential operator uses for IMRCP in tropical storms.

Time relative to onset of storm	Operations/maintenance activities and potential uses for IMRCP
-5 days / -120 hours	Forecasts show tropical storm cones and extent of precipitation in IMRCP.
-4 days / -96 hours	Continue to monitor storm path and development. State and parish emergency operations typically activated. IMRCP hurricane traffic models activated to predict evacuation conditions.
-3 days / -72 hours	Continue to monitor storm forecast. Public notifications prepared, depending on forecast path and strength of storm. Contraflow decisions need to be made with sufficient time for deployment of traffic control. IMRCP hurricane traffic models predicting evacuation conditions. IMRCP scenario analysis tools available for evacuation operations support.
-2 days / -48 hours	Continue to monitor storm forecast. Implementation of action statements and public advisories. State of Emergency declared (48 to 45 hours), if appropriate. Public advisory of specific areas to be affected. Mandatory evacuation areas and curfews announced along with times of commencement (48 to 45 hours), if appropriate. Evacuations proceeding. IMRCP monitoring conditions and available for scenario analysis.
-1 day / -24 hours	Continue to monitor storm forecast and traffic conditions.

Time relative to onset of storm	Operations/maintenance activities and potential uses for IMRCP
0-24 hours	Continue to monitor storm conditions. Focus shifts to awareness of hydrological and asset conditions. Remote sensors may become unavailable from communications, power, and physical failures.
24 hours	Storm passes.
Beyond 24 hours	Recovery phase. Information from field devices may be unavailable or incomplete. IMRCP event records used to review weather conditions and response as part of after action reviews. May perform scenario analysis of different traffic management strategies.

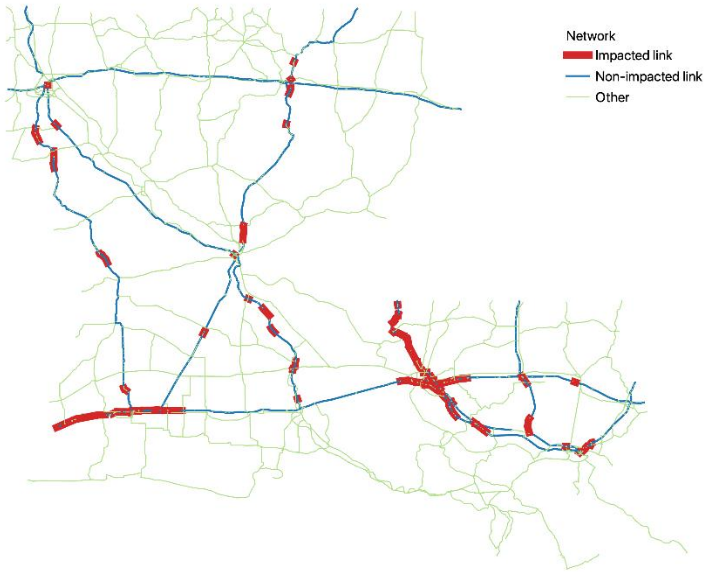
Source: FHWA.

Tropical storms are closely monitored and modeled by the National Oceanic and Atmospheric Administration's (NOAA) National Weather Service (NWS) and National Hurricane Center (NHC). State EOCs and transportation agencies similarly monitor the NHC and NWS forecasts for potential impacts on their states. IMRCP collects NHC and NWS data products for integration with its own traffic and pavement condition models. Forecast data sets collected by IMRCP include:

- Tropical storm path forecast cones.
- Wind and precipitation forecasts.
- Storm tide surge.
- NWS watches and warnings.
- River and stream levels.

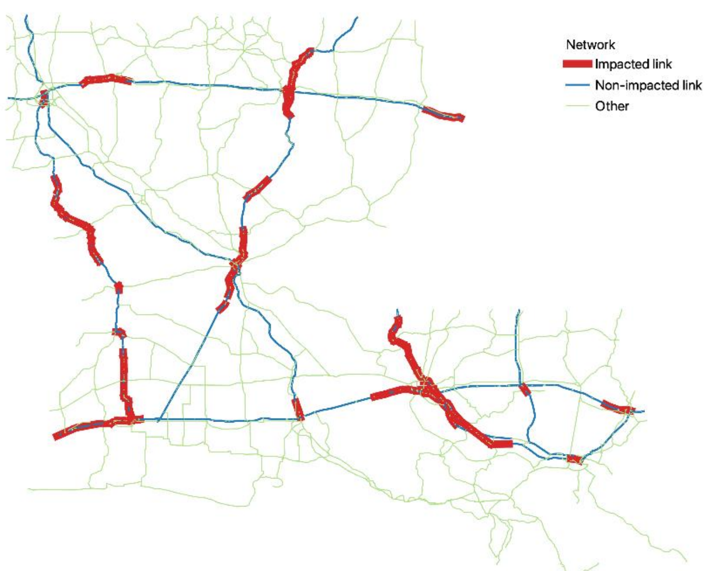
IMRCP uses these data to forecast potential road flooding and traffic based on the particular storm path and intensity. IMRCP can then be used by transportation agencies and their emergency operations partners in situation monitoring, evacuation planning, and operations during evacuations.

For tropical storms, setting up the traffic model involved getting data for as many storms as possible that had previously affected Louisiana road conditions. 2020 was a very busy tropical storm season in the Atlantic and Gulf of Mexico, and traffic and weather data records from 2020 in Louisiana were collected and processed into machine learning algorithms to build tropical storm traffic predictions for IMRCP. The resulting traffic speed model consists of three machine learning components models for predicting whether traffic on a link will be influenced by the approaching storm in a given day, predicting speeds on affected links within a given period, and predicting near-term speed based on real-time observed traffic speeds. Figure 28 shows the affected links observed for comparison to the affected links predicted as shown in Figure 29, one day before landfall for 2020 Hurricane Delta.



Source: FHWA.

