Integrated Modeling for Road Condition Prediction

System User Guide

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16. Abstract

Transportation systems management and operations is at a critical point in their development due to an explosion in data availability and analytics. Intelligent transportation systems gathering data about weather and traffic conditions coupled with the imminent deployment of connected vehicles will bring an increase in data availability to power traffic and road condition predictions. This convergence of opportunities has led the Federal Highway Administration's Road Weather Management Program to initiate research into integrated modeling for road condition prediction (IMRCP) to investigate and capture that potential. The product of this IMRCP research is a prototype system and demonstration deployment that provides a framework for the integration of road condition monitoring and forecast data to support decisions by travelers, transportation operators, and maintenance providers. The system collects and integrates environmental and transportation operations data, collects forecast weather data when available, initiates road weather and traffic forecasts, generates advisories and warnings, and provides the results to other applications and systems.

The purpose of this System User Guide is to provide users 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, a description of the study area, and definitions of the map interface layers, data types, and alerts.

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Chapter 1. Introduction

Background

Transportation systems management and operations (TSMO) is at the cusp of a revolution, spurred by the explosion in data from different sources and the increasing sophistication of models using this data. New approaches in road weather management are bringing together meteorology, traffic management, law enforcement, maintenance, and traveler information to support agency decision making and influence traveler behavior. Through these operational efforts and private sector innovations, travelers today have higher expectations for their travel experience. Travelers also now participate in generating and validating information as well as consuming it. This trend will accelerate with deployment of connected vehicle (CV) systems. Within this context, the role of prediction and forecasting will become more important to the travel and activity choices made by travelers, as well as to agency decisions in transportation operations. Freight carriers and logistics providers will also benefit in planning routes, times, and delivery schedules.

Development and adoption of traffic prediction approaches by operating agencies have been limited even with a growing body of research. While this is partly attributable to limited data, available predictive tools have been narrowly focused and have not taken full advantage of developments in related disciplines and domains. As a result, the use of predictive strategies in support of operational decisions continues to be limited.

Recent efforts to incorporate forecast weather conditions in traffic predictions in the United States Department of Transportation (U.S. DOT) Traffic Estimation and Prediction System (TrEPS) project have shown considerable promise. The utility of traffic predictions can, however, be further enhanced by augmenting the forecast weather conditions with known and likely capacity constraints, such as work zones and incidents. Factoring in reported conditions from environmental sensor stations, vehicle fleets, and citizen-reported conditions will further enhance predictions. Current and planned road treatment approaches, snowplow routing, parking restrictions, and maintenance decisions could be included as well.

Based on these opportunities, the Federal Highway Administration (FHWA) has initiated an investigation into and development of an Integrated Model for Road Condition Prediction (IMRCP). This effort includes an initial survey of available and imminent weather, hydrological, traffic, and related transportation management models; development of a concept of operations (ConOps); and development of fundamental system requirements. Follow-on efforts will develop a system architecture and system design, implement a foundational system, and deploy the system with an operating transportation agency to evaluate its effectiveness.

Purpose

As described in the IMRCP ConOps, the purpose of the IMRCP is to integrate weather and traffic data sources and predictive methods to effectively predict road and travel conditions. The first step in the study surveyed the existing field of predictive models in road weather, traffic, and related disciplines. The ConOps then developed the case for and a description of an integrated model for predicting road conditions that incorporates transportation and non-transportation data, deterministic and probabilistic data, and measured and reported data. The model could ultimately become a practical tool for transportation agencies to support traveler advisories, maintenance plans, and operational decisions at both strategic and tactical levels.

The purpose of this System User Guide is to provide users 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, a description of the study area, 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, and report/subscription page.

Chapter 4 outlines possible uses of the IMRCP system and instructions for performing these use cases.

Chapter 5 lists the references of the IMRCP User Guide.

Appendix A catalogs the acronyms used throughout the document.

Appendix B discusses the Kansas City study area as well as the sources located in the study area.

Appendix C defines each of the layers on the map interface.

Appendix D explains each of the observation types available in the system and the sources of each observation type.

Appendix E defines each of the possible alerts in 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.

Figure 1 provides an overview of the IMRCP system. The IMRCP system in this view performs five major functions:

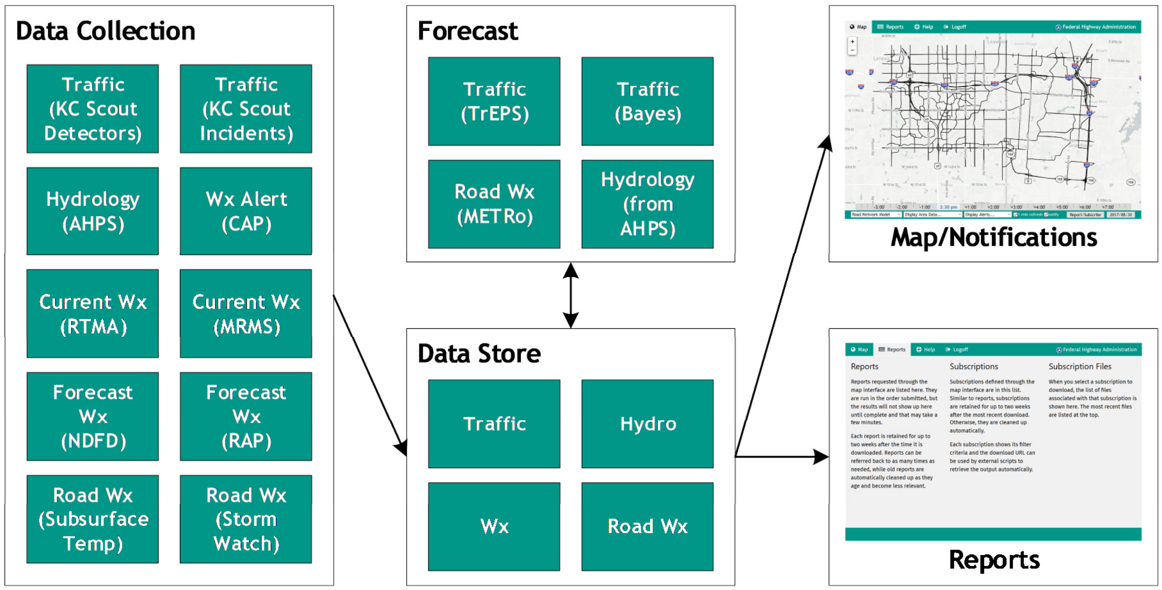
- Collecting weather, traffic, operations, and hydrological data from numerous online sources for use in predicting road and weather conditions.
- Storing the collected and system-generated data.
- Generating forecasts of road conditions.
- Mapping the forecasts, current conditions, alert notifications, and archive data for system users;
- Reporting on forecasts, current conditions, alerts, and archive data.

Data sources and the road network model are specific to a particular study area. The greater Kansas City metropolitan area was used for the IMRCP system demonstration as described in Appendix A. The data sources shown in Figure 1 are specific to the Kansas City demonstration but might be applicable to other study areas as well.

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, detectors, 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 for notifications. Users may also view the data through reports and subscriptions. The user interface functionalities are described in Chapter 3.



Source: FHWA, 2019

Figure 1. IMRCP Functions.

Chapter 3. User Instructions

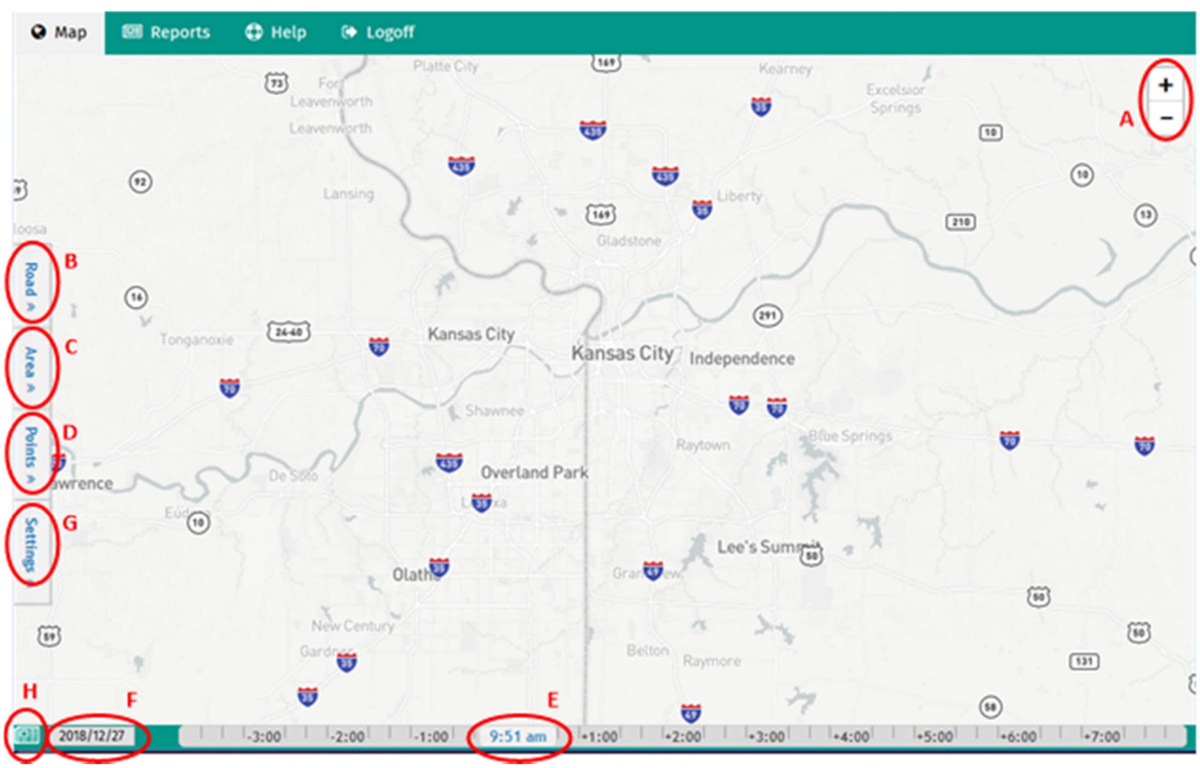
Login

The IMRCP user interface can be accessed at https://imrcp.data-env.com/. Users must input their username and password on the IMRCP home page to access the full user interface. Usernames and passwords must be provided by a system administrator.

Map

The IMRCP map provides views of alerts, road conditions, and weather in the immediate past, present, and near future.

The controls on the map in Figure 2, indicated by alphabetical notation, are described in the following sections.



Source: FHWA, 2019

Figure 2. Map User Controls.

Using Map Tools

1. To zoom into and out of the map, use the zoom controls **(A)** 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 disappear when zoomed out too far.
2. To move the map, click on the map and drag the cursor.

