Weather Event Reconstruction and Analysis Tool

Final Report

CLEAR ROADS

research for winter highway maintenance

The Narwhal Group

Project 1026089/CR16-05
January 2020

Pooled Fund #TPF-5(218)
www.clearroads.org

Clear Roads Project 16-05: Weather Event Reconstruction and Analysis Tool

Final Report

21 January 2020

The Narwhal Group

Leigh Sturges

Mike Holts

Brady Roberts

Chris Albrecht

Technical Report Documentation Page

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16. Abstract
The Clear Roads research consortium requested a tool to help transportation agencies more quickly and easily reconstruct winter weather events by drawing from data sources that cover the entire United States. The goals were to help agencies better understand the development and outcomes of hazardous weather events, react appropriately to them in the short and long term, and refine future maintenance decision-making. The tool would assist with after-action reviews and inform changes to practices at state, county and municipal levels of government.

During Clear Roads Project 16-05, the research team designed and built a web-based tool that accesses multiple types of weather data in order for a user to reconstruct what happened during a weather event. This final report describes the steps taken to accomplish this objective. They include: identifying appropriate weather data and locating the best online sources, sketching a mock version of the web-based tool, and, upon Clear Roads approval of the design, building and testing the tool. A guidance document was produced and technical support was provided to the Clear Roads users for one year.

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Contents

Executive Summary

The Clear Roads research consortium requested a tool to help transportation agencies more quickly and easily reconstruct winter weather events by drawing from data sources that cover the entire United States. The goals were to help agencies better understand the development and outcomes of hazardous weather events, react appropriately to them in the short and long term, and refine future maintenance decision-making. The tool would assist with after-action reviews and inform changes to practices at state, county and municipal levels of government.

The resulting project—Clear Roads Project 16-05—was a two-part project seeking to design (Part 1) and build (Part 2) a web-based tool that accesses multiple types of weather data in order for a user to reconstruct what happened during a weather event. Part 1 of the project consisted of three Tasks aimed at (1) identifying and (2) locating appropriate weather data, and then (3) sketching out a mock version of the tool. Part 2 consisted of five Tasks including (4) building and (5) testing the tool, (6) drafting guidance for its use, (7) providing technical support and (8) writing a final report.

A comprehensive list of data needed to reconstruct the key parts of a winter event was developed. The project team considered direct observations (weather stations), remote observations (radar and satellite) and model data (numerical analyses), and the data elements available within each platform. It was also important to consider the spatial extent of the data, such that coverage was possible on the regional to local scales and from the surface to the upper atmosphere.

The chosen data included surface atmospheric, pavement and upper atmospheric observations. Using meteorological principles, the most relevant data elements for event reconstruction were listed in a spreadsheet, along with an explanation of what the element is and why it is important for the tool. The spreadsheet was provided to the Clear Roads Technical Advisory Committee (TAC), and a survey was created that allowed the TAC to provide feedback on the list.

The survey asked respondents to say whether they thought each data element was critical for the tool, not needed in the tool, or whether they felt neutral about it. Free-form questions allowed the respondent to add any other data elements he/she would like to see in the tool or to make comments on his/her responses. To summarize survey results: none of the elements was deemed non-critical by a majority of the TAC, and one element was added based on a suggestion—incoming solar radiation (or cloud cover).

On completion of the surveys, the following observation data elements were chosen for inclusion in the tool:

- Air temperature
- Relative humidity
- Dewpoint temperature
- Wind speed
- Wind direction
- Visibility
- Precipitation type
- Precipitation intensity
- Snow accumulation
- Liquid precipitation accumulation
- Pavement temperature
- Freezing point (eutectic) temperature
- Road surface condition/state
- Friction
- Salinity
- Subsurface temperature
- Visible, infrared and water vapor satellite
- Radar

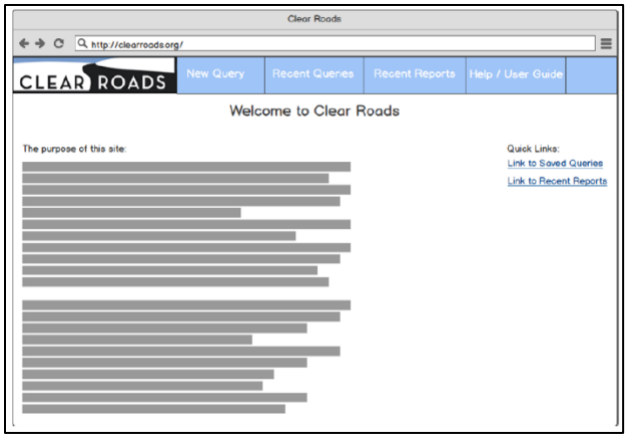
National Digital Forecast Database (NDFD) data generated from the National Weather Service (NWS) contains a multitude of forecast data elements (over 70) for which forecasts are made and plotted spatially on grids that cover the entire United States. Thus, a forecast of any one of these data elements is available at virtually every spot in the nation. The 70-plus list was narrowed down to those elements that most closely match the observed elements that the Clear Roads TAC wishes to collect for the tool. 10 forecast elements were chosen: air temperature, relative humidity, dewpoint temperature, wind speed (sustained), gust speed, wind direction, quantitative precipitation, ice accumulation, snow amount and sky (cloud) cover.

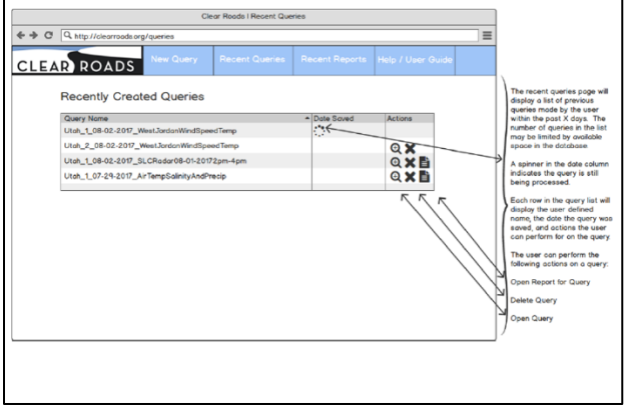
The research team utilized its professional knowledge and routine use of online weather data to craft an initial—and fairly sizable—data source catalog. Next, each source was put through a series of questions in an effort to refine the list and ensure that all data elements would be accessible and in the most efficient manner. The catalog was further refined by removing sources that duplicated data available in another source, while also being less complete or less efficient in some way, relative to the other source. Thus, the most complete and easy-to-access sources remained.

The primary source for point (weather station) data was chosen to be SynopticLabs (API services built by MesoWest). The Real-Time Mesoscale Analysis (RTMA) was chosen to fill in the data gaps between weather stations. It is a best-guess at the weather that is occurring where there is no weather station to measure the weather. RTMA data was pulled from the Iowa State University, Iowa Environmental Mesonet (IEM). Radar imagery data was also pulled from Iowa State's IEM. The NWS issues forecast text products such as watches, warnings, advisories and special weather statements; these products were also available on Iowa State's IEM. Ultimately, satellite and NDFD data were not included in the final design. More details about these omissions are available in the Task 3 section.

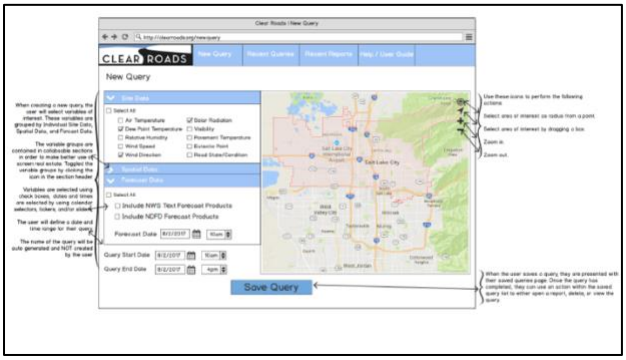
A draft proposal for a web tool was created and evaluated by the Clear Roads TAC. The tool would direct a user to create a weather event reconstruction query, which identifies and pulls requested data from the aforementioned external sources. Each user would be allowed to save up to three separate queries. All data returned from these queries was designed to be stored in the database. The option for the user to add their own notes on the event was also included. Here, personnel could also comment on the forecast, or include ancillary information pertinent to the event. When a saved query is deleted, all of the saved query's external weather event data will be deleted from the database. A report can be generated from a query in .pdf or .csv formats.