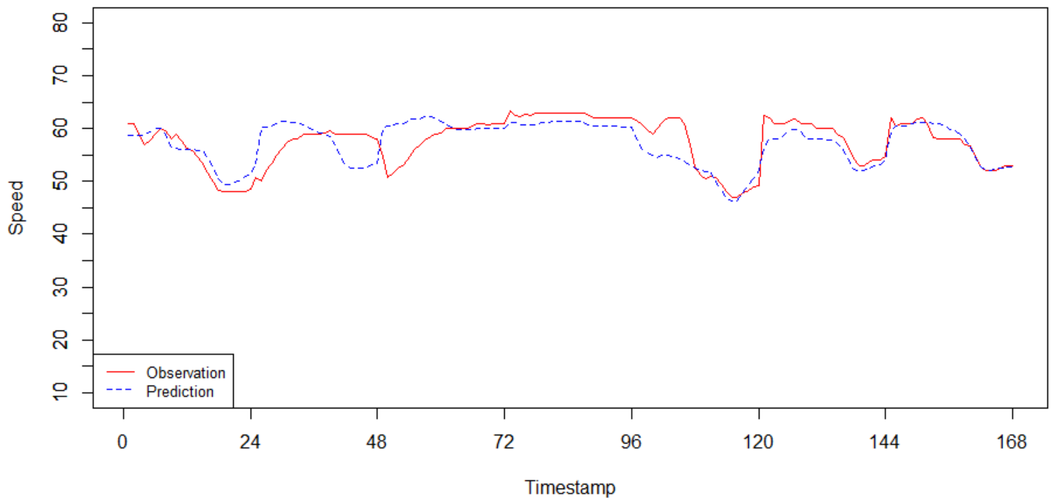
Figure 28. Graphic. Hurricane Delta congestion observations, one day before landfall.



Source: FHWA.

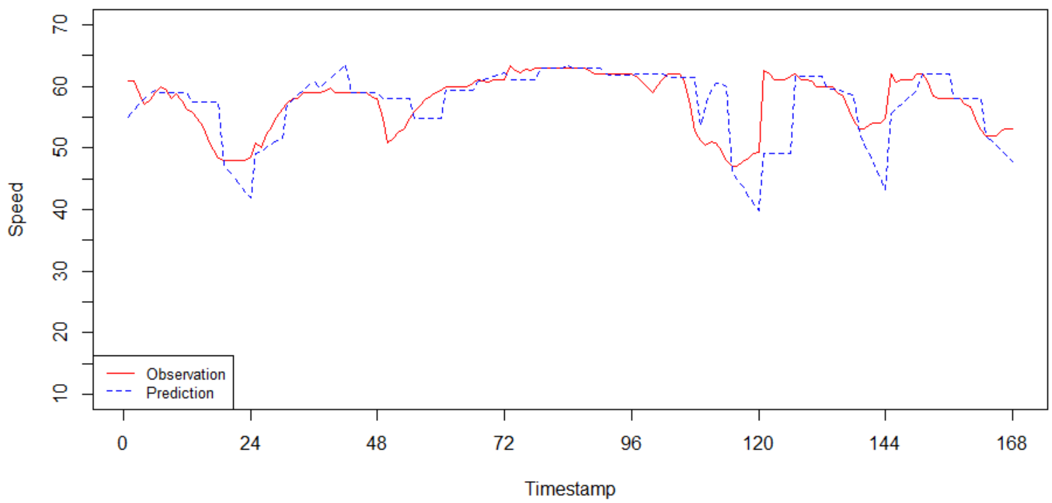
Figure 29. Graphic. Hurricane Delta congestions predictions, one day before landfall.

The three-part machine learning model also predicted traffic speeds at particular locations along evacuations for validated against observations for Hurricane Delta. In the example shown, traffic on I-10 eastbound approaching Baton Rouge was predicted based just on the training model and forecast landfall location in Figure 30, and as updated based on the hurricane path and local traffic conditions in Figure 31. Both results show excellent agreement with observations.



Source: FHWA.

Figure 30. Graphic. Speed prediction based on forecast Hurricane Delta path.



Source: FHWA.

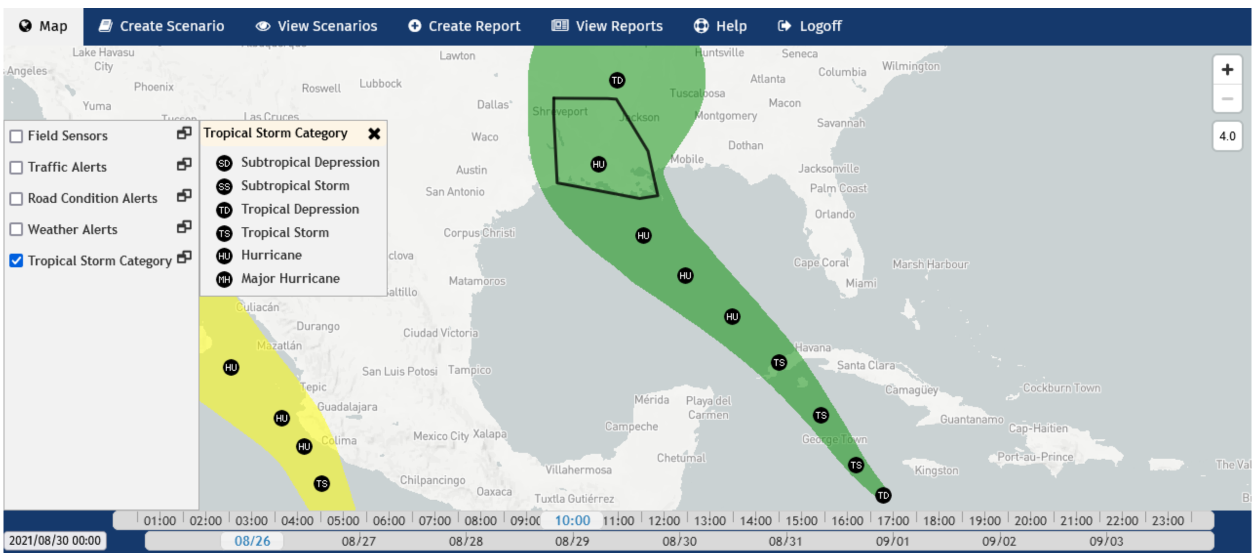
Figure 31. Graphic. On-line speed prediction based on 6-hour real-time updates.

Transportation operations as a tropical storm moves through an area are limited by necessity and practice to those essential to safety. IMRCP in this phase of a storm’s life cycle monitors wind, storm surge tide, and precipitation for potential impacts on the roadway and collects incident and event data as it becomes available to the TMC. Data collections and monitoring may be limited during the storm by power and communications outages and infrastructure damage from the storm.

The focus of transportation operations after a tropical storm has moved across a state turns to potential ongoing flooding and to recovery of infrastructure services. TMCs monitor roadway closures and other service outages in power and communications from wind and water damage. Roadways and bridges may be damaged and need emergency repairs or routing around longer closures. Storm debris may need to be removed from roadways over large areas. IMRCP can assist in monitoring weather conditions and, to the extent that road condition data is available from agencies, support post-event traffic analysis.