Viewing Road Condition Data

1. Select a road data layer from the "Road" tab and panel (B) on the left side of the page. Click the tab to open the panel, and then click the right-pointing arrow next to "Select Road Layer". A new panel will open to the right. Select the type of data to be displayed. A legend for the selected data type will appear in the left panel and a spinner icon will take the place of the left-pointing arrow while the data are loading. Click the left-pointing arrow to close the selection panel. Click the "Road" tab to close the legend panel; clicking the tab again will reopen the legend panel. The layer definitions can be found in Appendix C.
2. Click on a road segment on the map to view data for specific road segments in the study area.

Viewing Weather Condition Data

1. Select a data layer from the "Area" tab and panel **(C)** on the left side of the page. Click the tab to open the panel, and then click the right-pointing arrow next to "Select Area Layer". A new panel will open to the right. Select the type of data to be displayed. A legend for the selected data type will appear in the left panel and a spinner icon will take the place of the left-pointing arrow while the data are loading. Click the left-pointing arrow to close the selection panel. Click the "Area" tab to close the legend panel; clicking the tab again will reopen the legend panel. The layer definitions can be found in Appendix C.
2. Data for specific areas in the study area may be viewed by clicking on an area on the map.

Viewing Alerts and Station Data

1. Select a data layer from the "Points" tab and panel **(D)** on the left side of the page. Click the tab to open the panel, and then click the right-pointing arrow next to "Select Points Layer". A new panel will open to the right. Select the type of data to be displayed. A legend for the selected data type will appear in the left panel and a spinner icon will take the place of the left-pointing arrow while the data are loading. Click the left-pointing arrow to close the selection panel. Click the "Points" tab to close the legend panel; clicking the tab again will reopen the legend panel.
2. A description of an alert may be viewed by clicking on an alert icon. Alert definitions can be found in Appendix E, and the Traffic Detectors layer is described 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 time on the time scale at the bottom of the map using the slider tool **(E)**.
2. Time frames further in the past can be selected by clicking on the date display **(F)**. A small calendar dialog will pop up over the map. Select a date on the monthly calendar using the left and right arrows at the top of the dialog to change the month and the calendar to select the day. The reference time on that day is selected with the control 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 slider to the left will display data for that time; moving to the right will display forecasts as seen from that reference time.

3. To go back to the current time, click on the date display **(F)** and then double-click on “NOW” in the pop-up dialog.

Changing Settings for the Map View

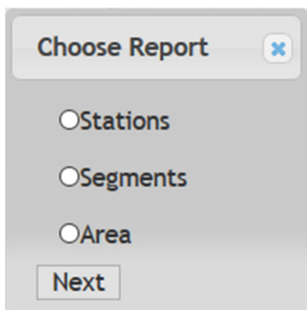
Map view options can be changed and saved as account defaults using the “Settings” tab and panel **(G)** on the left side of the page.

1. Set the map zoom level, location, and time frame.
2. Click on the “Settings” tab. Road types can be set with check boxes to “Highways”, “Arterials”, or both. Map Behaviors can refresh the map view once a minute and display (checked) or suppress (unchecked) notifications.
3. The current settings can be saved as defaults and will become active when the “Settings” tab is clicked.

Creating a Report or Subscription

Reports can be created to view specific observation and forecast types for the study area for specific time periods and locations.

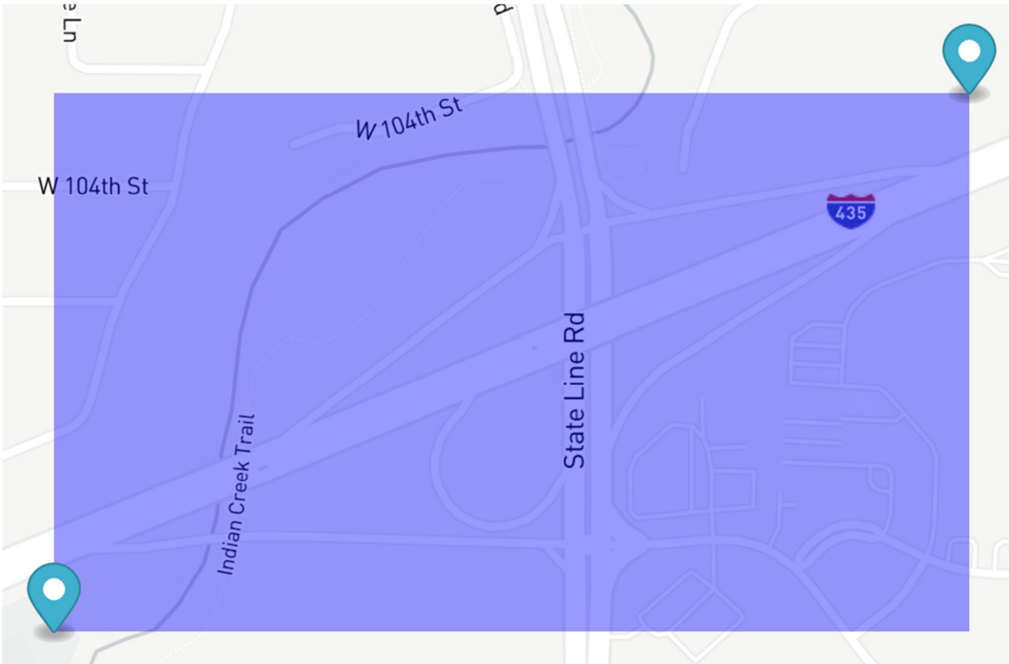
1. Select the “Report/Subscribe” button **(H)** in the lower left corner of the page. A small dialog will appear over the map. Select the type of report to create and click “Next”.



Source: FHWA, 2019

Figure 3. Report/Subscription Selection Dialog.

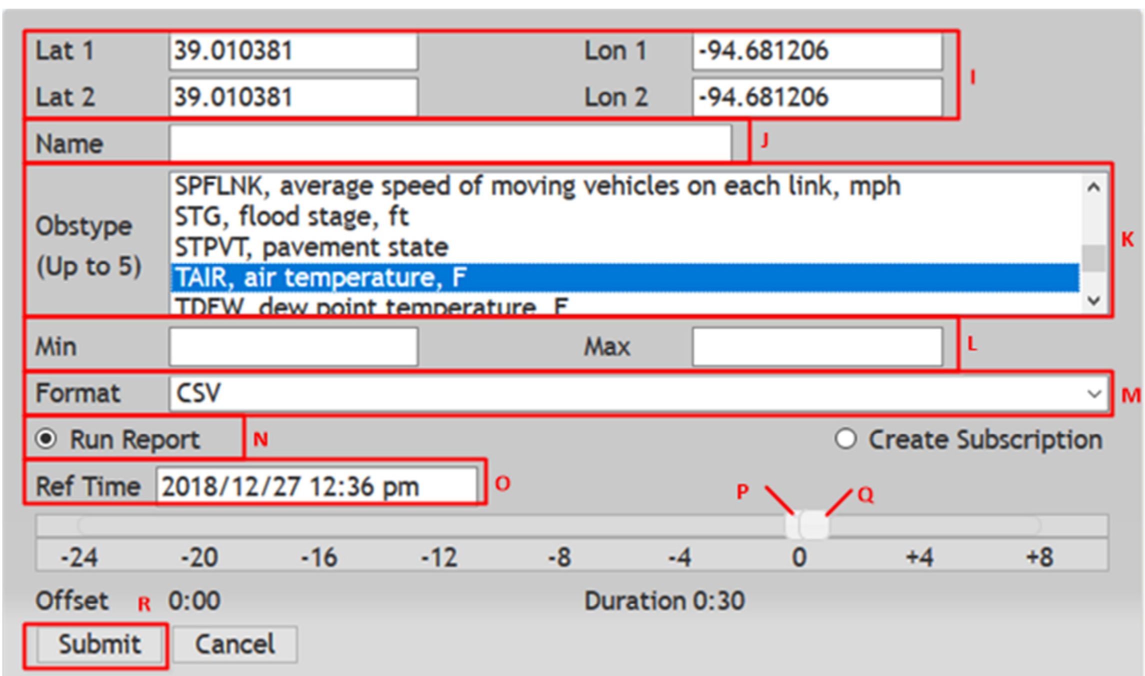
2. Follow the tool tips to select the particular stations, segments, or areas for the report or subscription. For stations, click on the stations for which to report, and press “esc” to clear or “enter” to select. For segments, click on the segments for which to report, and press “esc” to clear or “enter” to select. For an area, click and drag the cursor on the map to draw a box around the area from which you would like to collect data.
3. To adjust the box, click and drag the icons on the corners of the map**.** Press “esc” to clear or “enter” to select.



Source: FHWA, 2019

Figure 4. Area Selection Tool.

4. A dialog for setting the report/subscription details will appear over the map:



Source: FHWA, 2019

Figure 5. Report Details Dialog.

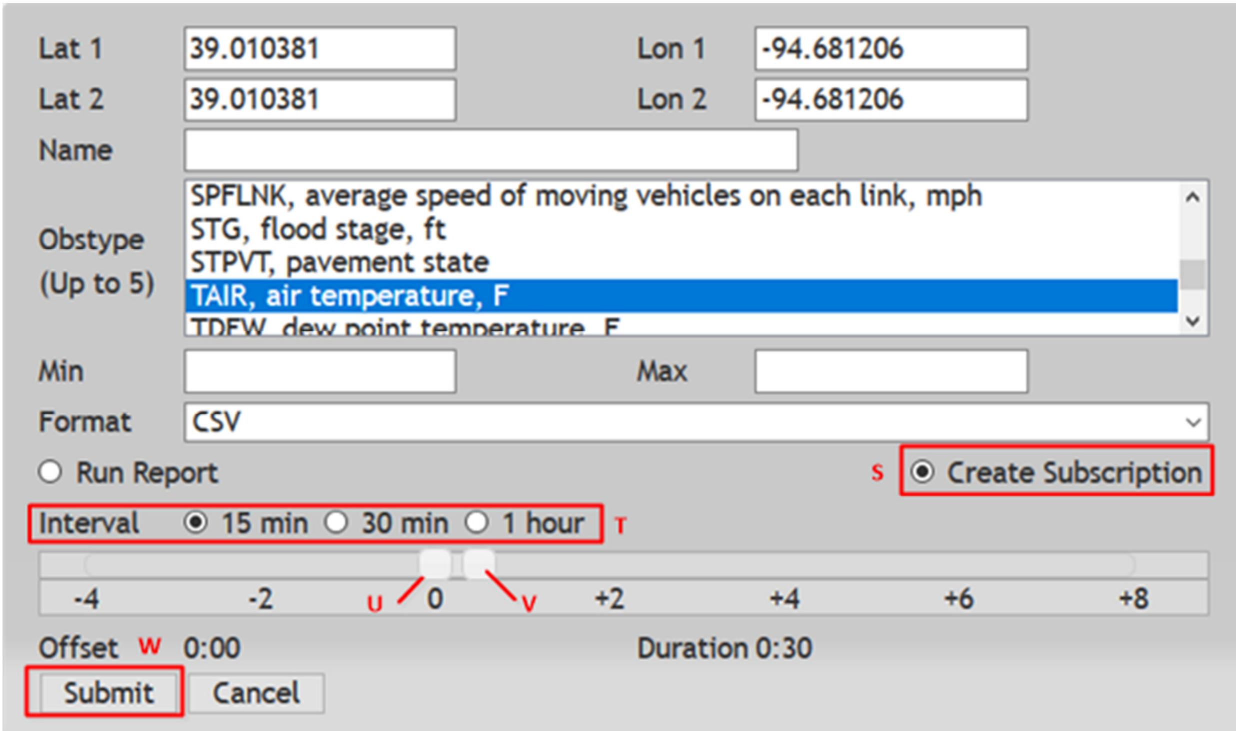
5. To manually adjust location of the box on the map, change the latitudes and longitudes in the Report/Subscription wizard **(I)**.
6. Type a name in the name field **(J)**.
7. Select the observation type(s) to be listed in the report/subscription **(K)**.
   a. To select multiple observation types, hold down the control key to select individual types, or use the shift key to select a range of types.
   b. If only selecting one observation type, optionally type a minimum and maximum value for that observation type in the “Min” and “Max” fields **(L)**.
8. Select the format for the report/subscription from the dropdown menu **(M)**.