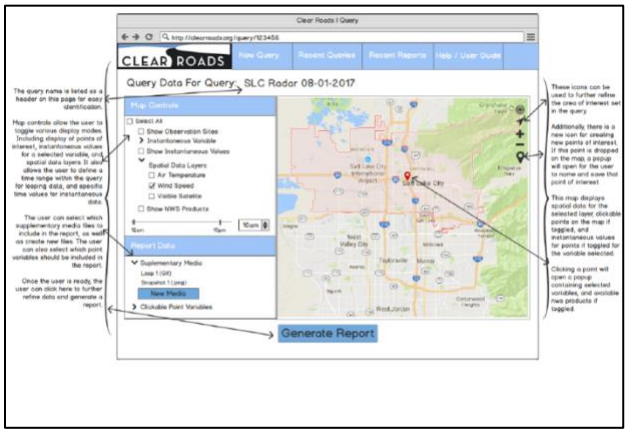
The final tool design is shown in the following visuals:

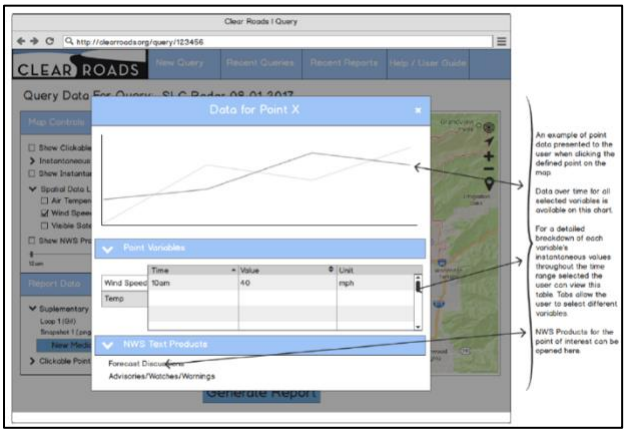

Clear Roads
http://clearroads.org/
CLEAR ROADS
New Query
Recent Queries
Recent Reports
Help / User Guide
Welcome to Clear Roads
The purpose of this site:
Quick Links:
Link to Saved Queries
Link to Recent Reports

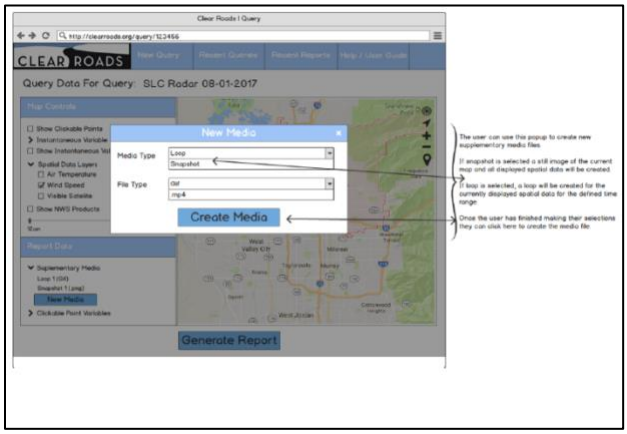

Clear Roads | Recent Queries
http://clearroads.org/queries
CLEAR ROADS
New Query
Recent Queries
Recent Reports
Help / User Guide
Recently Created Queries
Query Name
Date Saved
Actions
Utah_1_08-02-2017_WestJordonWindSpeedTemp
Utah_2_08-02-2017_WestJordonWindSpeedTemp
Utah_1_08-02-2017_SLCRadar08-01-2017 2pm-4pm
Utah_1_07-29-2017_AirTempSalinityAndPrecip
The recent queries page will display a list of previous queries made by the user within the past X days. The number of queries in the list may be limited by available space in the database.
A spinner in the date column indicates the query is still being processed.
Each row in the query list will display the user defined name, the date the query was saved, and actions the user can perform for on the query.
The user can perform the following actions on a query:
Open Report for Query
Delete Query
Open Query

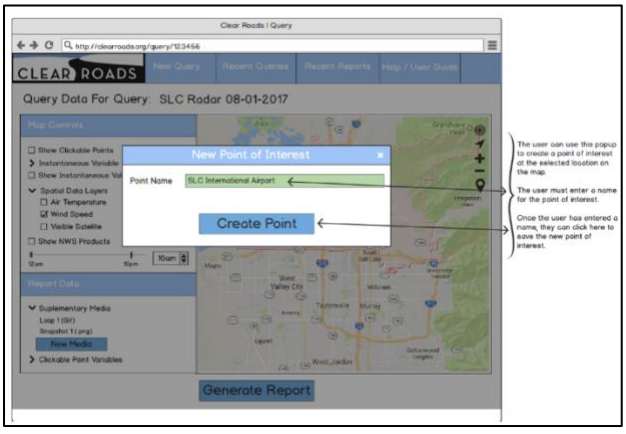

Clear Roads | Recent Reports
http://clearroads.org/reports
CLEAR ROADS
New Query
Recent Queries
Recent Reports
Help / User Guide
Recently Created Reports
Report Name
Date Generated
Actions
Utah_1_08-02-2017_WestJordonWindSpeedTemp(1)
Utah_2_08-02-2017_WestJordonWindSpeedTemp(2)
Utah_1_08-02-2017_SLCRadar08-01-2017 2pm-4pm(1)
Utah_1_07-29-2017_AirTempSalinityAndPrecip(1)
The recent reports page will display a list of reports generated by users within the past X days.
A spinner in the date column indicates the report is still being generated.
Each report in the table will display the name that the user has given the report, as well as the date the report was generated.
The user can perform the following actions on a report:
Download files associated with the report.
Delete the report.
Open the report.

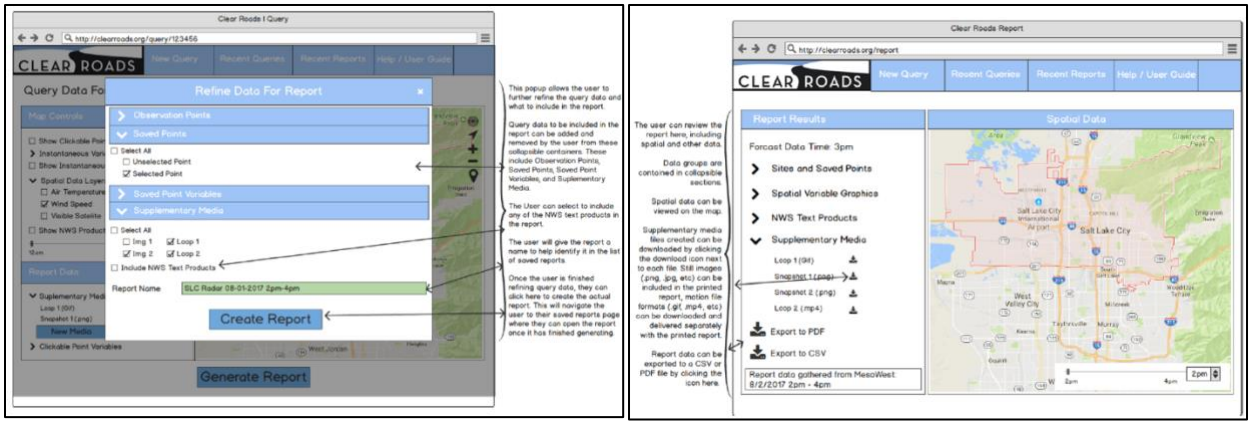

Clear Roads | New Query
CLEAR ROADS
New Query
Save Query


Clear Roads | Query
CLEAR ROADS
Query Data For Query: SLC Radar 08-01-2017
Generate Report


Clear Roads | Query
http://clearroads.org/query/123456
CLEAR ROADS
Data for Point X
Point Variables
Time
Value
Unit
Wind Speed
10am
40
mph
Temp
NWS Text Products
Forecast Discussions
Advisories/Watches/Warnings
An example of point data presented to the user when clicking the defined point on the map.
Data over time for all selected variables is available on this chart.
For a detailed breakdown of each variable's instantaneous values throughout the time range selected the user can view this table. Tabs allow the user to select different variables
NWS Products for the point of interest can be opened here.