Example Louisiana Tropical Storm – Hurricane Ida, August 26-31, 2021

The first indications of a tropical system that might affect Louisiana were released by the NHC on Thursday morning, August 26, 2021. The storm was identified as a tropical depression located southwest of the island of Jamaica. The entire coast of Louisiana was within the forecast cone of potential storm tracks with landfall forecast as hurricane (Figure 28). The Governor of Louisiana immediately declared a state of emergency and activated the Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP) EOC. The storm was upgraded from a tropical depression to a tropical storm named Ida within a few hours.

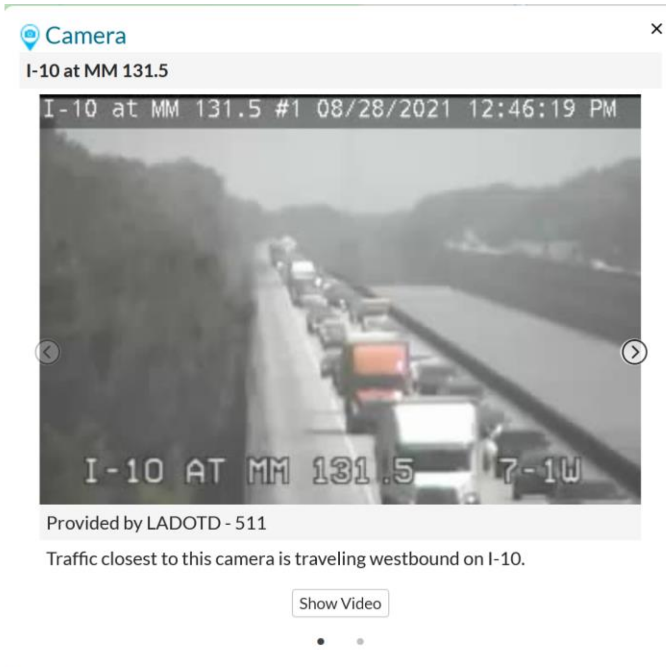


Source: FHWA.

Figure 32. Screen Capture. Forecast tropical storm track and category 8/26/2021 10:00 a.m. central time.

IMRCP monitors the developing hurricane track alongside its normal traffic and weather data sources to provide weather information for transportation operations as the hurricane approaches land. Traffic conditions are monitored in the emergency planning and evacuation phase. Ida developed very quickly and left only about 72 hours from formation to potential landfall.

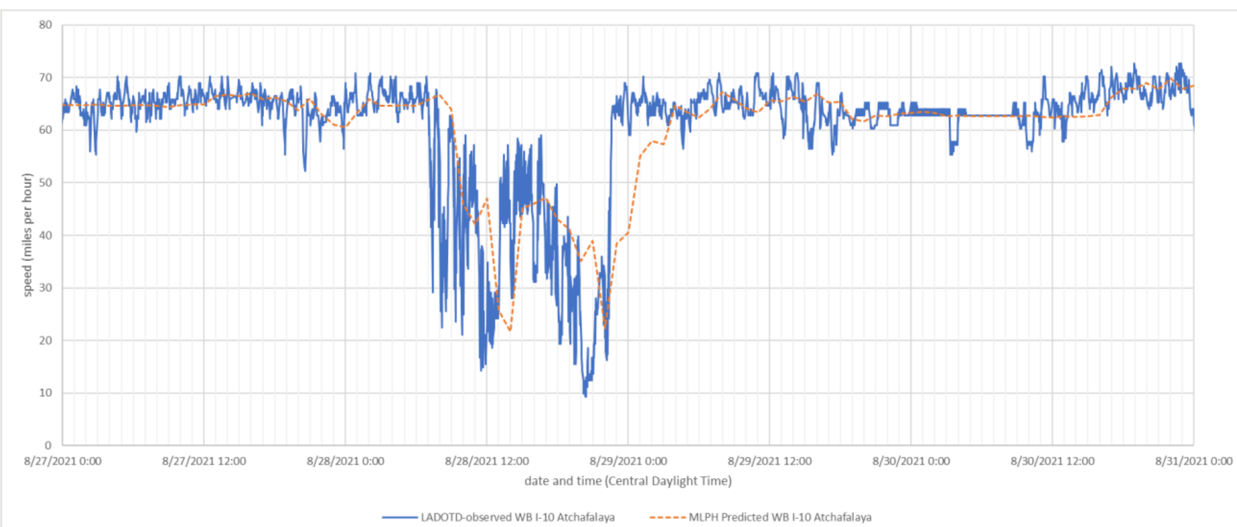
Traffic impacts from evacuations were observed Friday evening, August 27, and became widespread on Saturday the 28th. Traffic leaving Baton Rouge westbound on I-10 across the Atchafalaya Bridge was typical of conditions across the region (Figure 33).



Source: Louisiana Department of Transportation and Development.

Figure 33. Screen Capture. Traffic westbound on I-10 from Baton Rouge on August 28, 2021.

Figure 34 shows the IMRCP forecast of traffic speed over time at the same location captured by the traffic camera in Figure 33.



Source: FHWA.

Figure 34. Graphic. Observations and IMRCP forecast of traffic speed on Atchafalaya Bridge.

Traffic management strategies for improving traffic flow during evacuations focus on increasing the number of lanes available for traffic moving away from areas to be evacuated. Contraflow adds lanes by reversing the flow of traffic in existing lanes that would normally flow into those evacuation areas. Authorizing traffic on shoulders during evacuations can also be used to increase the traffic capacity.

IMRCP's scenario modeling tools theoretically can be used to simulate the effects of contraflow and shoulder running in evacuations. Data from prior instances of contraflow and shoulder running would be needed to train the traffic models. The scenario tools could then be used to indicate how many lanes would be opened and closed in each direction of travel over a time period for the evacuation.

Flooding from storm surge and tide can cause significant damage to roadways in low-lying coastal areas. IMRCP gets forecast storm surge from NOAA/NWS and computes potential roadway inundations using high-precision roadway elevations from their pavement management systems. Data for storm surge during hurricane Ida unfortunately were not captured by IMRCP.

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Leidos. 2015. "Integrated Modeling for Road Condition Prediction Model Analysis." Unpublished working paper developed under Federal Highway Administration contract DTFH61-12-D-00050, Task Order 5022, Integrated Modeling for Road Condition Prediction, May 10.

Leidos. 2015. "Integrated Modeling for Road Condition Prediction Concept of Operations." Unpublished working paper developed under Federal Highway Administration contract DTFH61-12-D-00050, Task Order 5022, Integrated Modeling for Road Condition Prediction, November 25.