To run a report:

9. Select the “Run Report” radio button on the Report/Subscription wizard **(N)**.
10. Select a reference date and time by clicking on the “Ref Time” input box **(O)**.
11. Set the time range for the report relative to the reference time using the left **(P)** and right **(R)** 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 **(R)**.
13. For further information on viewing a report, see the “Viewing a Report” section in this document.

To create a subscription, complete the top part of the dialog and then:

14. Select the “Create Subscription” radio button on the Report/Subscription wizard **(S)**.
15. Select an interval radio button **(T)**.
16. Set the time range for the report relative to the reference time using the left **(U)** and right **(V)** 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.
17. Select the “Submit” button **(W)**.



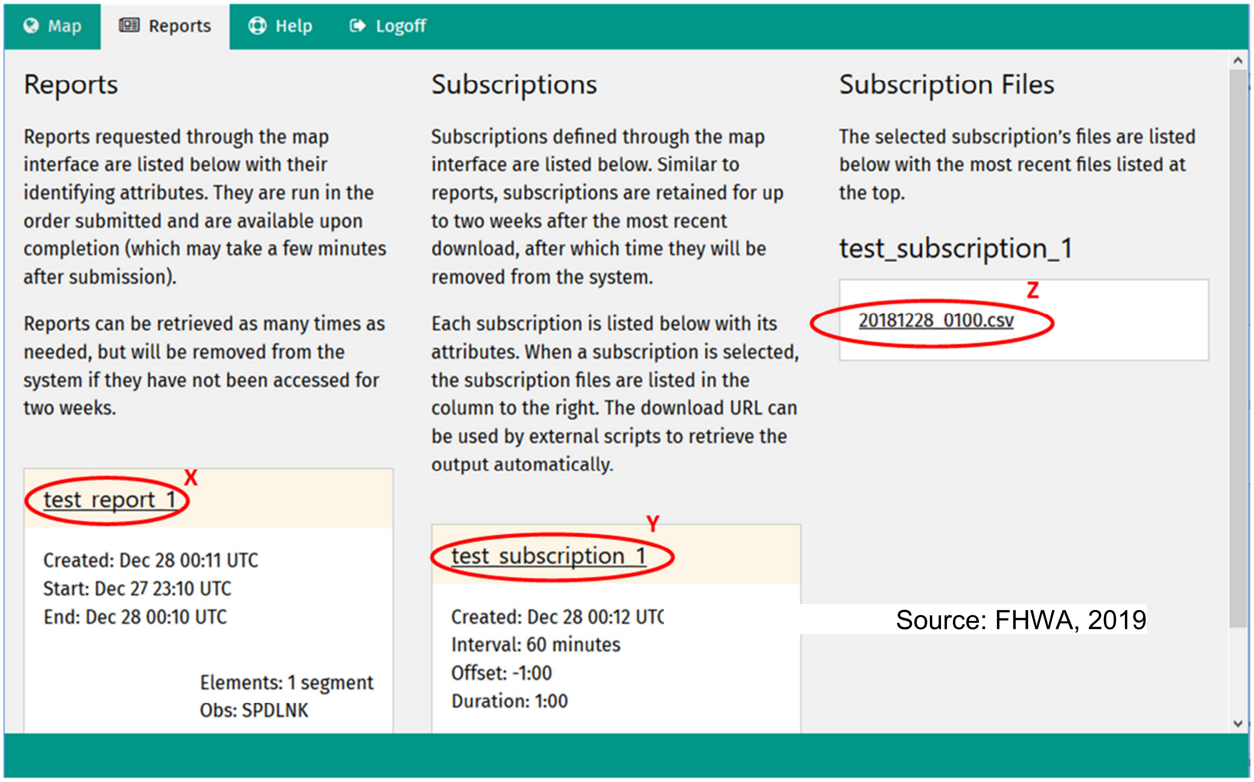
Source: FHWA, 2019

Figure 6. Subscription Details Dialog.

For further information on viewing a subscription, see the "Viewing a Subscription" section in this document.

Reports

On the IMRCP Reports page, the reports requested by the user are listed in the left panel and the subscriptions requested by the user are listed in the center panel. The creation date and filter criteria for each report and subscription is listed below its name. Each report and subscription is retained for 2 weeks after it has been downloaded and will then be removed from the system. Observation type definitions and units can be found in Appendix D.



Source: FHWA, 2019

Figure 7. Reports and Subscription Listings.

Viewing a Report

1. To view a report, click on the report name **(X)** 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

1. To view a subscription, click on the subscription's name **(Y)** in the center panel of the page. The files generated for that subscription will appear in the right panel of the page.
2. Click on the subscription file you would like to open **(Z)**. The subscription files are named based on the time they are generated in a "YYYYMMDD_HHMM" format.

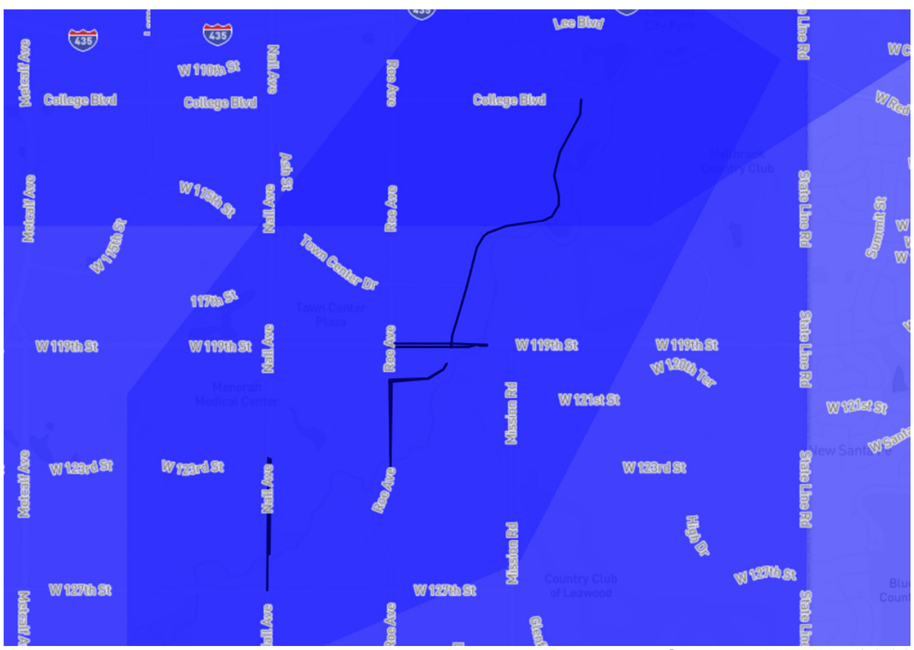
Chapter 4. Example Uses

Roadway Flooding

One use of the IMRCP system may be to view hydrological conditions on roadways during flooding events. The Kansas City demonstration study area was chosen in part because of its hydrological challenges. Users can use the IMRCP system to view predictions for flooded roads or to look back at the behaviors of a hydrological event.

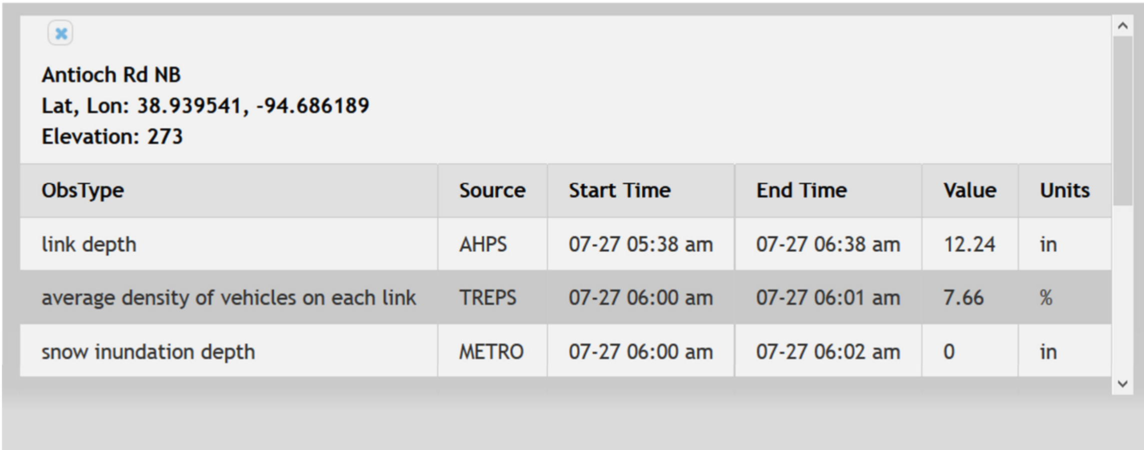
The small-stream flooding of July 27, 2017, proved to be a challenging hydrological event for the Kansas City study area. Several roads in the study area experienced flooding and closures. This event can be reconstructed on the map using various layers and the date/time function. In the case pictured below, the date/time function has been set to 7/27/17 6:00 a.m. The Pavement Flood Depth layer and NWS Alert layer have been selected. The Pavement Flood Depth layer displays the roads that the IMRCP indicated as flooded based on data received from the NWS. The roads with pavement flood depths above 12 inches are coded in dark blue. The NWS Alert layer displays several blue polygon overlays representing flood-related NWS alerts in the study area. The overlays are darker in some areas to indicate multiple alert overlays on top of one another.

The time slider can be moved backward or forward to view the changes in the flood depths of the roads and the NWS Alert overlays. When a link is selected on the map, a pop-up box displays the flood depth calculated for the link at the time of the time slider. When an area is selected on the map, all overlays that intersect with that point are listed in the pop-up box at the time of the time slider.