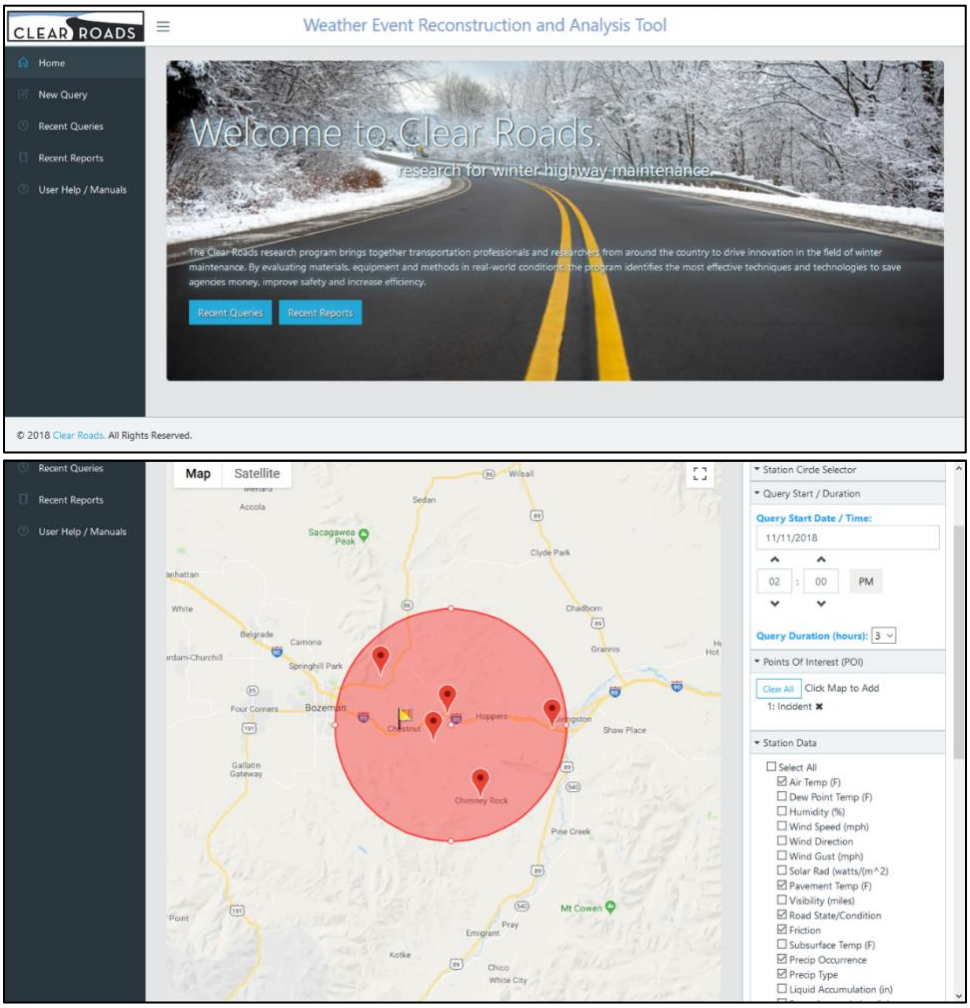

Clear Roads | Query
CLEAR ROADS
Query Data For Query: SLC Radar 08-01-2017
New Media
Media Type
Loop
Snapshot
File Type
Create Media
Generate Report

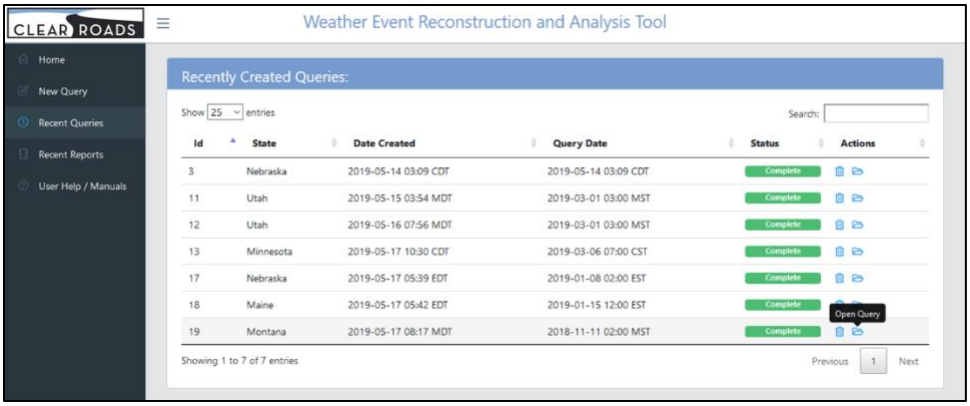

Clear Roads | Query
CLEAR ROADS
Query Data For Query: SLC Radar 08-01-2017
New Point of Interest
Point Name
SLC International Airport
Create Point
Generate Report
The user can use this popup to create a point of interest at the selected location on the map.
The user must enter a name for the point of interest.
Once the user has entered a name, they can click here to save the new point of interest.

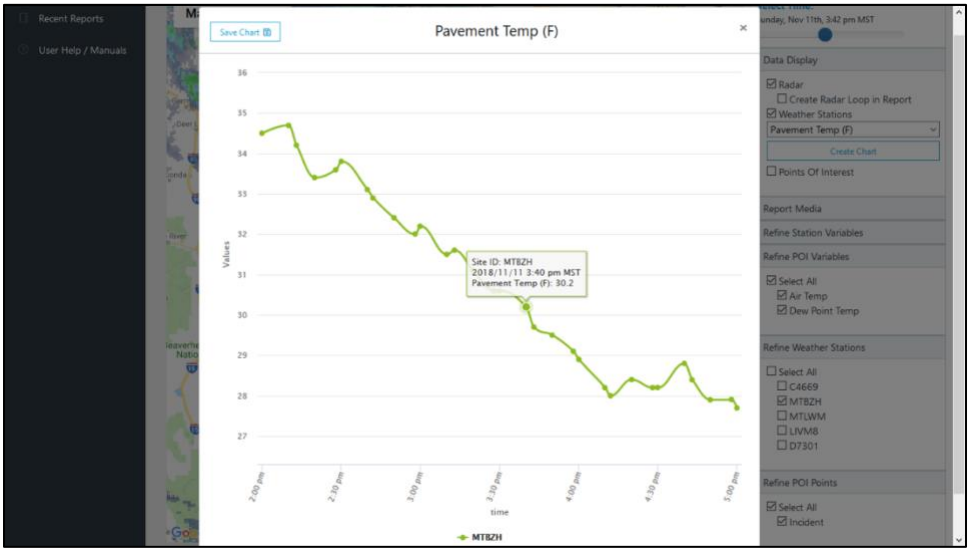


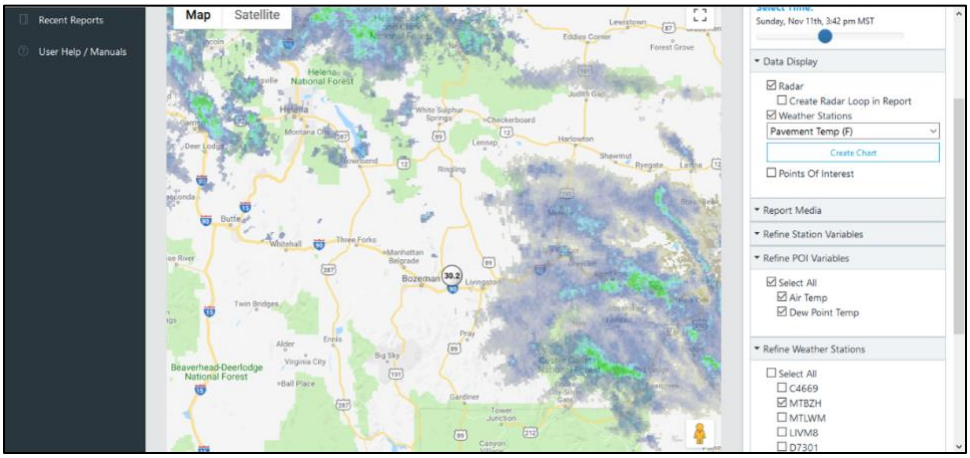
From the final tool design, the Clear Roads TAC decided to go forward with production of the web tool.

A beta version of the web tool was delivered to the Clear Roads TAC in February 2019; feedback was provided, and edits were made. The final Weather Event Reconstruction and Analysis Tool was delivered on 1 April 2019 at https://clearroads.org/eventreconstruction. A user manual and help video were created and made available from the homepage. Sample screenshots of the homepage and a basic query being produced and viewed are shown below.