Leidos. 2016. "Integrated Modeling for Road Condition Prediction System Requirements." Unpublished working paper developed under Federal Highway Administration contract DTFH61-12-D-00050, Task Order 5022, Integrated Modeling for Road Condition Prediction, January 25.

APPENDIX A. OBSERVATION TYPE DEFINITIONS

Table 3. Observation type descriptions.

Name	Description
COVCLD	total cloud cover
DIRWND	wind direction
DPHLIQ	liquid inundation depth
DPHLNK	link depth
DPHSN	snow inundation depth
EVT	event
GSTWND	wind speed gust
KRTPVT	kriged pavement temperature
KTSSRF	kriged subsurface temperature
MPLOW	MAC main plow
PCCAT	precipitation category
PRSUR	surface pressure
RH	relative humidity
RTEPC	precipitation rate
RTLIQM	liquid material rate
RTPREM	prewet material rate
RTSLDM	solid material rate
SPDLNK	average speed of vehicles on each link
SPDWND	wind speed
SSCST	extra tropical storm surge combined surge and tide
STG	flood stage
STPVT	pavement state
TAIR	air temperature
TDEW	dew point
TPLIQM	liquid material type
TPLOW	MAC tow plow
TPPREM	prewet material type
TPSLDM	solid material type
TPVT	pavement temperature
TRFLNK	traffic
TRSCAT	tropical storm category
TRSCNE	tropical storm cone
TRSTRK	tropical storm track
TSSRF	subsurface temperature
TYPPC	precipitation type
VIS	surface visibility
WPLOW	MAC wing plow

Source: FHWA.

Table 4. Observation types enumeration.

Name	Enumeration	Description
EVT	101	light-winter-precip
	102	moderate-winter-precip
	103	heavy-winter-precip
	104	light-precip
	105	moderate-precip
	106	heavy-precip
	107	low-visibility
	108	flood-stage-action
	109	flood-stage-flood
	201	dew-on-roadway
	202	frost-on-roadway
	203	blowing-snow
	204	icy-roadway
	301	incident
	302	workzone
	303	slow-traffic
	304	very-slow-traffic
	305	flooded-road
	306	lengthy-queue
	307	unusual-congestion
	399	test
	512	accident
	513	serious-accident
	514	injury-accident
	515	minor-accident
	516	multi-vehicle-accident
	517	numerous-accidents
	518	accident-involving-a-bicycle
	519	accident-involving-a-bus
	520	accident-involving-a-motorcycle
	521	accident-involving-a-pedestrian
	522	accident-involving-a-train
	523	accident-involving-a-truck
	524	accident-involving-a-semi-trailer
	525	accident-involving-a-hazardous-materials
	526	earlier-accident
	527	medical-emergency
	528	secondary-accident
	529	rescue-and-recovery-work-removed
	530	accident-investigation-work
	531	incident
	532	stalled-vehicle
	533	abandoned-vehicle
	534	disabled-vehicle

Name	Enumeration	Description
	535	disabled-truck
	536	disabled-semi-trailer
	537	disabled-bus
	538	disabled-train
	539	vehicle-spun-out
	540	vehicle-on-fire
	541	vehicle-in-water
	542	vehicles-slowing-to-look-at-accident
	543	jackknifed-semi-trailer
	544	jackknifed-trailer-home
	545	jackknifed-trailer
	546	spillage-occurring-from-moving-vehicle
	547	acid-spill
	548	chemical-spill
	549	fuel-spill
	550	hazardous-materials-spill
	551	oil-spill
	552	spilled-load
	553	toxic-spill
	554	overturned-vehicle
	555	overturned-truck
	556	overturned-semi-trailer
	557	overturned-bus
	558	derailed-train
	559	stuck-vehicle
	560	truck-stuck-under-bridge
	561	bus-stuck-under-bridge
	562	accident-cleared
	563	incident-cleared
	1000	Extreme Fire Danger
	1001	Fire Warning
	1002	Fire Weather Watch
	1003	Red Flag Warning
	1004	Heat Advisory
	1005	Excessive Heat Warning
	1006	Excessive Heat Watch
	1007	Severe Thunderstorm Warning
	1008	Severe Thunderstorm Watch
	1009	Storm Warning
	1010	Storm Watch
	1011	Tornado Warning
	1012	Tornado Watch
	1013	Severe Weather Statement
	1014	High Wind Warning
	1015	High Wind Watch

Name	Enumeration	Description
	1016	Wind Advisory
	1017	Extreme Wind Warning
	1018	Brisk Wind Advisory
	1019	Blowing Dust Advisory
	1020	Dust Storm Warning
	1021	Dense Fog Advisory
	1022	Dense Smoke Advisory
	1023	Air Quality Alert
	1024	Air Stagnation Advisory
	1025	Ashfall Advisory
	1026	Ashfall Warning
	1027	Earthquake Warning
	1028	Volcano Warning
	1029	Winter Storm Warning
	1030	Winter Storm Watch
	1031	Winter Weather Advisory
	1032	Ice Storm Warning
	1033	Blizzard Warning
	1034	Blizzard Watch
	1035	Avalanche Warning
	1036	Avalanche Watch
	1037	Blowing Snow Advisory
	1038	Snow and Blowing Snow Advisory
	1039	Heavy Snow Warning
	1040	Sleet Advisory
	1041	Sleet Warning
	1042	Snow Advisory
	1043	Freeze Warning
	1044	Freeze Watch
	1045	Freezing Drizzle Advisory
	1046	Freezing Fog Advisory
	1047	Freezing Rain Advisory
	1048	Freezing Spray Advisory
	1049	Frost Advisory
	1050	Hard Freeze Warning
	1051	Hard Freeze Watch
	1052	Wind Chill Advisory
	1053	Wind Chill Warning
	1054	Wind Chill Watch
	1055	Extreme Cold Warning
	1056	Extreme Cold Watch
	1057	Flash Flood Statement
	1058	Flash Flood Warning
	1059	Flash Flood Watch
	1060	Flood Advisory