Source: FHWA, 2019

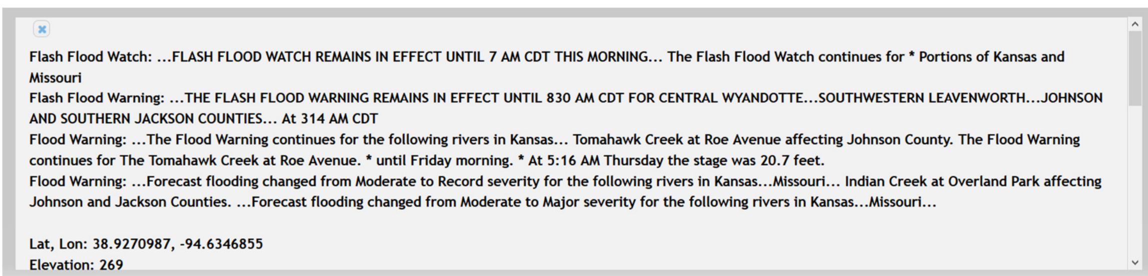
Figure 8. July 27, 2017, Hydrological Event, Map View.



ObsType	Source	Start Time	End Time	Value	Units
link depth	AHPS	07-27 05:38 am	07-27 06:38 am	12.24	in
average density of vehicles on each link	TREPS	07-27 06:00 am	07-27 06:01 am	7.66	%
snow inundation depth	METRO	07-27 06:00 am	07-27 06:02 am	0	in

Source: FHWA, 2019

Figure 9. July 27, 2017, Hydrological Event, Link Data.



Source: FHWA, 2019

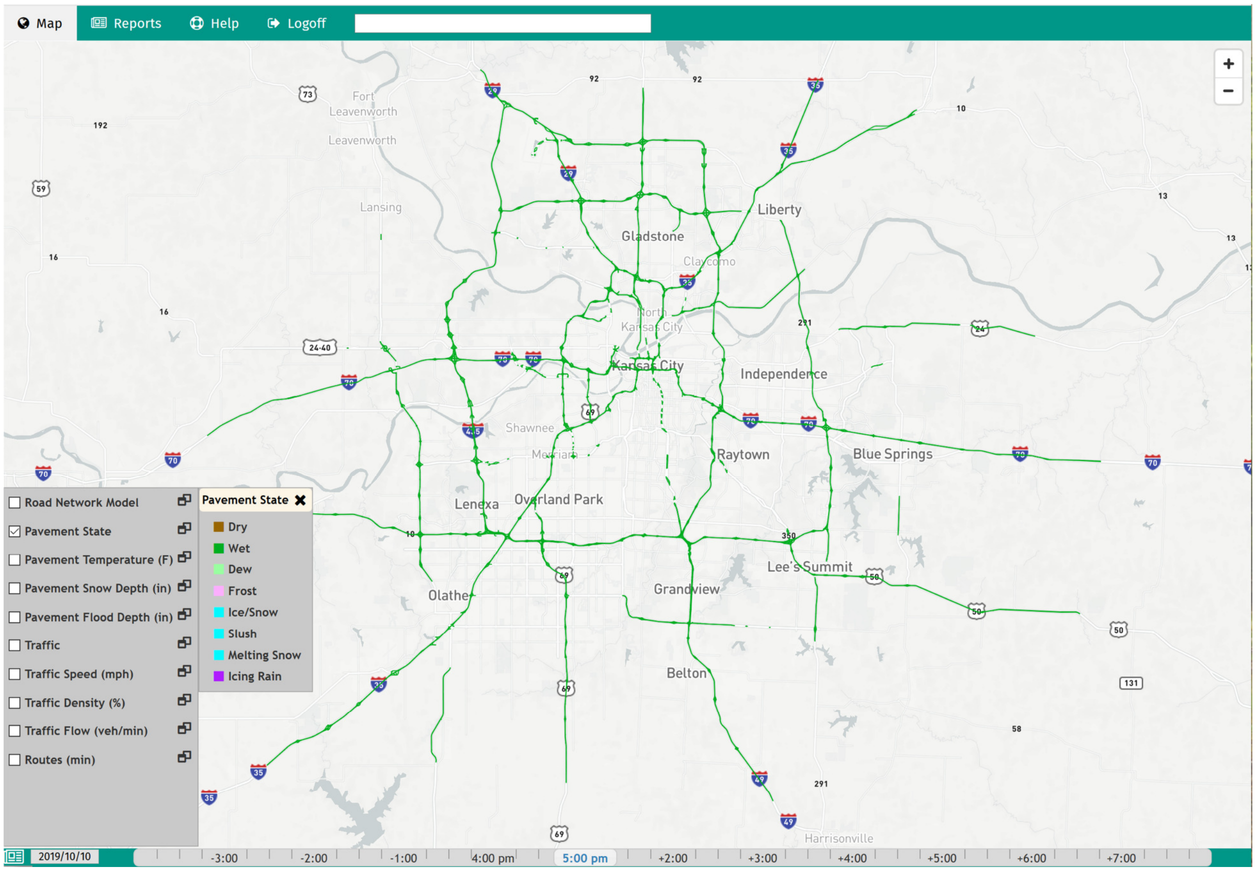
Figure 10. July 27, 2017, Hydrological Event, Area Data.

Pavement State Prediction

It may be beneficial for operators to view pavement state predictions as a weather event approaches, especially if the event will occur immediately prior to or during peak traffic hours. Predictions that indicate wet or icy roads may allow operators to prepare for such events. The map and reports function can be used to view these predictions.

Traffic operators can use this pavement condition prediction to make plans for inclement weather. Knowing the potential risks ahead of time, maintenance staff can make more specific plans for anti-icing and snow removal operations. Operations staff can provide more timelay and accurate traveler information for travelers dealing with the inclement conditions.

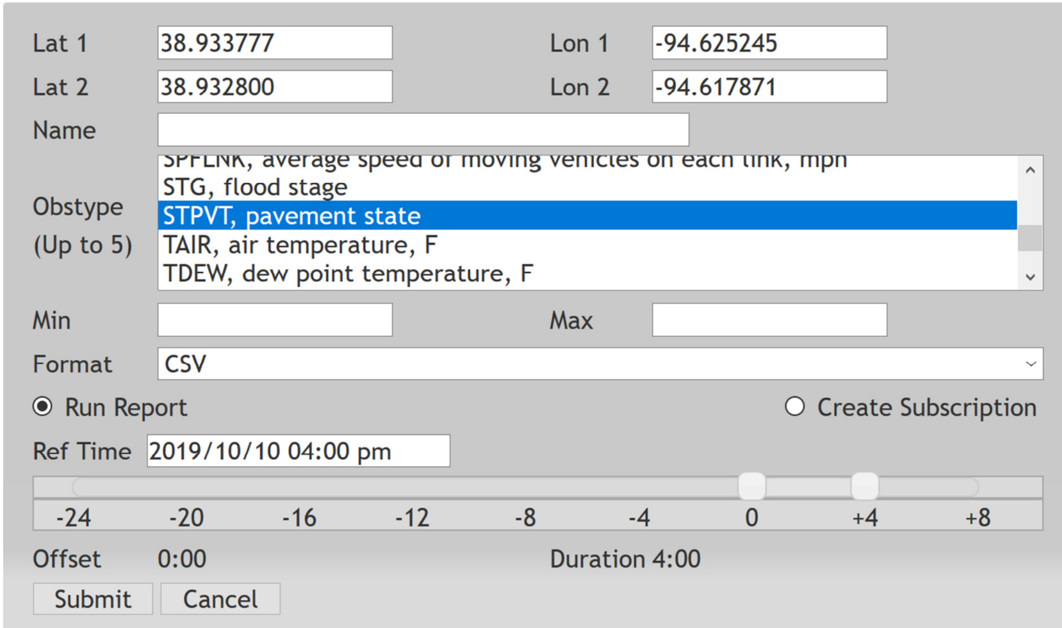
To view pavement state predictions on the map, users can set the date/time function to “Now” and select the Pavement State road data layer. Then the user can move the time selector to peak traffic times. The color of the segments on the map based on the legend indicates the pavement state predictions. Users can zoom in and out of the map to view different parts of the study area and segments on the map can be selected to confirm the pavement state through the detailed pop-up box. Users can use the 1-minute refresh option to allow the map to update with new predictions as new information becomes available. Figure 11 shows the pavement state predicted at 4:00 p.m. for for the study area at 5:00 p.m. on 10/10/2019. The map forecasts wet pavement throughout the study area.



Source: FHWA, 2019

Figure 11. Pavement State Prediction Example.

To get predictions from the system in report form, the report/subscription function can be used to draw a box around the study area or a portion of the study area. The user should set the report conditions to an obstype of STPVT (pavement state) and to the Report radio button. The reference time should be set to the current time and the offset should be set to 0:00 so that only predictions will be returned in the report. The duration should be set to the amount of time until the end of peak traffic hours. For example, Figure 12 shows the report/subscription wizard for a report with a reference time of 4:00 p.m. on 10/10/2019, an offset of 0:00, and a duration of 4:00. This will return a report for pavement state predictions between 4:00 and 8:00 p.m. on 10/10/2019.



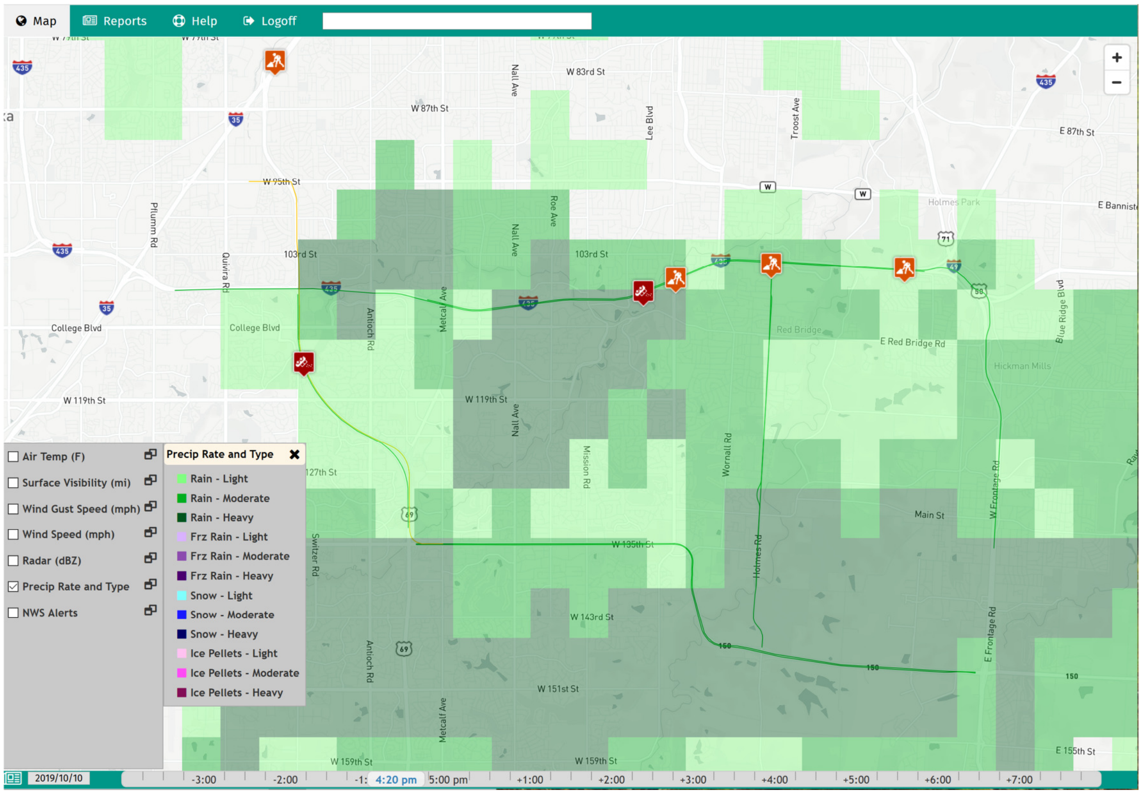
Source: FHWA, 2019

Figure 12. Report Wizard for Pavement State Predictions.