CLEAR ROADS
Weather Event Reconstruction and Analysis Tool
Home
New Query
Recent Queries
Recent Reports
User Help / Manuals
Recently Created Queries:
Show 25 entries
Search:
Id
State
Date Created
Query Date
Status
Actions
3 Nebraska 2019-05-14 03:09 CDT 2019-05-14 03:09 CDT Complete
11 Utah 2019-05-15 03:54 MDT 2019-03-01 03:00 MST Complete
12 Utah 2019-05-16 07:56 MDT 2019-03-01 03:00 MST Complete
13 Minnesota 2019-05-17 10:30 CDT 2019-03-06 07:00 CST Complete
17 Nebraska 2019-05-17 05:39 EDT 2019-01-08 02:00 EST Complete
18 Maine 2019-05-17 05:42 EDT 2019-01-15 12:00 EST Complete
19 Montana 2019-05-17 08:17 MDT 2018-11-11 02:00 MST Complete
Open Query
Showing 1 to 7 of 7 entries
Previous
1
Next


Recent Reports
User Help / Manuals
Save Chart
Pavement Temp (F)
Values
time
Site ID: MTBZH
2018/11/11 3:40 pm MST
Pavement Temp (F): 30.2
MTBZH
Sunday, Nov 11th, 3:42 pm MST
Data Display
Radar
Create Radar Loop in Report
Weather Stations
Pavement Temp (F)
Create Chart
Points Of Interest
Report Media
Refine Station Variables
Refine POI Variables
Select All
Air Temp
Dew Point Temp
Refine Weather Stations
C4669
MTBZH
MTLWM
LIVM8
D7301
Refine POI Points
Incident


Recent Reports
User Help / Manuals
Map
Satellite
Sunday, Nov 11th, 3:42 pm MST
Data Display
Radar
Create Radar Loop in Report
Weather Stations
Pavement Temp (F)
Create Chart
Points Of Interest
Report Media
Refine Station Variables
Refine POI Variables
Select All
Air Temp
Dew Point Temp
Refine Weather Stations
C4669
MTBZH
MTLWM
LIVM8
D7301

Project Background and Overview

Background

Transportation agencies are continually striving to improve mobility and safety on their roadways, all while operating with improved efficiency and effectiveness. It is often the unusual, non-recurring events that truly put operational methods and practices to the test. Furthermore, winter weather events—whether extreme or climatologically average—are often the most challenging. Snow and ice storms reduce mobility, compromise safety, and tax an agency's resources as it works to mitigate impacts.

As it strives to reach goals and improve operations, a forward-looking transportation agency knows the value of looking backward—to learn from past events and to improve performance based on lessons learned. Yet, looking backward is not necessarily a straightforward undertaking. Winter storms are multivariate events in which environmental conditions (weather and road state), traffic conditions, and maintenance capabilities converge to create the ultimate impact of the event.

Better tools are needed to assist with the evaluation of past events, so that agencies can more easily isolate individual variables. By isolating the environmental component, the agency can understand how their response played a role in the event's ultimate impact on roadway mobility and safety.

Project Objective

The objective of this project was to capture the environmental component of winter storms by building a query-based web tool that quickly retrieves and integrates desired environmental datasets into an interface with which a user can "reconstruct" and better analyze a storm event. Ultimately, the tool will produce a report that tells the whole weather story: a collection of all environmental information into a single place. The tool will also, as efficiently as possible, do the job of gathering the necessary data and presenting it in a straightforward manner so that it is a useful and usable tool that provides worthwhile benefit to its agency users.

Executed Project Overview

The executed project—Clear Roads Project 16-05—was a two-part project that designed (Part 1) and built (Part 2) a web-based tool that accesses multiple types of weather data from a chosen weather event and integrates that information into a report. Part 1 of the project consisted of three Tasks aimed at (1) identifying and (2) locating appropriate weather data, and then (3) drafting a mock version of the tool. Part 2 consisted of five Tasks including (4) building and (5) testing the tool, (6) developing guidance for its use, (7) providing technical support and (8) writing a final report. This document satisfies Task 8, and is the final report for the project. It is broken into two main segments—Parts 1 and 2—and the tasks and their deliverables are described therein.

Part 1: Analysis and Catalog of Existing Data Resources

Task 1: Development of Data Requirements

Task Objective

The objective of Task 1 was to develop a comprehensive list of data needed to reconstruct the key parts of a winter event. The project team considered direct observations (weather stations), remote observations (radar and satellite) and model data (numerical analyses), and the data elements available within each platform. It was also important to consider the spatial extent of the data, such that coverage was possible on the regional to local scales and from the surface to the upper atmosphere. The geographic and temporal qualities of each data element were more finely tuned in Task 2.

Refining the Data Requirements

The chosen data included surface atmospheric, pavement and upper atmospheric observations. Using meteorological principles, the most relevant data elements for event reconstruction were listed in a spreadsheet, along with an explanation of what the element is and why it is important for the tool. The spreadsheet was provided to the Clear Roads Technical Advisory Committee (TAC), and a survey was created that allowed the TAC to provide feedback on the list. The TAC was also welcomed to contact the project team directly with any thoughts or feedback on the list.

Survey Results

The survey was open for eight days, and 22 respondents provided feedback. The survey asked respondents to say whether they thought each data element was critical for the tool, not needed in the tool, or whether they felt neutral about it. Free-form questions allowed the respondent to add any other data elements he/she would like to see in the tool or make comments on his/her responses. To summarize survey results: none of the elements was deemed non-critical by a majority of the TAC, and one element was added based on a suggestion. The following three paragraphs explain the survey results in detail.

For surface atmospheric data, respondents provided feedback on air temperature, relative humidity, dewpoint temperature, wind speed, wind direction, visibility, precipitation type, precipitation intensity, snow accumulation and liquid precipitation accumulation. All data elements, except relative humidity, wind speed and direction, and visibility, were deemed critical for the tool by most respondents. Relative humidity, wind and visibility were met with a more neutral response. None of these data elements were struck from the final list. Incoming solar radiation (or cloud cover) was a suggested addition by one respondent, and thus that element was added to the final list.

For pavement data, respondents provided feedback on pavement temperature, freezing point (eutectic) temperature, road surface condition/state, friction, salinity and subsurface temperature. Pavement temperature, road surface condition and friction were all deemed critical for the tool by most respondents, and freezing point temperature, salinity and subsurface temperature were met with a more neutral response. None of these data elements were struck from the final list. No additions were suggested by respondents.

For upper atmospheric data, respondents provided feedback on visible, infrared and water vapor satellite, and radar data. As respondents are likely most familiar with the use of radar during weather events, that element was chosen by a majority as critical for the tool, while the satellite elements were met with a more neutral response. None of these data elements were struck from the final list. No additions were suggested by respondents.

Forecast Data

It was important to the Clear Roads TAC that forecast data be made available via the tool in order to compare what the agency expected would happen, versus what actually happened. National Digital Forecast Database (NDFD) data generated from the National Weather Service (NWS) contains a multitude of data elements (over 70) for which forecasts are made and plotted spatially on grids that cover the entire United States. Thus, a forecast of any one of these data elements is available at virtually every spot in the nation. The list of over 70 data elements was narrowed down to those which most closely match the data that the Clear Roads TAC wishes to collect for the tool. Ten forecast parameters were chosen: air temperature, relative humidity, dewpoint temperature, wind speed (sustained), gust and direction, quantitative precipitation, ice accumulation, snow amount and sky (cloud) cover. It is important to note that the NWS does not publish pavement forecasts.

Final Task 1 Data List

Table 1 shows the finalized Task 1 observed data element spreadsheet. The table has three columns that list (1) each data element, (2) notes on some of the elements that may have needed clarification, and (3) explanations for each data element on why it would be important for the tool. (Note: the information in columns 2 and 3—notes and explanations—were provided to the TAC prior to their survey responses.)

Table 2 shows the finalized Task 1 forecast (NDFD) data elements.

Table 1. Final Task 1 spreadsheet showing chosen data elements for observation data.

Data Element	Notes	Why it's important
Air temperature (2m)		Affects precipitation type, can show where frost pockets can form, affects road surface temp.
Relative Humidity		When used with air temperature, can diagnose fog; when used with pavement temperature, can diagnose frost formation on roads.
Dewpoint Temperature		
Wind Speed (10m)		Blowing snow, reducing visibility, moderating temperatures.
Sustained		
Gust		
Wind Direction		Cross-winds cause more of the above hazards.
Visibility (direct)		Can give you a sense of how intensely it is precipitating, lacking other observation; can create operational hazards for operators and public.
Visibility (proxy)		
Precipitation Intensity	Assume loss of vis at certain intensity	
Wind Speed	In the presence of fresh snow, dust, smoke	
Fog, as reported	Direct fog measurements	
Precipitation		What falls from the sky is important, but what it does once it hits the road is even more so.
Occurrence (yes/no)	Lacking other observations, this element can be used.	
Type	Precipitation occurrence plus surface temperature	
Road Precipitation Type	Precipitation occurrence plus pavement temperature	
Intensity (in/hr)		
Snow Accumulation		
Liquid Accumulation	Either liquid precipitation or liquid equivalent	
Solar Radiation	Direct measurements of solar radiation are not always available; cloud cover via visible satellite can also be used.	Incoming solar radiation has a significant impact on pavement temperature and other physical processes at the surface.
Pavement Temperature		Dictates road surface state
Eutectic Point		Shows how chemicals changed the freezing point
Road State		Shows the ultimate result of maintenance operations

Data Element	Notes	Why it's important
Friction		Shows the ultimate result of maintenance operations
Salinity		
Subsurface Temperature		Shows how heat has been retained and transferred to pavement surface
Vis Satellite	Loop	Shows general pattern of storm, plus individual
IR Satellite	Loop	elements within the larger storm that may have caused
WV Satellite	Loop	a particular problem.
Radar	Base reflectivity loop	Shows smaller scale pattern and timeline of storm; shows areas of intense precipitation.