Name	Enumeration	Description
	1061	Flood Statement
	1062	Flood Warning
	1063	Flood Watch
	1064	Hydrologic Advisory
	1065	Hydrologic Outlook
	1066	Beach Hazards Statement
	1067	Coastal Flood Advisory
	1068	Coastal Flood Statement
	1069	Coastal Flood Warning
	1070	Coastal Flood Watch
	1071	Gale Warning
	1072	Gale Watch
	1073	Hazardous Seas Warning
	1074	Hazardous Seas Watch
	1075	Heavy Freezing Spray Warning
	1076	Heavy Freezing Spray Watch
	1077	High Surf Advisory
	1078	High Surf Warning
	1079	Lake Effect Snow Advisory
	1080	Lake Effect Snow and Blowing Snow Advisory
	1081	Lake Effect Snow Warning
	1082	Lake Effect Snow Watch
	1083	Lakeshore Flood Advisory
	1084	Lakeshore Flood Statement
	1085	Lakeshore Flood Warning
	1086	Lakeshore Flood Watch
	1087	Lake Wind Advisory
	1088	Low Water Advisory
	1089	Marine Weather Statement
	1090	Rip Current Statement
	1091	Small Craft Advisory
	1092	Special Marine Warning
	1093	Tsunami Advisory
	1094	Tsunami Warning
	1095	Tsunami Watch
	1096	Hurricane Force Wind Warning
	1097	Hurricane Force Wind Watch
	1098	Hurricane Statement
	1099	Hurricane Warning
	1100	Hurricane Watch
	1101	Hurricane Wind Warning
	1102	Hurricane Wind Watch
	1103	Tropical Storm Warning
	1104	Tropical Storm Watch
	1105	Tropical Storm Wind Warning

Name	Enumeration	Description
	1106	Tropical Storm Wind Watch
	1107	Typhoon Statement
	1108	Typhoon Warning
	1109	Typhoon Watch
	1110	Hazardous Weather Outlook
	1111	Special Weather Statement
	1112	911 Telephone Outage
	1113	Administrative Message
	1114	Child Abduction Emergency
	1115	Civil Danger Warning
	1116	Civil Emergency Message
	1117	Evacuation Immediate
	1118	Hazardous Materials Warning
	1119	Law Enforcement Warning
	1120	Local Area Emergency
	1121	Nuclear Power Plant Warning
	1122	Radiological Hazard Warning
	1123	Shelter In Place Warning
	1124	Test
	5888	impassable
	5889	almost-impassable
	5890	passable-with-care
	5891	passable
	5892	surface-water-hazard
	5893	danger-of-hydroplaning
	5894	wet-pavement
	5895	treated-pavement
	5896	slippery
	5897	low-ground-clearance
	5898	at-grade-level-crossing
	5899	mud-on-roadway
	5900	leaves-on-roadway
	5901	loose-sand-on-roadway
	5902	loose-gravel
	5903	fuel-on-roadway
	5904	oil-on-roadway
	5905	road-surface-in-poor-condition
	5906	melting-tar
	5907	uneven-lanes
	5908	rough-road
	5909	rough-crossing
	5910	ice
	5911	icy-patches
	5912	black-ice
	5913	ice-pellets-on-roadway

Name	Enumeration	Description
	5914	ice-build-up
	5915	freezing-rain
	5916	wet-and-icy-roads
	5917	melting-snow
	5918	slush
	5919	frozen-slush
	5920	snow-on-roadway
	5921	packed-snow
	5922	packed-snow-patches
	5923	plowed-snow
	5924	wet-snow
	5925	fresh-snow
	5926	powder-snow
	5927	granular-snow
	5928	froazen-snow
	5929	crusted-snow
	5930	deep-snow
	5931	snow-drifts
	5932	drifting-snow
	5933	expected-snow-accumulation
	5934	current-snow-accumulation
	5935	sand
	5936	gravel
	5937	paved
	5938	dry-pavement
	5939	snow-cleared
	5940	pavement-conditions-improved
	5941	skid-hazard-reduced
	5942	pavement-conditions-cleared
MPLOW	0	Plow up
	1	Plow down

Name	Enumeration	Description
PCCAT	0	no-precipitation
	1	light-rain
	2	moderate-rain
	3	heavy-rain
	4	light-freezing-rain
	5	moderate-freezing-rain
	6	heavy-freezing-rain
	7	light-snow
	8	moderate-snow
	9	heavy-snow
	10	light-ice
	11	moderate-ice
	12	heavy-ice
	101	other
	102	unknown
	104	light-unidentified
	105	moderate-unidentified
	106	heavy-unidentified
STG	0	not-defined
	1	no-action
	2	action
	3	flood
	4	moderate
	5	major
STPVT	1	other
	2	error
	3	dry
	4	trace-moisture
	5	wet
	6	chemically-wet
	7	ice-warning
	8	ice-watch
	9	snow-warning
	10	snow-watch
	11	absorption
	12	dew
	13	frost
	14	absorption-at-dewpoint
	20	ice/snow
	21	slush
	22	melting-snow
	23	icing-rain
	30	flooded
TPLOW	0	Plow up
	1	Plow down

Name	Enumeration	Description
TRSCAT	479 642 809 1057 1072 37345 37360	Tropical Depression Hurricane Major Hurricane Tropical Depression Tropical Storm Subtropical Depression Subtropical Storm
TRSCNE	479 642 809 1057 1072 37345 37360	Tropical Depression Hurricane Major Hurricane Tropical Depression Tropical Storm Subtropical Depression Subtropical Storm
TRSTRK	479 642 809 1057 1072 37345 37360	Tropical Depression Hurricane Major Hurricane Tropical Depression Tropical Storm Subtropical Depression Subtropical Storm
TYPPC	0 1 2 3 4 5 6	none rain snow ice-pellets freezing-rain other unknown
WPLOW	0 1	Plow up Plow down

Source: FHWA.

Table 5. Observation type source descriptions.

Source	Forecast/ Observation	Spatial Extent	Temporal Extent	Observation Types
ADCIRC	forecasts	2.5 km x 2.5 km grid for CONUS	1 hour forecasts for 120 hours starting 6 hours after collection	SSCST
AHPS	observations and forecasts	Individual stations	Most recent observed values and 24 hour forecast	EVT, STG, STPVT
CAP	observations and forecasts	County and custom polygons	Varies	EVT
Geotab	observations	Individual vehicles	Observations valid for 1 minute	MPLOW, RTLIQM, RTPREM, RTSLDM, SPDLNK, TPLIQM, TPLOW, TPPREM, TPSLDM, TPVT, WPLOW
GFS	forecasts	25 km x 25 km grid for entire world	3 hour forecasts for 168 hours starting 54 hours after collection	DPHSN, GSTWND, PCCAT, PRSUR, RH, RTEPC, SPDWND, TAIR, TDEW, TYPPC, VIS
IMRCP	observations	Area surrounding individual stations	Observations valid for 1 hour	KRTPVT, KTSSRF
IMRCP	forecasts	2.5 km x 2.5 km grid for CONUS	1 hour forecasts for 72 hours starting 1 hour after collection	PCCAT
IMRCP	observations	1 km x 1 km grid for CONUS	Observations valid for 4 minutes	PCCAT
INRIX	observations	Individual segments	Observations valid for 5 minutes	SPDLNK
Lac2c	observations	Individual geo coordinates	Observations valid for 1 minute	EVT, SPDLNK
Ladotd511	observations	Individual geo coordinate points and polylines	Varies	EVT
METRo	forecasts	Individual segments	2 minute forecasts for 1 hour, then 20 minute forecasts for 11 hours	DPHLIQ, DPHSN, STPVT, TPVT, TSSRF
mlp	forecasts	Individual segments	15 minute forecasts for 2	SPDLNK, TRFLNK