Travel Time Predictions

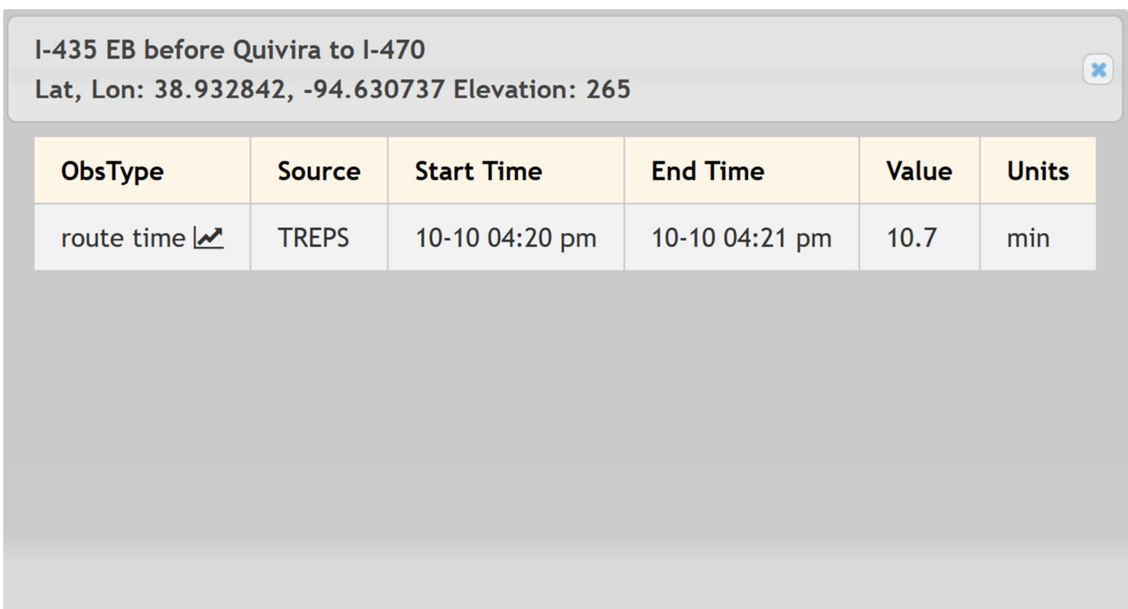
Operators and travelers may find the route travel times produced by the IMRCP useful for monitoring congestion and commute times. During inclement weather events, a user could use the IMRCP to adjust the departure time for their daily commute. For instance, a user who works at Overland Park Regional Medical Center near I-435 and Quivira and lives near Three Trails Crossing could check to see if the approaching thunder storm will affect their usual evening commute home by using the IMRCP.

The user can select the Routes layer from the road data layer drop-down box on the map interface. This layer shows routes with available travel times in black on the map. Each of the routes can be selected and the travel time will be displayed in the pop-up box. It may also be beneficial to display the Precipitation Rate and Type to view the forecasted precipitation over the near future. In Figure 13 below, the Routes and Precipitation Rate and Type layers have been selected and are displayed for the current time. Figure 14 shows that the travel time for the I-435 EB before Quivira to I-470 route is 10.7 minutes.



Source: FHWA, 2019

Figure 13. Routes and Precipitation Rate & Type Layers during rain event.


I-435 EB before Quivira to I-470
Lat, Lon: 38.932842, -94.630737 Elevation: 265

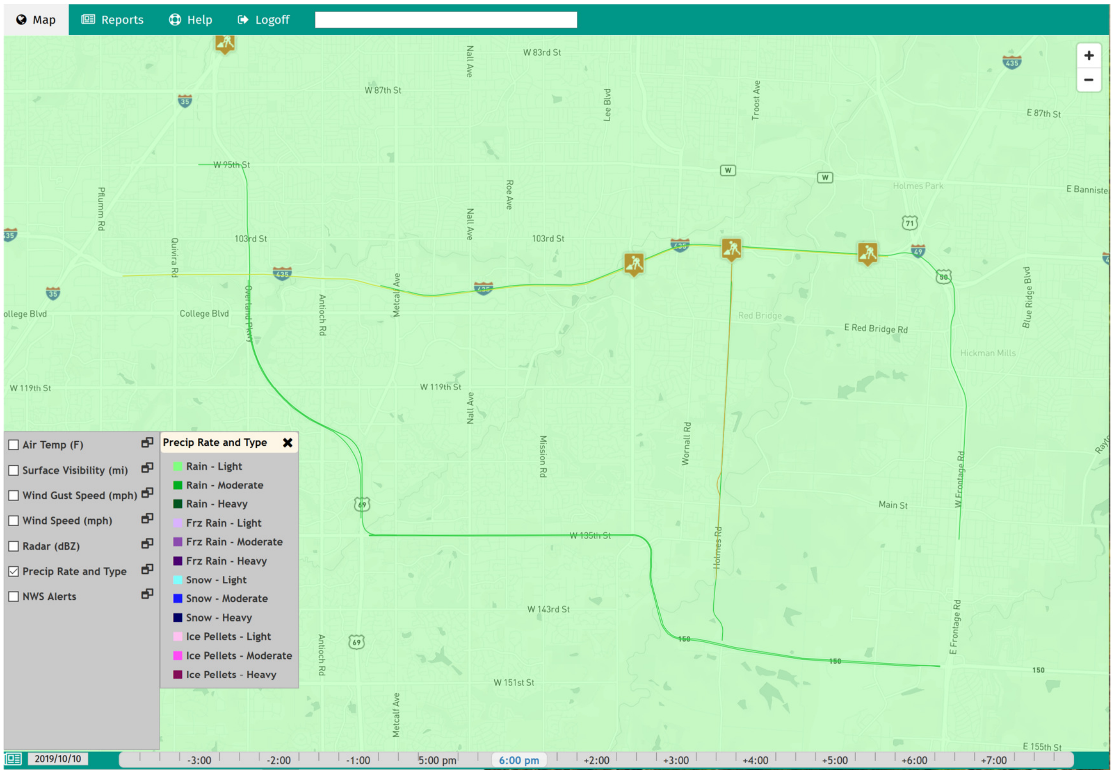
ObsType	Source	Start Time	End Time	Value	Units
route time	TREPS	10-10 04:20 pm	10-10 04:21 pm	10.7	min

Source: FHWA, 2019

Figure 14. Pop-up box for I-435 EB before Quivira to I-470 route.

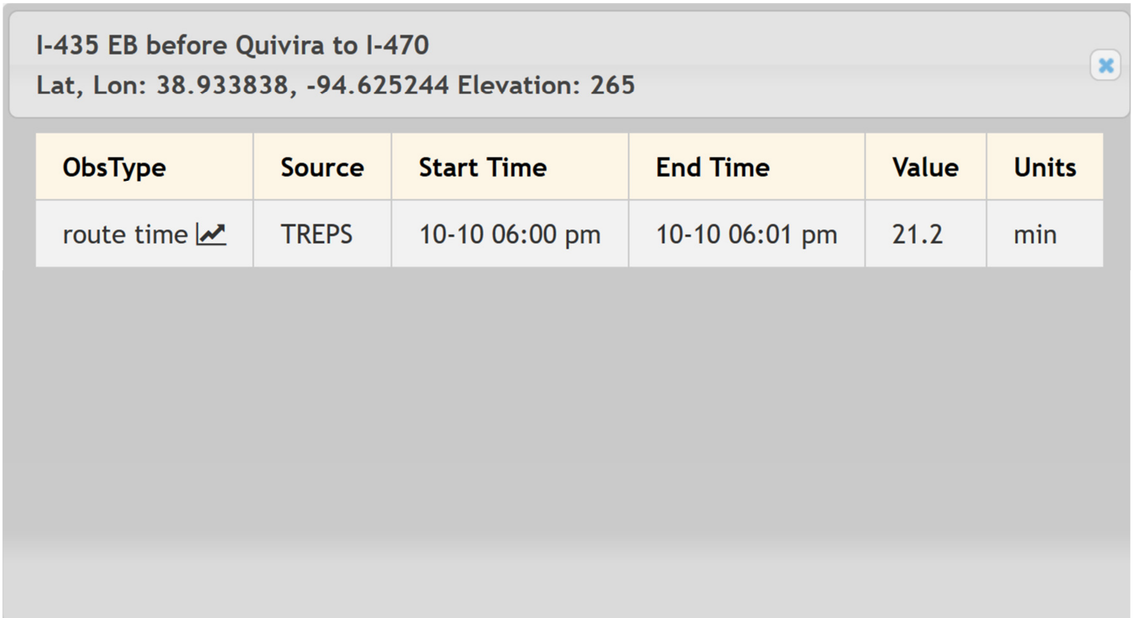
The user can slide the time selector into the future to determine future route travel time predictions. The user may see that if they delay their commute until 6:00 p.m., precipitation is predicted to continue.

According to the IMRCP, the travel time for the I-435 EB before Quivira to I-470 route if they delay the commute would be longer at 21.2 minutes. The user can make a decision on whether to leave at the regula time or delay their normal commute based on this information.



Source: FHWA, 2019

Figure 15. Predicted Routes and Precipitation Rate & Type Layers during Rain Event.


I-435 EB before Quivira to I-470
Lat, Lon: 38.933838, -94.625244 Elevation: 265

ObsType	Source	Start Time	End Time	Value	Units
route time	TREPS	10-10 06:00 pm	10-10 06:01 pm	21.2	min

Source: FHWA, 2019

Figure 16. I-435 EB before Quivira to I-470 Predicted Travel Time.