Table 2. Final Task 1 forecast (NDFD) data elements.

NDFD Data Element
Air Temperature
Relative Humidity
Dewpoint Temperature
Wind Speed
Wind Gust
Wind Direction
Quantitative Precipitation Estimation
Ice Accumulation
Snow Amount
Sky Cover

Task 2: Production of Data Source Catalog

Task Objective

The objective of Task 2 was to create and refine a detailed catalog of the online sources of the data elements identified in Task 1.

Refining the Catalog

The research team utilized its professional knowledge and routine use of online weather data to craft an initial—and fairly sizable—list. The sources were divided into three categories: those which provide point observation data (from weather stations), those which provide spatial observation data (from numerical analyses, radar or satellite) and those which provide NWS forecast data of various types. The sources were divided as such, because different data processing considerations would have to be made to collect and display point versus spatial versus forecast data in the tool.

Next, each source was put through a series of questions, as follows, in an effort to refine the list and ensure that all data elements would be accessible and in the most efficient manner:

- What data elements are available from this source?
- What data elements are not available from this source?
- How broad is the geographic coverage of this source?
- How quickly are data posted to/available from this data source after the event?
- What is the temporal resolution of the data?
- How long are data archived at this source?
- Regarding data accessibility:
    - How is the data accessed from this source?
    - Is there an API to facilitate downloads?
    - What is the format of the data (i.e., does it exist in a table or is it graphical or map-based) and, thus, what work is required to extract the desired data elements?
    - What process is required to export image loops (from satellite, radar and model forecasts)?

The catalog was further refined by removing sources that duplicated data available in another source, while also being less complete or less efficient in some way, relative to the other source. Thus, the most complete and easy-to-access sources remained.

Final Task 2 Data Source Catalog

Table 1A in Appendix A shows the finalized Task 2 data source catalog. Sources for point data, spatial data (model analyses and radar or satellite) and forecast data are shown separated into four separate tables.

Task 3: Development of Web Tool Proposal

Task Objective

The objective of Task 3 was to draft a proposal for a web tool that would incorporate the data identified in Task 1, pulling from the sources and requirements identified in Task 2. The proposal was presented to the Clear Roads TAC, the design was approved with modifications requested, and the decision was made to go forward with Part 2 of the project (discussed in the next chapter).

User Needs Outline

As an initial step in building the website, Narwhal summarized all features that were requested of the system into a user needs outline. The user needs outline is reproduced in Appendix B. The outline represents a web-based system, the overarching goal of which will be to provide a tool that will pull in archived data from many sources and build graphics that will help the user visualize the environmental conditions from a past weather event over a designated space and time.

Web Tool Proposed Design

Definitions

The **weather event query** identifies the data to collect from the external weather services. The user sets the timing and data requirements of the query, and the tool pulls the necessary files.

Reports are constructed using the saved external weather data saved in the database as the query. Each saved query can have one saved report. Reports can be edited and resaved.

Media is any file generated from the tool, including data charts or loops or snapshots of radar imagery. Still images of media can be included in reports.

Archived Weather Data Access

The Weather Event Reconstruction Tool requires the collection of data from various external sources. The following subsections describe the weather services ultimately chosen to gather this data.

Point Observation Data

For point observation data—specifically NWS/FAA, RAWS and RWIS data—the external source will be SynopticLabs (API services built by MesoWest; see Table 1A, page 14, and note the nomenclature difference from Table 1A). SynopticLabs data includes the following point elements, observed by each of these types of weather station networks, as available:

Atmospheric Data
- Air Temperature
- Dewpoint Temperature
- Relative Humidity
- Wind Speed
- Wind Direction
- Visibility
- Solar Radiation

Pavement Data
- Pavement Temperature
- Eutectic Point
- Road State/Condition
- Friction
- Salinity
- Subsurface Temperature

Precipitation Data
- Occurrence (Yes/No)
- Precipitation Type
- Intensity
- Accumulation, Liquid
- Accumulation, Snow

Spatial Observation Data

The Real-Time Mesoscale Analysis (RTMA) was chosen to fill in the data gaps between weather stations. The RTMA is a 2.5-km (1.55-mi) resolution (3-km [1.86-mi] resolution in Alaska) gridded dataset that interpolates conditions between weather stations. In other words, it is a best-guess at the weather that is occurring where there is no station to measure the weather. The dataset is hourly.

Table 1A (page 15), shows that RTMA data is available via federal government sources (NCEP and NOAA); however, the timing of the design phase coincided with a federal government shutdown, and these data sources were unavailable at that time. Fortunately, RTMA data is also hosted by the Iowa State University, Iowa Environmental Mesonet (IEM), and, thus, the data were pulled from that site. Data elements available from the RTMA are:

- Air Temperature
- Dewpoint Temperature
- Visibility
- Wind Speed
- Wind Direction
- Wind Gust

Radar imagery data was also pulled from Iowa State's IEM (Table 1A, page 16) and included only national composite reflectivity imagery. Quantitative precipitation estimation was not included in the final design, because there was no source that would be easily integrated and available for a long enough duration for the tool.

Table 1A (page 16) lists sources for satellite data, and yet satellite data was not included in the final design. In part, it was decided that the added cost of including satellite data to the design was not worth the benefit, considering the lukewarm responses to satellite data during the Task 2 surveys. Compounding this decision was the fact that the timing of the design phase coincided with the federal government shutdown, and the government-owned satellite data archives were thus unavailable.

Forecast Data

Table 1A (page 17) lists sources for NWS National Digital Forecast Database (NDFD) data, and yet NDFD data was not included in the final design. Its omission was due to the federal government shutdown, and the ultimate decision that the cost of integrating the data was not beneficial, given that other, more easily accessible forecast products were available, as follows.

The NWS issues forecast text products such as watches, warnings, advisories and special weather statements. These products were pulled from Iowa State's IEM (Table 1A, page 17).