Source	Forecast/ Observation	Spatial Extent	Temporal Extent	Observation Types
			hours, or 1 hour forecasts for 24 hours	
mrms	observations	1 km x 1 km grid for CONUS	Observations valid for 4 minutes	RDR0, RTEPC
ndfd	forecasts	2.5 km x 2.5 km grid for CONUS	1to 3 hour forecasts for 72 hours starting 1 hour after collection	COVCLD, RTEPC, SPDWND, TAIR, TDEW
nhc	forecasts	Tropical storm cones of probability	6 hour forecasts for 120 hours	TRSCAT, TRSCNE, TRSTRK
ohgo	observations	Individual geo coordinates	Observations valid for 5 minutes	EVT
rap	forecasts	13 km x 13 km grid for CONUS	1 hour forecasts for 21 hours	PCCAT, PRSUR, RTEPC, SPDWND, TYYPC, VIS
rtma	forecasts	2.5 km x 2.5 km grid for CONUS	1 hour forecast	COVCLD, DIRWND, GSTWND, PRSUR, SPDWND, TAIR, TDEW, VIS
wxde	observations	Individual stations	Observations valid for 1 hour	DIRWND, DPHLNK, GSTWND, PCCAT, PRSUR, RH, RTEPC, SPDWND, STPVT, TAIR, TDEW, TPVT, TSSRF, TYPPC, VIS

Source: FHWA.

Table 6. Observation type synthesis algorithms.

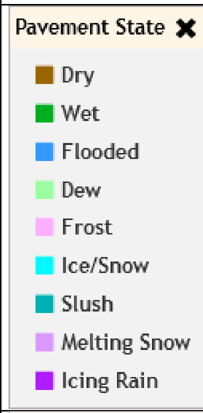
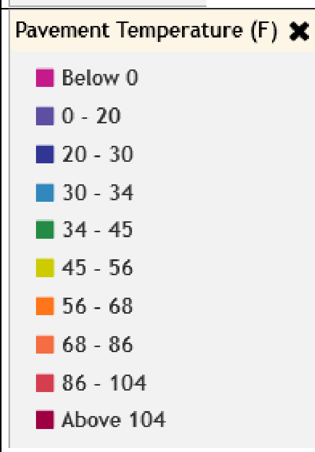
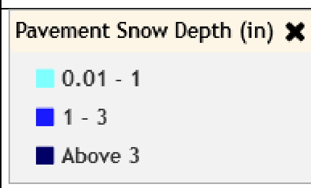
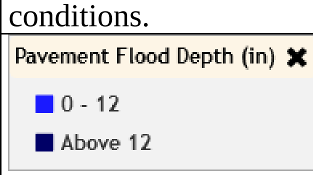
Name	Description	Source – Observations	Source – Predictions
dphliq	liquid inundation depth	Model of the Environment and Temperature of Roads (METRo) is run for each link in the road network model to determine liquid inundation depth estimations.	METRo is run for each link in the road network model to determine liquid inundation depth predictions.
dphlnk	link depth	AHPS stage observations at select locations in the road network model are collected when new values are available. These values are used to determine the flood depth on links based on inundation mapping provided by NOAA/NWS.	AHPS stage predictions at three locations in the road network model are collected when new values are available. These values are used to determine the flood depth on links based on inundation mapping provided by NOAA.
dphsn	snow inundation depth	METRo is run for each link in the road network model to determine pavement snow depth estimations. The snow inventory is tracked from previous runs.	METRo is run for each link in the road network model to determine pavement snow depth predictions. The snow inventory is tracked from each run to the next, accounting for new accumulation and melting.
evt	event	Workzone and Incident event details are collected from contributing transportation management centers. National Weather Service (NWS) Common Alerting Protocol (CAP) alert events are collected from NWS. CAP alerts affecting counties use previously stored county defintions to display on the map. CAP alerts affecting areas other than counties use the area definition provided in the CAP alert to display on the map.	Workzone and Incident event details are collected from contributing transportation management centers. NWS CAP alert events are collected from NWS. CAP alerts affecting counties use previously stored county defintions to display on the map. CAP alerts affecting areas other than counties use the area definition provided in the CAP alert to display on the map.

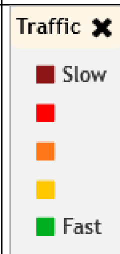
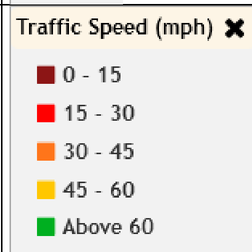
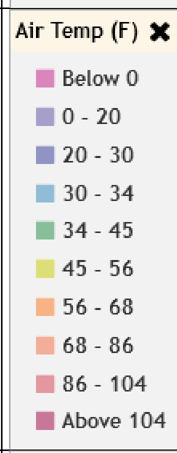
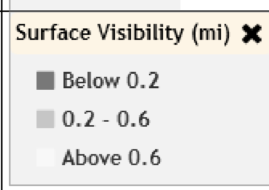
Name	Description	Source – Observations	Source – Predictions
pccat	precipitation category	The precipitation category is determined based on observation TYPPC and RTEPC. • Light Freezing Rain: RTEPC <= 7.056x10-5 kg/m2-s and TYPPC = [freezing rain] • Medium Freezing Rain: 7.056x10-5 < RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [freezing rain] • Heavy Freezing Rain: 7.056x10-4 < RTEPC kg/m2-s and TYPPC = [freezing rain] • Light Snow: RTEPC <= 7.056x10-5 kg/m2-s and TYPPC = [snow] • Medium Snow: 7.056x10-5 < RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [snow] • Heavy Snow: 7.056x10-4 < RTEPC kg/m2-s and TYPPC = [snow] • Light Ice Pellets: RTEPC <= 7.056x10-5 kg/m2-s and TYPPC = [ice pellets,] • Medium Ice Pellets: 7.056x10-5 < RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [ice pellets,] • Heavy Ice Pellets: 7.056x10-4 < RTEPC kg/m2-s and TYPPC = [ice pellets] • Light Rain: RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [rain]	The precipitation category is determined based on predicted TYPPC and RTEPC. • Light Freezing Rain: RTEPC <= 7.056x10-5 kg/m2-s and TYPPC = [freezing rain] • Medium Freezing Rain: 7.056x10-5 < RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [freezing rain] • Heavy Freezing Rain: 7.056x10-4 < RTEPC kg/m2-s and TYPPC = [freezing rain] • Light Snow: RTEPC <= 7.056x10-5 kg/m2-s and TYPPC = [snow] • Medium Snow: 7.056x10-5 < RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [snow] • Heavy Snow: 7.056x10-4 < RTEPC kg/m2-s and TYPPC = [snow] • Light Ice Pellets: RTEPC <= 7.056x10-5 kg/m2-s and TYPPC = [ice pellets,] • Medium Ice Pellets: 7.056x10-5 < RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [ice pellets,] • Heavy Ice Pellets: 7.056x10-4 < RTEPC kg/m2-s and TYPPC = [ice pellets] • Light Rain: RTEPC <= 7.056x10-4 kg/m2-s and TYPPC = [rain]