Chapter 5. References

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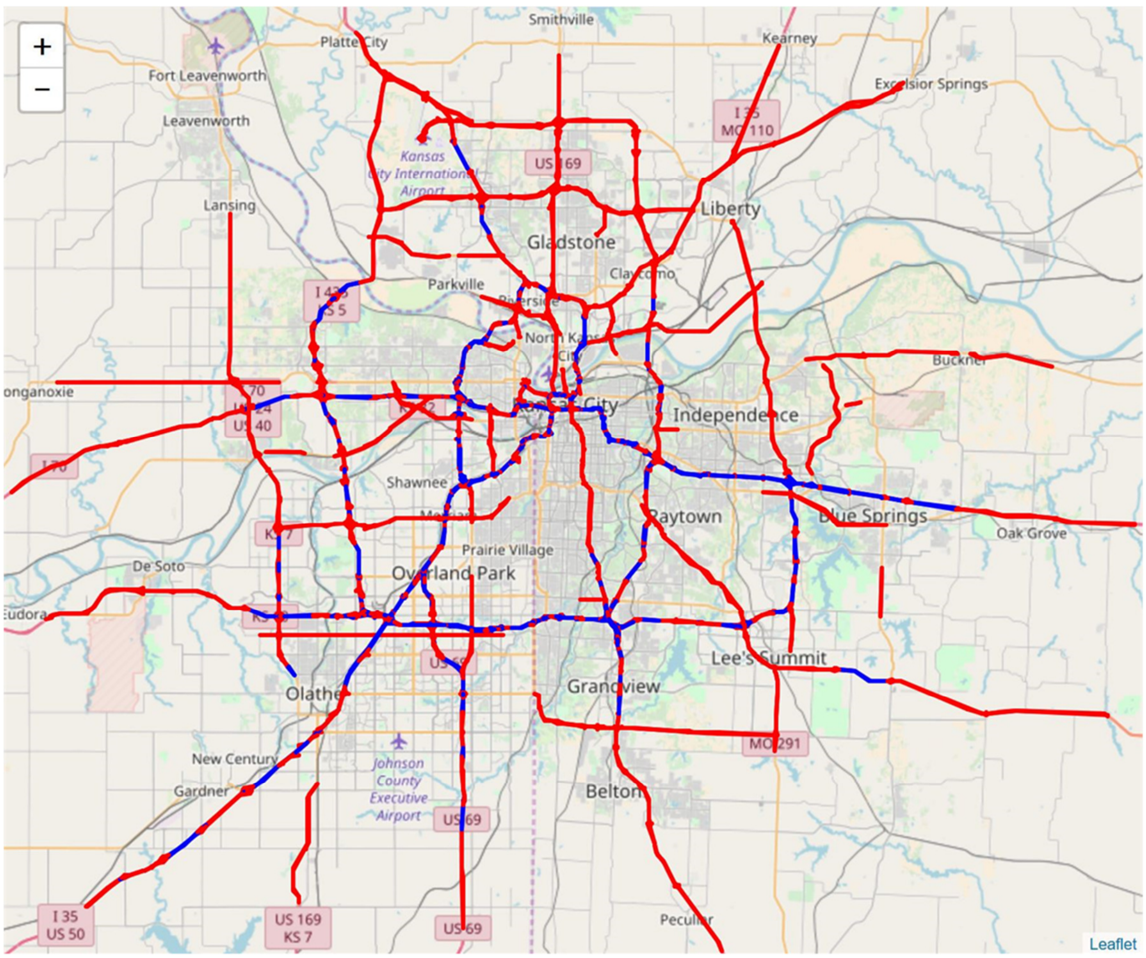
Appendix A. Glossary

AHPS	Advanced Hydrologic Prediction Service
ASOS	Automated Surface Observing System
CAP	Common Alerting Protocol
ConOps	Concept of Operations
CV	Connected Vehicle
DMS	Dynamic Message Signs
FHWA	Federal Highway Administration
IMRCP	Integrated Model for Road Condition Prediction
METRo	Model of the Environment and Temperature of Roads
NDFD	National Digital Forecast Database
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
RAP	Rapid Refresh
RTMA	Real-Time Mesoscale Analysis
TrEPS	Traffic Estimation and Prediction System
TSMO	Transportation Systems Management and Operations
USDOT	United States Department of Transportation

Appendix B. Kansas City Study Area

The study city for the IMRCP was selected out of several candidate cities in the United States based on several criteria. Kansas City was chosen because of the working relationship between the local agencies and the data availability. The Kansas City Metro area is subject to highly variable weather conditions and local recurring congestion.

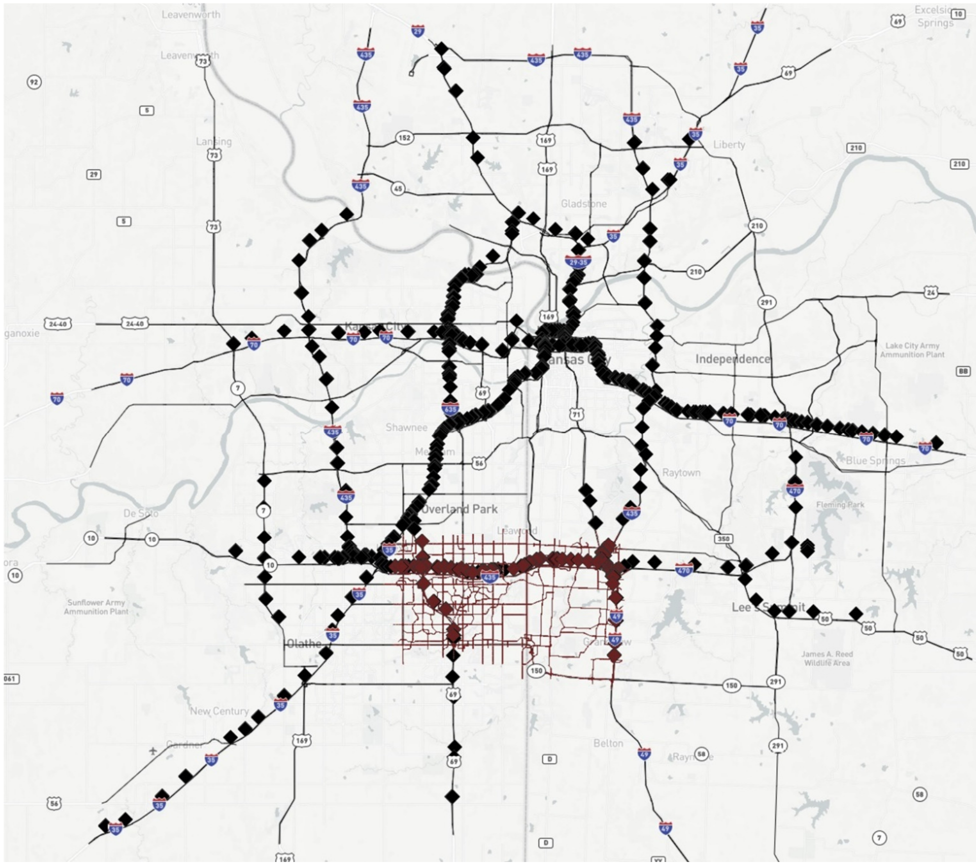
The road network model (Figure 17) includes links both with and without traffic detectors.



Source: FHWA, 2019

Figure 17. Road Network Configuration for Study Area.

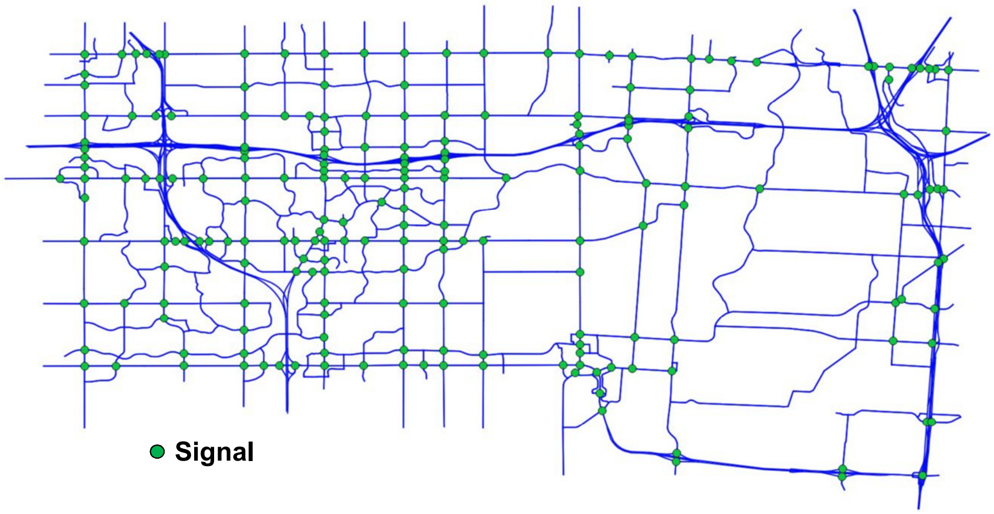
Traffic detectors are spread widely but unevenly across the metro area, as shown in Figure 18.



Source: FHWA, 2019

Figure 18. Traffic Detectors in Study Area.

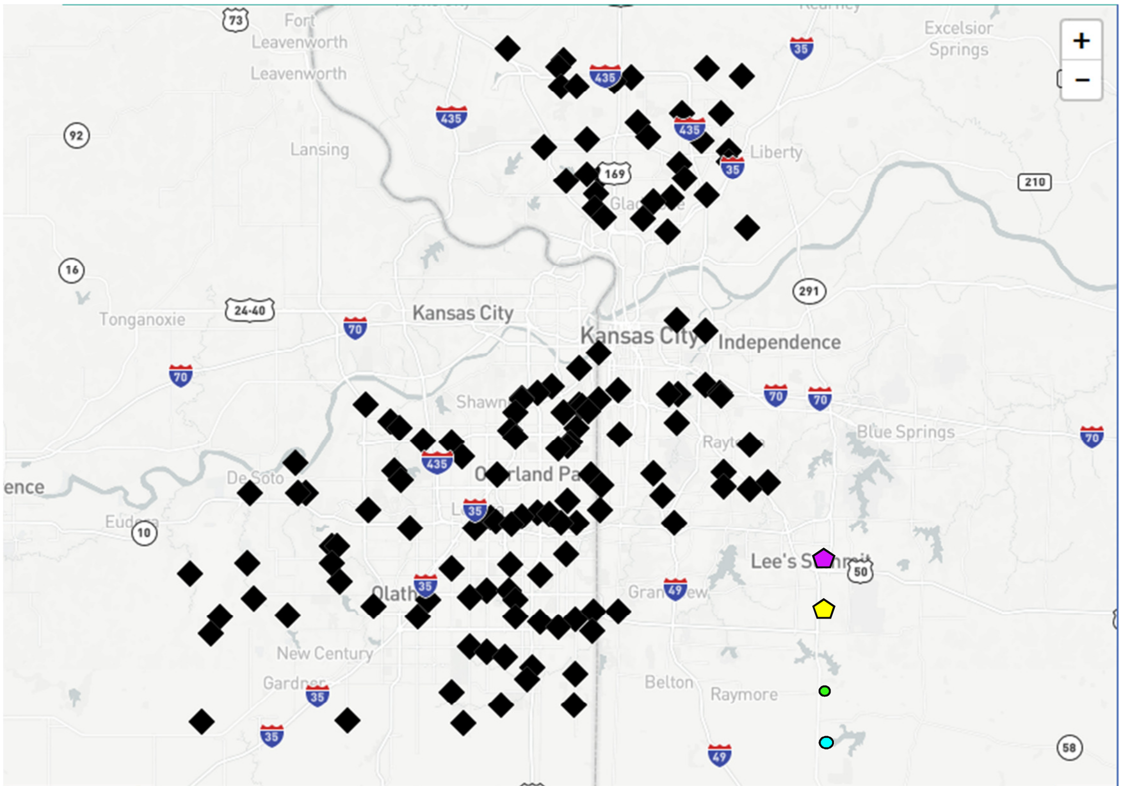
A total of 215 traffic signals, all in the IMRCP Phase 2 study area shown in Figure 19, are being modeled.