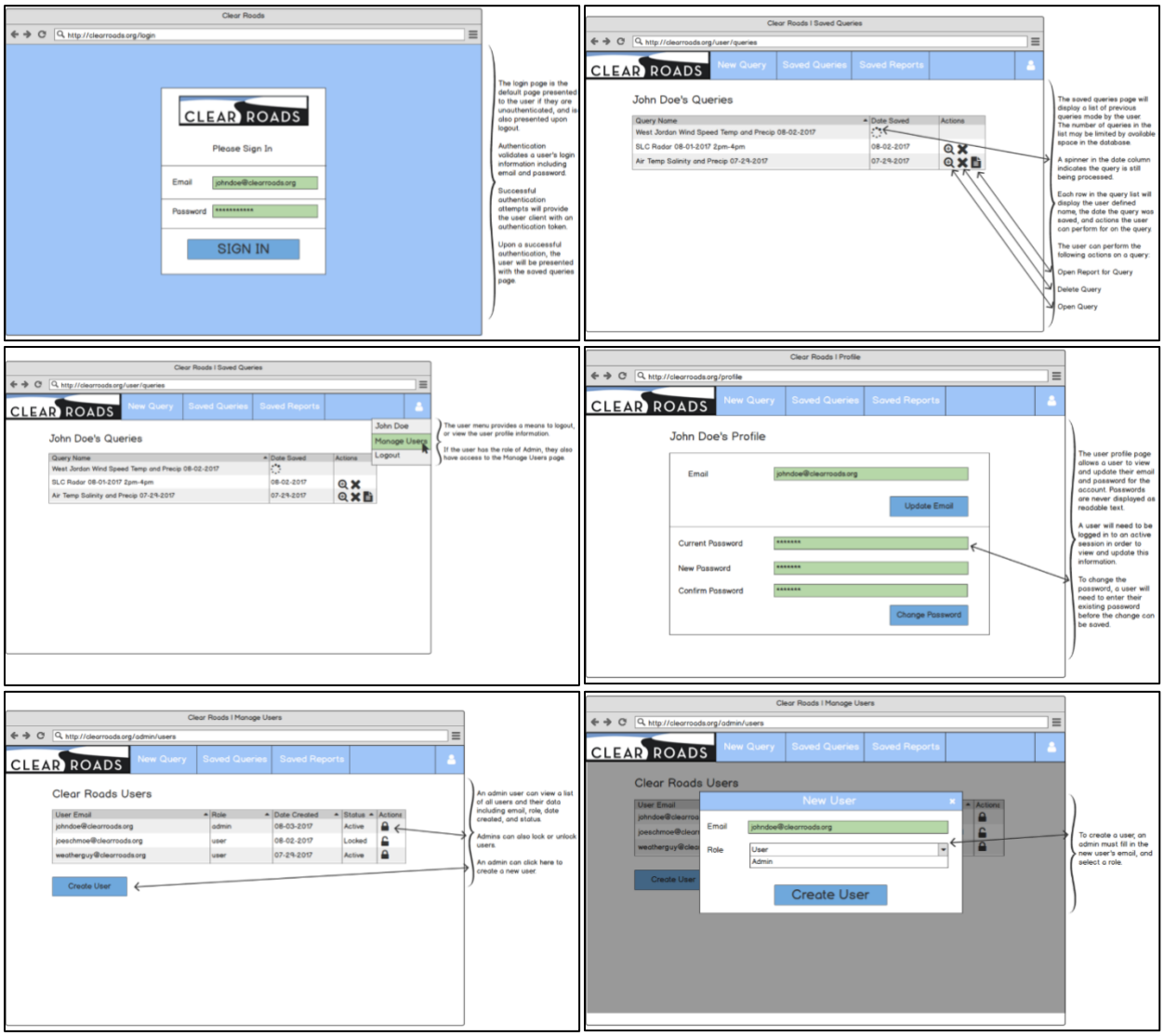
Design

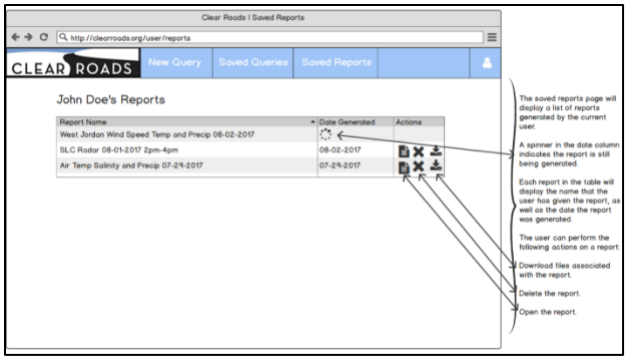
The tool was designed to direct a user to create a weather event query, in which location, timing and data information would be specified. The query would direct the system to pull the corresponding data from the aforementioned external sources. Each user would be allowed to save up to three separate queries. All data returned from these queries would be stored in the database. Database size will depend on the amount of data returned and the number of current users**.** When a saved query is deleted, all of the saved query's external weather event data will be deleted from the database. A report could be generated from a query in .pdf or .csv formats.

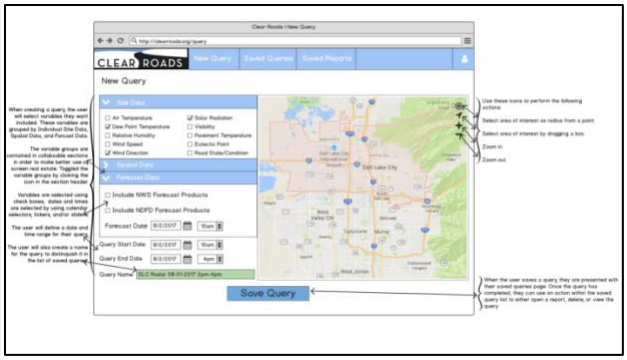
A few special functions were included to improve the utility of the tool, such as adding personal notes or retrieving data at points of interest. The option for the user to add their own notes on the event was included, because human observation can often capture the "weather story" in a way that data alone

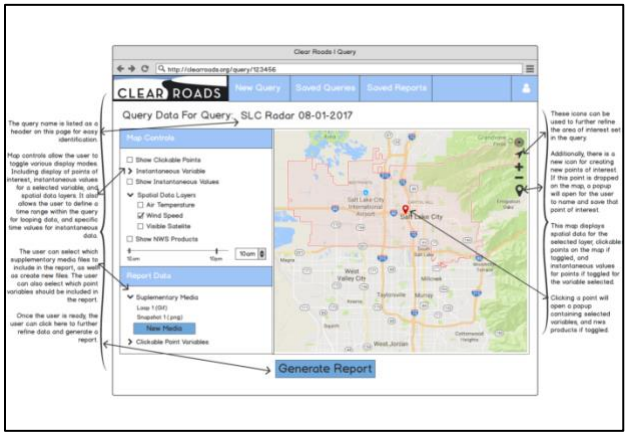
cannot. Here, personnel could also comment on the forecast, or include ancillary information pertinent to the event. A user would also be able to select a point on the map—one where there is no weather station data—and retrieve weather information via the RTMA. This function allows a user to gather data at a point of interest (POI), such as where a crash occurred, or where maintenance efforts were particularly difficult.

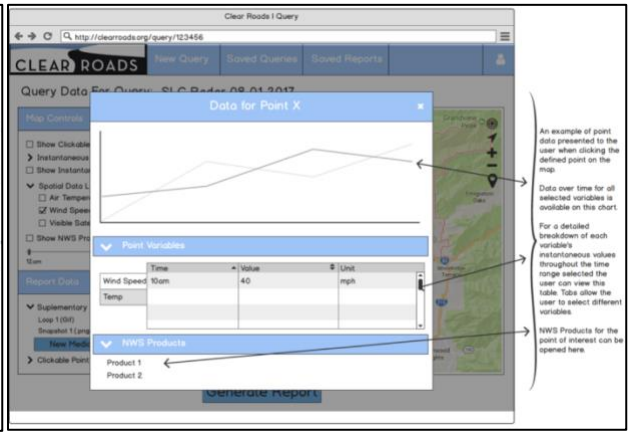
An initial website design was presented to the Clear Roads TAC. The layout of the proposed tool is presented in the 14 visuals shown below (following left to right, top to bottom).

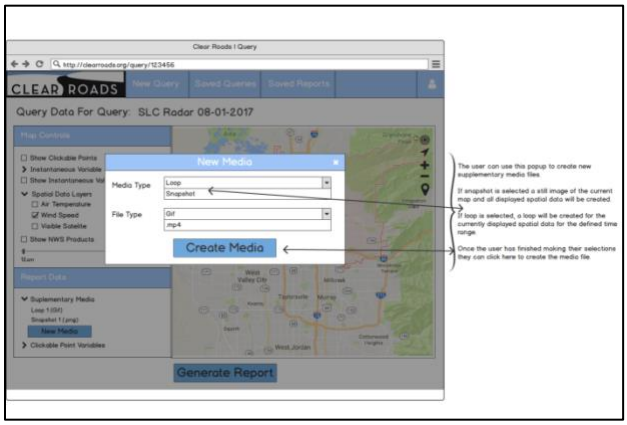


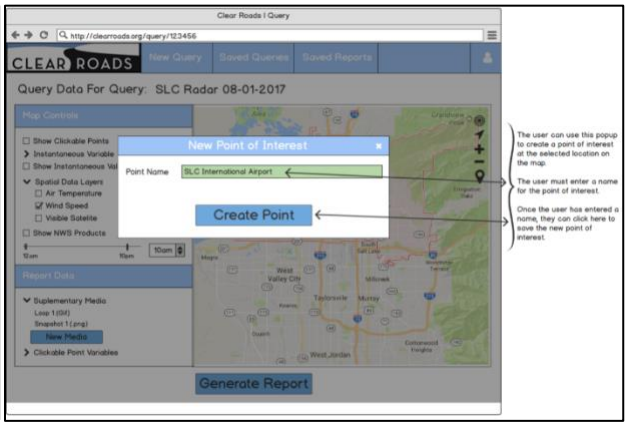

Clear Roads | Saved Reports
CLEAR ROADS
New Query
Saved Queries
Saved Reports
John Doe's Reports
Report Name
Date Generated
Actions
West Jordon Wind Speed Temp and Precip 08-02-2017
SLC Radar 08-01-2017 2pm-4pm
08-02-2017
Air Temp Salinity and Precip 07-24-2017
07-24-2017
The saved reports page will display a list of reports generated by the current user.
A spinner in the date column indicates the report is still being generated.
Each report in the table will display the name that the user has given the report, as well as the date the report was generated.
The user can perform the following actions on a report:
Download files associated with the report.
Delete the report.
Open the report.