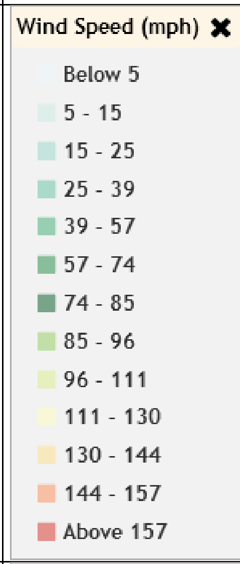
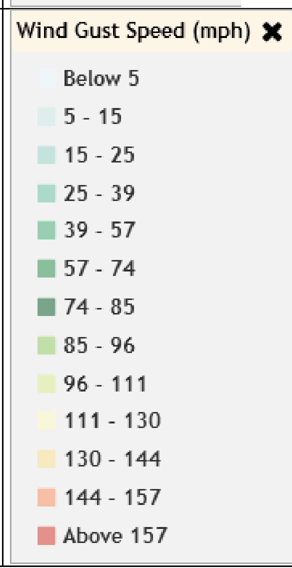
Name	Description	Source – Observations	Source – Predictions
		• Medium Rain: 7.056×10^{-4} < RTEPC <= 2.117×10^{-3} kg/m^2-s and TYPPC = [rain] • Heavy Rain: 2.117×10^{-3} < RTEPC kg/m^2 and TYPPC = [rain]	• Medium Rain: 7.056×10^{-4} < RTEPC <= 2.117×10^{-3} kg/m^2-s and TYPPC = [rain] • Heavy Rain: 2.117×10^{-3} < RTEPC kg/m^2 and TYPPC = [rain]
STpvt	pavement state	METRo is run for each link in the road network model to determine pavement state estimations. • Dry Road: The water reservoir contains less than 0.01 mm and the ice/snow reservoir contains less than .2 mm of water equivalent. • Wet road: The water reservoir contains more than 0.01 mm of water. • Ice/Snow: The ice/snow reservoir contains more than 0.2 mm of water equivalent. • Water/Snow: Both of the reservoirs (water and ice/snow) contain more than 0.2 mm of water equivalent. • Dew: Condensation on the road when the temperature of the surface of the road is above the freezing point. • Frost: Condensation on the road when the temperature of the surface of the road is below the freezing point or water already present on the road is turning into ice.	METRo is run for each link in the road network model to determine pavement state predictions. • Dry Road: Each reservoir (water and ice/snow) contains less than 0.01 mm of liquid water equivalent. • Wet road: The water reservoir contains more than 0.01 mm of water. • Ice/Snow: The ice/snow reservoir contains more than 0.2 mm of water equivalent. • Water/Snow: Both of the reservoirs (water and ice/snow) contain more than 0.2 mm of water equivalent. • Dew: Condensation on the road when the temperature of the surface of the road is above the freezing point. • Frost: Condensation on the road when the temperature of the surface of the road is below the freezing point or water already present on the road is turning into ice.
trflnk	traffic	The estimated speed value for each link is divided by the speed limit for that link.	The predicted speed value for each link is divided by the speed limit for that link.

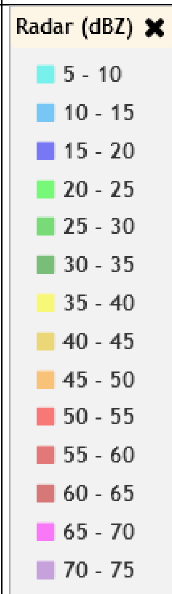
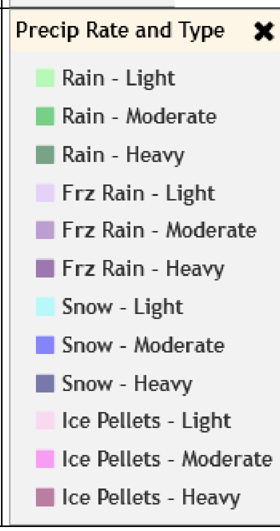
APPENDIX B. MAP LAYER LEGENDS

Table 7. Layer Definitions.

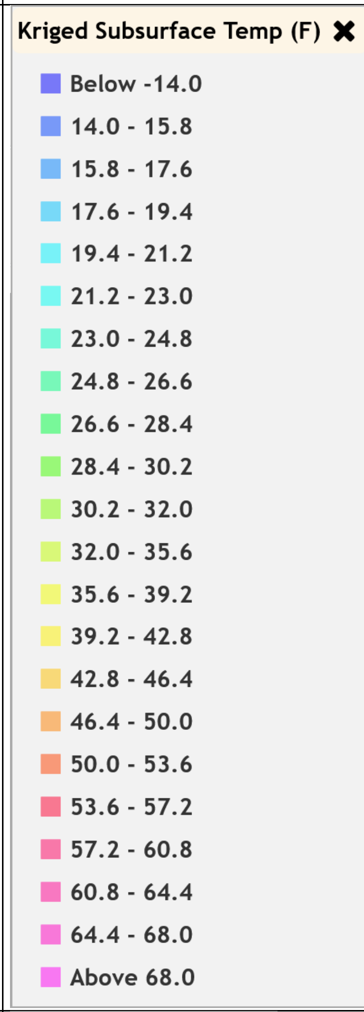
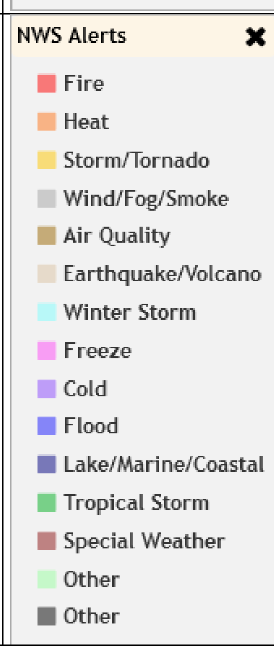
Layer	Observation Type	Legend
Pavement State	STPVT	 The Pavement State layer categories are consistent with the METRo model pavement state categories. A flooded state is projected from local inundation calculations, where available.
Pavement Temperature	TPVT	 The Pavement Temperature map layer is divided into levels based on pavement behaviors at temperature intervals. Pavement temperatures between 30°F and 34°F indicate a transition to freezing conditions. Salt treatment may be effective on pavement at temperatures between 20°F and 29°F. Salt loses its effectiveness as an anti-icing agent below 20°F.
Pavement Snow Depth	DPHSN	 The Pavement Snow Depth layer is represented in bands for noticeable, actionable, and significant impacts on travel conditions.
Pavement Flood Depth	DPHLNK	 The flood depth calculation is available only at specific locations, and an absence of a flood depth indication is not necessarily evidence of an absence of flooding.