Source: FHWA, 2019

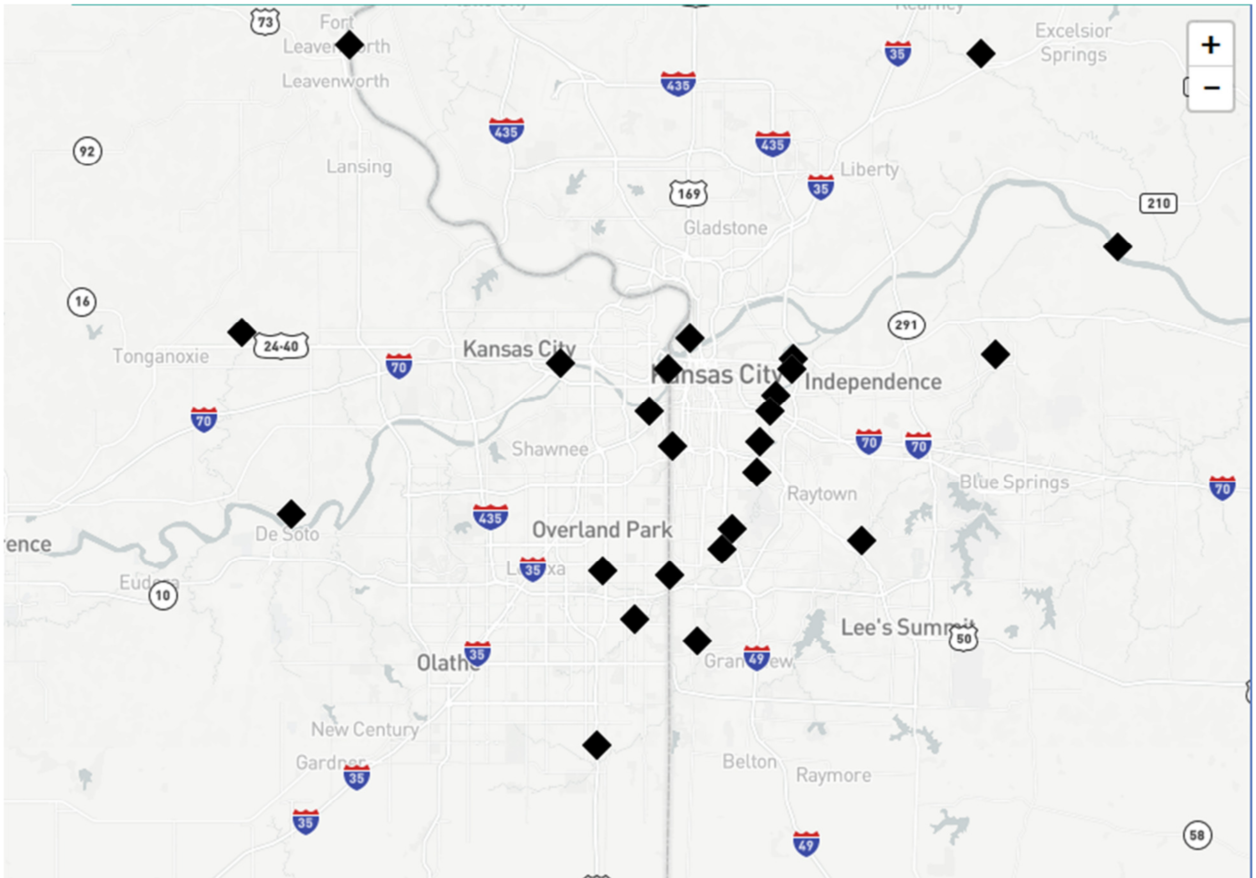
Figure 19. Traffic Signals Modeled in Study Area.

Weather data in the study area is collected from weather stations including StormWatch stations (Figure 20), AHPS stations (Figure 21), and an Automated Surface Observing System (ASOS) station.



Source: FHWA, 2019

Figure 20. Stormwatch Hydrology Stations in Study Area.



Source: FHWA, 2019

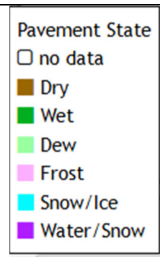
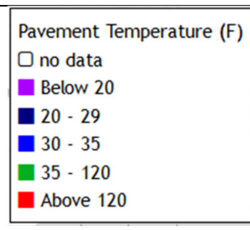
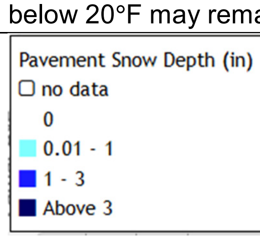
Figure 21. AHPS Hydrology Stations in Study Area

Work Zone data is also collected from the following agency websites:

- The MissouriDOT work zones information page located at: http://traveler.modot.org/report/modottext.aspx
- The Overland Park, Kansas Future Projects information page located at https://www.opkansas.org/resident-resources/traffic-and-transportation/road-constructionpublic-improvement-projects/future-road-constructionpublic-improvement-projects/
- The Kansas DOT Kansas City Metro Projects page located at https://www.ksdot.org/kcMetro/laneclose.asp
- The City of Leawood (Kansas) Engineering projects page located at https://www.leawood.org/public%20works/constructionprojects.aspx
- The City of Kansas City, MO Project Tracker located at http://maps.kcmo.org/apps/cip/

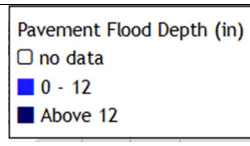
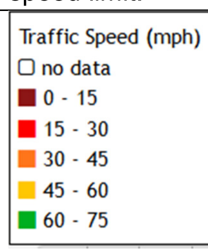
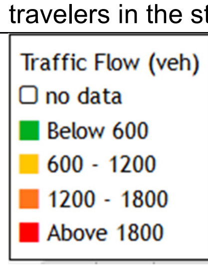
Appendix C. Layer Definitions

Table 1. Layer Definitions.

Layer	Observation Type	Definition
Pavement State	STPVT	 The Pavement State layer is divided into categories for the map based on METRo's output for pavement state.
Pavement Temperature	TPVT	 The Pavement Temperature layer is divided into levels for the map based on pavement behaviors at temperature intervals. Pavement temperatures above 120°F may cause the pavement to be at risk of high temperature degradation. Pavement temperatures between 35°F and 120°F are considered normal. Pavement temperatures between 32°F and 35°F are likely to cause the pavement to meet the freezing point. Pavement treatment may be effective on pavement at temperatures between 20°F and 29°F where as pavement at tempertures below 20°F may remain frozen in response to treatment.
Pavement Snow Depth	DPHSN	 The Pavement Snow Depth layer consists of four levels ranging from 0 in. to above 3 in.

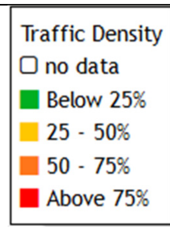
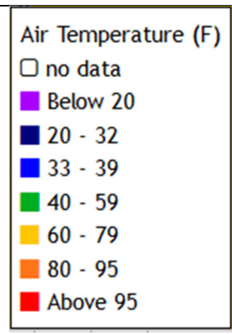
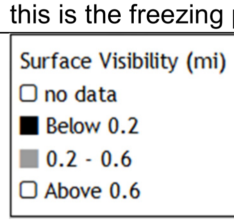
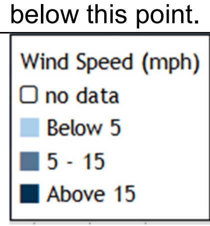
Source: FHWA, 2019

Table 1. Layer Definitions. (continued)

Layer	Observation Type	Definition
Pavement Flood Depth	DPHLNK	 On the Pavement Flood Depth layer, links will appear transparent until flooding occurs on the pavement. When the flooding on the pavement reaches 12 in. (or 1 ft.), the link coding reaches a new level because flooding above 12 in. can carry away a car.
Traffic	TRFLNK	 The Traffic layer is divided into five equal levels ranging from standstill traffic to traffic moving at full speed relative to the speed limit.
Traffic Speed	SPDLNK	 The Traffic Speed layer is divided into five equal levels ranging from 0 to 75 mph, a reasonable upper bound for the speed of travelers in the study area.
Traffic Flow	VOLLNK	 The Traffic Flow layer is divided into four equal levels ranging from below 600 to above 1800 vehicles per hour. A traffic flow above 1800 vehicles per hour on any link in the study area can cause major congestion.

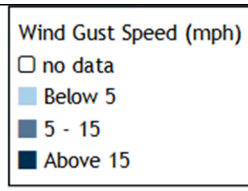
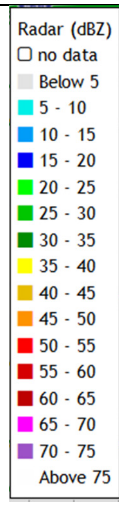
Source: FHWA, 2019

Table 1. Layer Definitions. (continued)

Layer	Observation Type	Definition
Traffic Density	DNTLNK	 The Traffic Density layer is divided into four equal levels ranging from below 25% to above 75%. Traffic density above 75% indicates major congestion and below 25% indicates free flow.
Routes	TIMERT	The Routes layer displays routes on the map when they have an available route travel time.
Air Temperature	TAIR	 The Air Temperature Layer is divided into layers based on typical temperature behaviors. There is a breakpoint at 32°F because this is the freezing point.
Surface Visibility	VIS	 The Surface Visibility layer remains white until the visibility is below 0.6 mi. Travelers can be siginificantly affected by visibility below this point.
Wind Speed	SPDWND	 The Wind Speed layer is divided into levels that are typical of the study area.