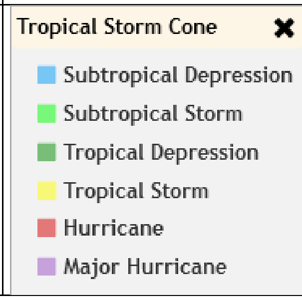
Layer	Observation Type	Legend
Traffic	TRFLNK	 The Traffic layer is divided into five categories ranging from standstill traffic to traffic moving at or near the local speed limit.
Traffic Speed	SPDLNK	 The Traffic Speed layer is divided into five equal bands ranging from 0 to 75 mph.
Air Temperature	TAIR	 The Air Temperature layer is divided into layers based on typical temperature behaviors. The narrow band at 32 F highlights the precipitation freezing point.
Surface Visibility	VIS	 The Surface Visibility layer remains white until the visibility is below 0.6 mi (1 km). Travelers can be significantly affected by visibility below this point.

Layer	Observation Type	Legend
Wind Speed	SPDWND	 The Wind Speed bands mark increasing intensity up to and through the tropical storm and hurricane levels.
Wind Gust Speed	GSTWND	 The Wind Gust Speed bands use the same levels as Wind Speed.

Layer	Observation Type	Legend
Radar	RDR0	 The Radar layer is divided into levels based on those used by the NWS.
Precipitation Rate & Type	PCCAT	 The Precipitation Rate & Type layer is divided into categories based on the observation returned by PCCAT. PCCAT categories are described in 0.

Layer	Observation Type	Legend	
Surge and Tide	DPHLIQ	Surge and Tide (ft) Below 0.3 0.3 - 0.6 0.6 - 0.9 0.9 - 1.2 1.2 - 1.5 1.5 - 1.8 1.8 - 2.1 2.1 - 2.4 2.4 - 2.7 2.7 - 3.0 3.0 - 3.3 3.3 - 3.6 3.6 - 3.9 Above 3.9	The surge and tide layer presents the depth of water from storm surge and tide over the coastal landform, provided by the NWS from its SLOSH/ADCIRC model.
Kriged Pavement Temp	KRTPVT	Kriged Pavement Temp (F) Below -14.0 14.0 - 15.8 15.8 - 17.6 17.6 - 19.4 19.4 - 21.2 21.2 - 23.0 23.0 - 24.8 24.8 - 26.6 26.6 - 28.4 28.4 - 30.2 30.2 - 32.0 32.0 - 35.6 35.6 - 39.2 39.2 - 42.8 42.8 - 46.4 46.4 - 50.0 50.0 - 53.6 53.6 - 57.2 57.2 - 60.8 60.8 - 64.4 64.4 - 68.0 Above 68.0	Spatial estimates of pavement temperature are computed by IMRCP from measurements at environmental sensor stations (ESS) using Kriging statistical methods.

Layer	Observation Type	Legend
Kriged Subsurface Temp	KTSSRF	 Spatial estimates of subsurface temperature are computed by IMRCP from measurements at environmental sensor stations (ESS) using Kriging statistical methods.
NWS Alerts	EVT	 The NWS Alerts Layer is categorized based on the type of alert issued by the NWS.

Layer	Observation Type	Legend
Tropical Storm Cone	n/a	 Tropical storm cones are represented from National Hurricane Center (NHC) data to show the potential path and current category of tropical storms.

Source: FHWA.

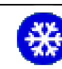
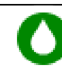
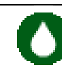
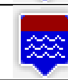
APPENDIX C. ALERT DEFINITIONS

Table 8.Traffic Alert Definitions

Type	Algorithm	Extent	Reference	Notify	Icon
Incident	EVT=Incident	point	TMC	n/a	
Work Zone	EVT=Workzone	link	TMC	n/a	

Source: FHWA.

Table 9. Weather Alert Definitions.

Type	Algorithm	Extent	Reference	Notify	Icon
Medium Winter Precip	PCCAT= [Medium Freezing Rain, Medium Snow, Medium Ice Pellets]	area	METRo	n/a	
Heavy Winter Precip	PCCAT= [Heavy Freezing Rain, Heavy Snow, Heavy Ice Pellets]	area	METRo	n/a	
Medium Precip	PCCAT= [Medium Rain]	area	METRo	n/a	
Heavy Precip	PCCAT= [Heavy Rain]	area	METRo	n/a	
Flood Stage Action	n/a	point	AHPS	n/a	
Flood Stage Flood	n/a	point	AHPS	n/a	

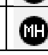
Source: FHWA.

Table 10. Road Condition Alert Definitions.

Type	Algorithm	Extent	Reference	Notify	Icon
Low Visibility	VIS < 0.2 mi	area	RAP	n/a	
Ice on Bridge	STPVT= [ice]	segment	METRo	n/a	
Flooded Road	DPHLNK > 0 in.	segment	AHPS	n/a	

Source: FHWA.

Table 11. Tropical Storm Categories.

Type	Algorithm	Extent	Reference	Notify	Icon
Subtropical Depression	From NHC	point	NHC	n/a	
Subtropical Storm	From NHC	point	NHC	n/a	
Tropical Depression	From NHC	point	NHC	n/a	
Tropical Storm	From NHC	point	NHC	n/a	
Hurricane	From NHC	point	NHC	n/a	
Major Hurricane	From NHC	point	NHC	n/a	

Source: FHWA.