Source: FHWA, 2019

Table 1. Layer Definitions. (continued)

Layer	Observation Type	Definition
Wind Gust Speed	GSTWND	 The Wind Gust Speed layer is divided into levels that are typical of the study area.
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.

Source: FHWA, 2019

Table 1. Layer Definitions. (continued)

<table>
<tr><th>Layer</th><th>Observation Type</th><th>Definition</th></tr>
<tr><td>NWS Alerts</td><td>EVT</td><td>

The NWS Alerts Layer is divided into categories based on the type of alert issued.</td></tr>
</table>

Source: FHWA, 2019

Appendix D. Observation Type Definitions

Table 2. Observation Type Definitions.

NAME	DESCRIPTION	SOURCE – OBSERVATIONS	SOURCE – PREDICTIONS
COVCLD	total cloud cover	Total cloud coverage observation values are collected from Real-Time Mesoscale Analysis (RTMA) in 3 km x 3 km grids.	Total cloud coverage predicted values are collected from National Digital Forecast Database (NDFD) in 3 km x 3 km grids.
CTLEFT	number of left-turning vehicles on each link	The estimated number of left-turning vehicles on each link is collected from TrEPS.	The predicted number of left-turning vehicles on each link is collected from TrEPS.
CTMID	cumulative number of vehicles on each link	The estimated cumulative number of vehicles on each link is collected from TrEPS.	The predicted cumulative number of vehicles on each link is collected from TrEPS.
CTTHRU	number of vehicles that pass through the link	The estimated number of vehicles that pass through the link is collected from TrEPS.	The predicted number of vehicles that pass through the link is collected from TrEPS.
DIRWND	wind direction	Wind direction observation values are collected from RTMA in 3 km x 3 km grids.	Wind direction predicted values are collected from NDFD in 3 km x 3 km grids.
DNFLNK	average density of moving vehicles on each link	The estimated average density of moving vehicles on each link is collected from TrEPS.	The predicted average density of moving vehicles on each link is collected from TrEPS.
DNTLNK	average density of vehicles on each link	The estimated density values for each link are collected from TrEPS.	The predicted density values for each link are collected from TrEPS.
DPHLIQ	liquid inundation depth	Model of the Environment and Temperature of Roads (METRo) is run for each link in the study area to determine liquid inundation depth estimations.	METRo is run for each link in the study area to determine liquid inundation depth predictions.
DPHLNK	link depth	AHPS stage observations at three locations in the study area 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.	AHPS stage predictions at three locations in the study area 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 (National Oceanic and Atmospheric Administration).

Table 2. Observation Type Definitions. (continued)

NAME	DESCRIPTION	SOURCE – OBSERVATIONS	SOURCE – PREDICTIONS
DPHSN	snow inundation depth	METRo is run for each link in the study area to determine pavement snow depth estimations.	METRo is run for each link in the study area to determine pavement snow depth predictions.
DURGRN	average green time for each link	The estimated average green time for each link is collected from TrEPS.	The predicted average green time for each link is collected from TrEPS.
EVT	event	Workzone and Incident event details are collected from KC Scout. 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 KC Scout. 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.
FLWCAT	predicted flow category	All of the possible outcomes of the MLP model are stored in a table in the database. The system performs a lookup in the table based on the inputs of each of the links in the model for each time period to determine the predicted flow category.	All of the possible outcomes of the MLP model are stored in a table in the database. The system performs a lookup in the table based on the inputs of each of the links in the model for each time period to determine the predicted flow category.
GENLNK	number of vehicles generated on each link	The estimated number of vehicles generated on each link are collected from TrEPS.	The predicted vehicles generated on each link are collected from TrEPS.
GSTWND	wind speed gust height above ground	Wind gust speed observation values are collected from RTMA in 3 km x 3 km grids.	
OCCCAT	predicted occupancy category	All of the possible outcomes of the MLP model are stored in a table in the database. The system performs a lookup in the table based on the inputs from each of the links in the model for each time period to determine the predicted occupancy category.	All of the possible outcomes of the MLP model are stored in a table in the database. The system performs a lookup in the table based on the inputs from each of the links in the model for each time period to determine the predicted occupancy category.

Table 2. Observation Type Definitions. (continued)

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]

Table 2. Observation Type Definitions. (continued)

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 andTYPPC = [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 andTYPPC = [rain]
PRSUR	surface pressure	Surface pressure observation values are collected from RTMA in 3 km x 3 km grids.	Surface pressure predicted values are collected from Rapid Refresh (RAP) in 13 km x 13 km grids.
QPRLNK	queue percentage on link	The estimated queue percentage on each link is collected from TrEPS.	The predicted queue percentage on each link is collected from TrEPS.
QUELNK	number of queued vehicles on each link	The estimated number of queued vehicles on each link is collected from TrEPS.	The predicted number of queued vehicles on each link is collected from TrEPS.
RDR0	merged base reflectivity	Radar observation values are collected from MRMS in 1 km x 1 km grids	
RH	relative humidity	Relative humidity observation values are collected from RTMA in 3 km x 3 km grids.	Relative humidity predicted values are collected from NDFD in 3 km x 3 km grids.
RTEPC	precipitation rate surface	Precipitation rate observation values are collected from MRMS in 1 km x 1 km grids.	Precipitation rate predicted values are collected from RAP in 13 km x 13 km grids.
SPDCAT	predicted speed category	All of the possible outcomes of the MLP model are stored in a table in the database. The system performs a lookup in the table based on the inputs from each of the links in the model for each time period to determine the predicted speed category.	All of the possible outcomes of the MLP model are stored in a table in the database. The system performs a lookup in the table based on the inputs from each of the links in the model for each time period to determine the predicted speed category.
SPDLNK	average speed of vehicles on each link	The estimated speed values for each link are collected from TrEPS.	The predicted speed values for each link are collected from TrEPS.
SPDWND	wind speed height above ground	Wind speed observation values are collected from RTMA in 3 km x 3 km grids.	Wind speed forecast values are collected from NDFD in 3 km x 3 km grids.
SPFLNK	average speed of moving vehicles on each link	The estimated average speed of moving vehicles on each link is collected from TrEPS.	The predicted average speed of moving vehicles on each link is collected from TrEPS.

Table 2. Observation Type Definitions. (continued)

NAME	DESCRIPTION	SOURCE – OBSERVATIONS	SOURCE – PREDICTIONS
STPVT	pavement state	METRo is run for each link in the study area 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 study area 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.
TAIR	air temperature	Air temperature observation values are collected from RTMA in 3 km x 3 km grids.	Air temperature predicted values are collected from NDFD in 3 km x 3 km grids.
TDEW	dew point temperature	Dew point temperature observation values are collected from RTMA in 3 km x 3 km grids.	Dew point temperature predicted values are collected from NDFD in 3 km x 3 km grids.
TDNLNK	traffic density	The traffic density is the normalized density from MLP to historical data.	The traffic density is the normalized density from MLP to historical data.

Table 2. Observation Type Definitions. (continued)

NAME	DESCRIPTION	SOURCE – OBSERVATIONS	SOURCE – PREDICTIONS
TIMERT	route time	Routes are preconfigured. The estimated travel times for each link are collected from TrEPS. The travel times of the links that make up a preconfigured route are added together to determine the estimated total travel time of the route.	Routes are preconfigured. The predicted travel times for each link are collected from TrEPS. The travel times of the links that make up a preconfigured route are added together to determine the predicted total travel time of the route.
TPVT	pavement temperature	METRo is run for each link in the study area to determine pavement temperature estimations.	METRo is run for each link in the study area to determine pavement temperature predictions.
TRFLNK	traffic	The estimated speed value for each link collected from TrEPS is divided by the speed limit for that link.	The predicted speed value for each link collected from TrEPS is divided by the speed limit for that link.
TSSRF	subsurface temperature	The subsurface temperture observation is collected from an ASOS station.	
TYPPC	precipitation type	Precipitation type observation values are collected from MRMS in 1 km x 1 km grids.	Precipitation type predicted values are collected from RAP in 13 km x 13 km grids.
VEHLNK	number of vehicles on each link	The estimated number of vehicles on each link is collected from TrEPS.	The predicted number of vehicles on each link is collected from TrEPS.
VIS	surface visibility	Surface visibility observation values are collected from RTMA in 3 km x 3 km grids.	Surface visibility forecast values are collected from RAP in 13 km x 13 km grids.
VOLLNK	link volume	The estimated flow values for each link are collected from TrEPS.	The predicted flow values for each link are collected from TrEPS.

Source: FHWA, 2019

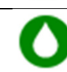
Appendix E. Alert Definitions

Table 3.Traffic Alert Definitions

Type	Algorithm	Extent	Reference	Notify	Icon
Incident	EVT=Incident	point	KC Scout	Y	
Work Zone	EVT=Workzone	link	KC Scout	N	
Slow Traffic	20<TRFLNK<40%	link	KC Scout, TrEPS, MLP	N	
Very Slow Traffic	0<TRFLNK<20%	link	KC Scout, TrEPS, MLP	Y	
Lengthy Queue	QPRLNK > 0.3	link	TrEPS (fort.600)	N	
Unusual Congestion	0<TRFLNK<0.5*MODE[TRFLNK]	link	TrEPS, Scout	Y	

Source: FHWA, 2019

Table 4. Weather Alert Definitions.

Type	Algorithm	geoExtent	Reference	Notify	Icon
Light Winter Precip	PCCAT= [Light Freezing Rain, Light Snow, Light Ice Pellets]	area	Pikalert	N	
Medium Winter Precip	PCCAT= [Medium Freezing Rain, Medium Snow, Medium Ice Pellets]	area	Pikalert	Y	
Heavy Winter Precip	PCCAT= [Heavy Freezing Rain, Heavy Snow, Heavy Ice Pellets]	area	Pikalert	Y	
Light Precip	PCCAT= [Light Rain]	area	Pikalert	N	
Medium Precip	PCCAT= [Medium Rain]	area	Pikalert	N	
Heavy Precip	PCCAT= [Heavy Rain]	area	Pikalert	Y	
Blowing Snow	10 < SPDWND m/s and 1 < DPHSN cm within last 24 hours 31 > TAIR F within the last 24 hours	segment	RAP/METRo	Y	
Low Visibility	VIS < 0.2 mi	area	RAP	Y	

Source: FHWA, 2019

Table 5. Road Condition Alert Definitions.

Type	Algorithm	geoExtent	Reference	Notify	Icon
Dew on Roadway	STPVT= [dew]	segment	METRo	N	
Frost on Roadway	STPVT= [frost]	segment	METRo	N	
Ice on Bridge	STPVT= [ice]	segment	METRo	Y	
Flooded Road	DPHLNK > 0 in.	segment	AHPS	Y	

Source: FHWA, 2019

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