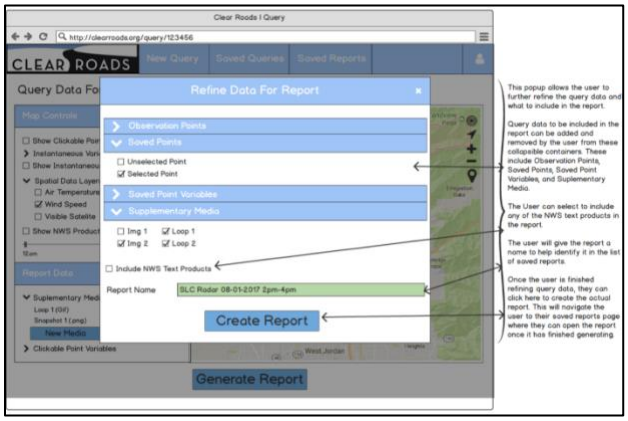

Clear Roads | New Query
CLEAR ROADS
New Query
Saved Queries
Saved Reports
Save Query

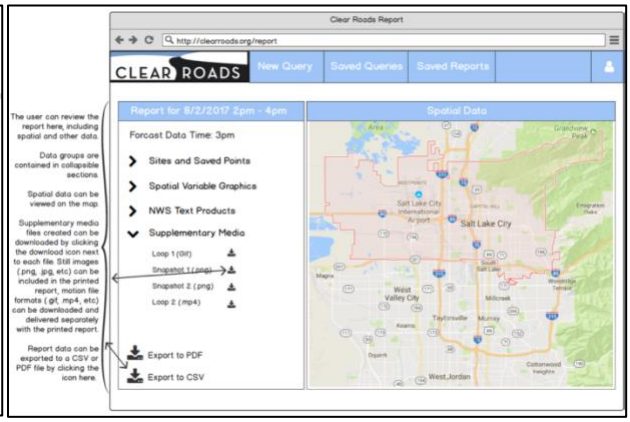

Clear Roads | Query
CLEAR ROADS
New Query
Saved Queries
Saved Reports
Query Data For Query: SLC Radar 08-01-2017
Map Controls
Report Data
Generate Report


Clear Roads | Query
CLEAR ROADS
New Query
Saved Queries
Saved Reports
Data for Point X
Point Variables
Time
Value
Unit
Wind Speed
10am
40
mph
Temp
NWS Products
Product 1
Product 2


Clear Roads | Query
CLEAR ROADS
Query Data For Query: SLC Radar 08-01-2017
New Media
Media Type
Loop
Snapshot
File Type
Gif
.mp4
Create Media
Generate Report


Clear Roads | Query
CLEAR ROADS
Query Data For Query: SLC Radar 08-01-2017
New Point of Interest
Point Name
SLC International Airport
Create Point
Generate Report

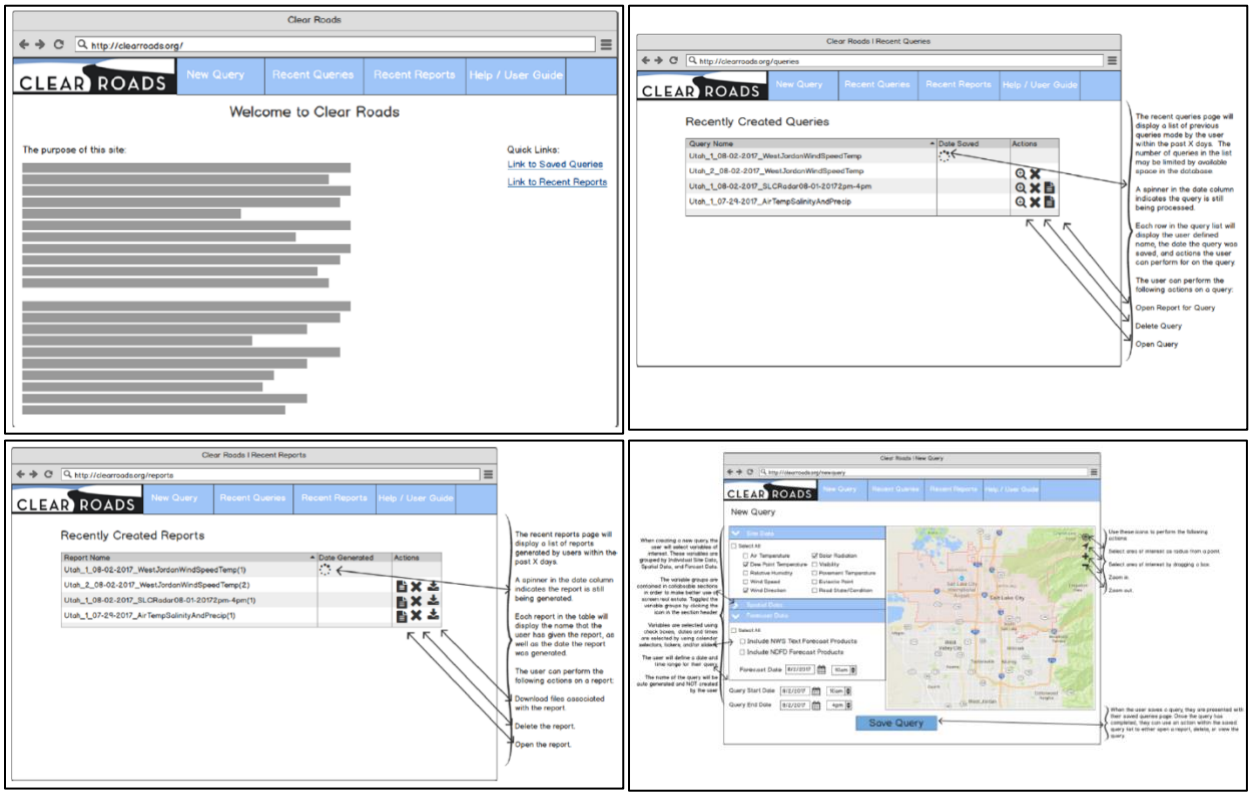

Clear Roads | Query
CLEAR ROADS
Refine Data For Report
Observation Points
Saved Points
Unselected Point
Selected Point
Saved Point Variables
Supplementary Media
Include NWS Text Products
Report Name
SLC Radar 08-01-2017 2pm-4pm
Create Report
Generate Report

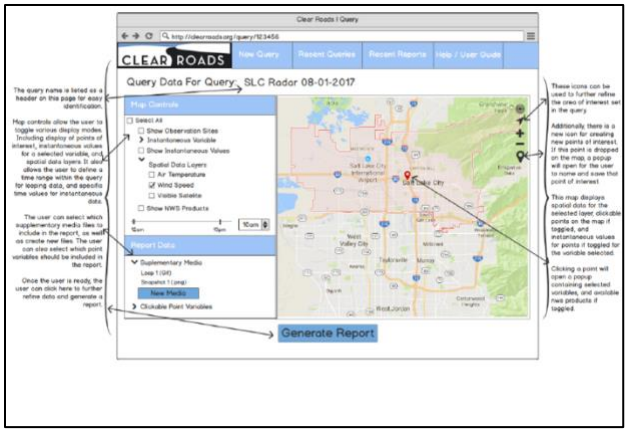

Clear Roads Report
CLEAR ROADS
New Query
Saved Queries
Saved Reports
Report for 8/2/2017 2pm - 4pm
Forcast Data Time: 3pm
Sites and Saved Points
Spatial Variable Graphics
NWS Text Products
Supplementary Media
Loop 1 (Gif)
Snapshot 1 (.png)
Snapshot 2 (.png)
Loop 2 (.mp4)
Export to PDF
Export to CSV
Spatial Data
Salt Lake City
West Jordan

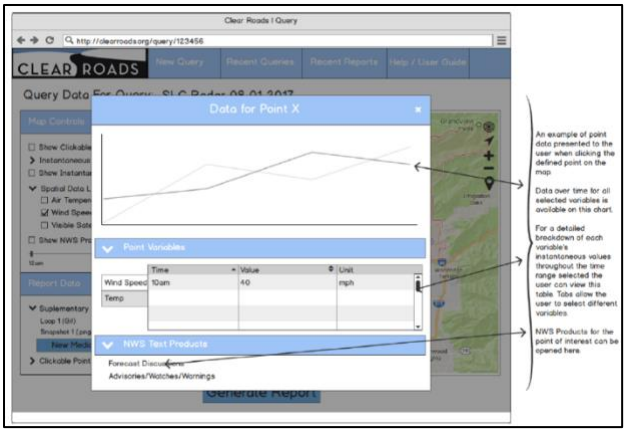
After review of the initial proposal, the Clear Roads TAC provided the following feedback and requests for revisions to the proposal:

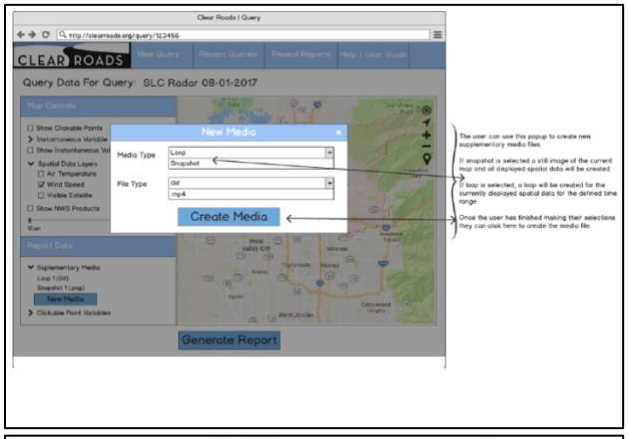
- Add system security and user (individual access) management functionality.
- Add new landing page containing static text describing the purpose of the site.
- Add Help/User Manual menu option.
- Provide links to view saved queries and reports.
- Add customized points of interest.
- Allow saving of video files.
- Allow querying of multiple spatial data sources.
- Add select/unselect all features for all groups of check boxes or multi select drop down controls.
- Auto generate the Query and Report names.
- Query names will contain STATE, UNIQUE NUMBER, TIMESTAMP.
- Report names will be Query name + sequential report number (1, 2, 3, etc., allowing multiple reports to be saved from a single one query).
- Add a footnote to report of data source (e.g., NWS, Synoptic, etc.) and timestamp.

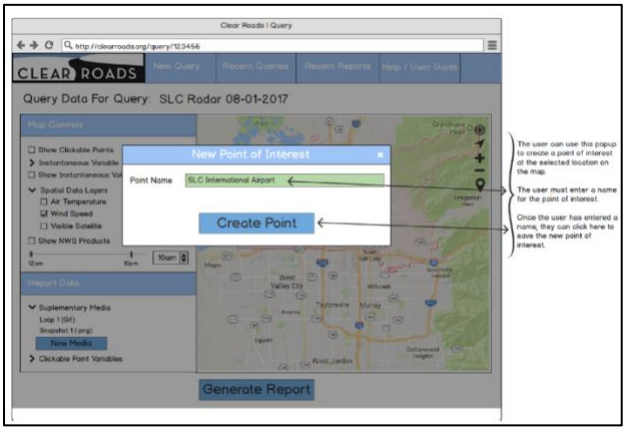
Following the requests for revisions, the website design was updated. The layout of the subsequent version is shown below.

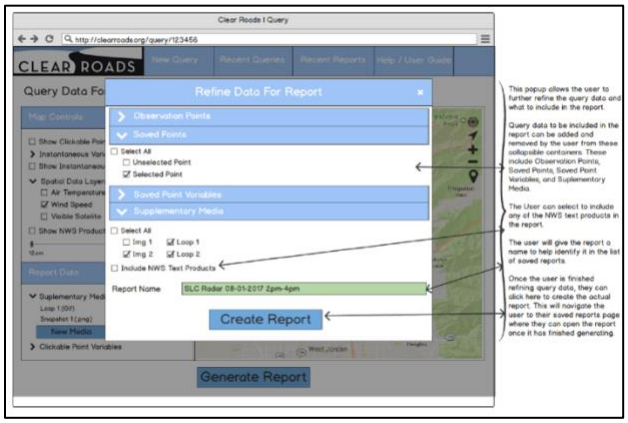


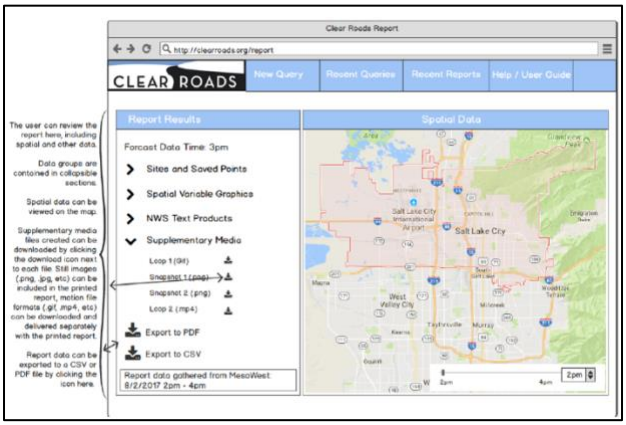

Clear Roads | Query
CLEAR ROADS
New Query
Recent Queries
Recent Reports
Help / User Guide
Query Data For Query: SLC Radar 08-01-2017
Generate Report


Clear Roads | Query
CLEAR ROADS
Data for Point X
Point Variables
NWS Text Products
Generate Report


Clear Roads | Query
CLEAR ROADS
Query Data For Query: SLC Radar 08-01-2017
New Media
Media Type
File Type
Create Media
Generate Report


Clear Roads | Query
CLEAR ROADS
Query Data For Query: SLC Radar 08-01-2017
New Point of Interest
Point Name
SLC International Airport
Create Point
Generate Report


Clear Roads | Query
CLEAR ROADS
Refine Data For Report
Observation Points
Saved Points
Saved Point Variables
Supplementary Media
Report Name
SLC Radar 08-01-2017 2pm-4pm
Create Report
Generate Report


Clear Roads Report
CLEAR ROADS
New Query
Recent Queries
Recent Reports
Help / User Guide
Report Results
Spatial Data
Forecast Data Time: 3pm
Sites and Saved Points
Spatial Variable Graphics
NWS Text Products
Supplementary Media
Export to PDF
Export to CSV
Report data gathered from MesoWest
8/2/2017 2pm - 4pm
Salt Lake City

Part II: Customized Weather Data Tool

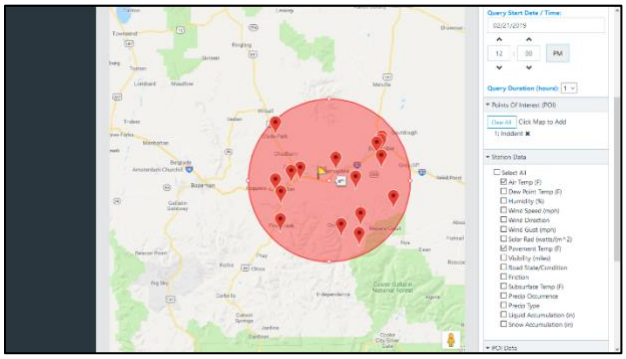
Task 4: Development of the Weather Event Reconstruction and Analysis Tool

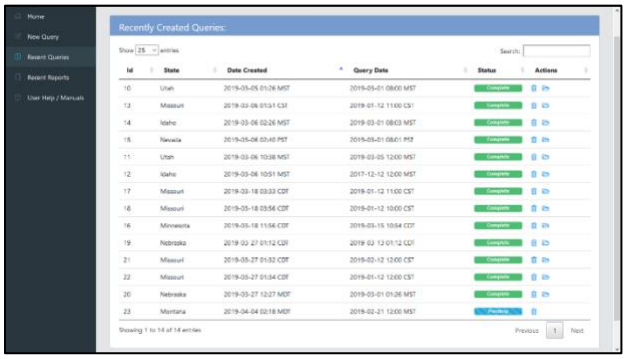
Task Objective

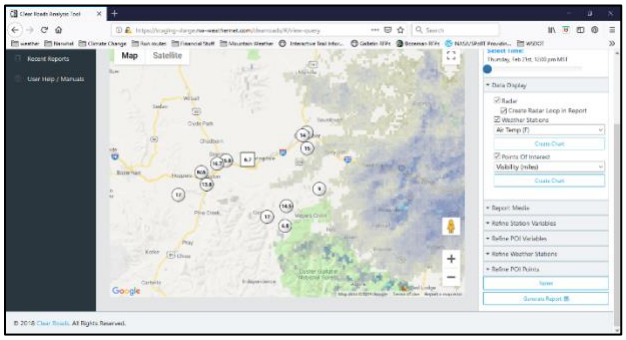
The objective of Task 4 was to build the web tool. According to the goals of the Clear Roads team, Narwhal worked to ensure that the tool (1) could be installed on the Clear Roads website, (2) would be compatible with the server, and (3) would work on recent versions of common browsers. The tool's code was designed to be open source: managed by, accessible to and editable by Clear Roads. Most importantly, this tool was designed to be intuitive and as simple and straightforward as possible to maximize its utility.

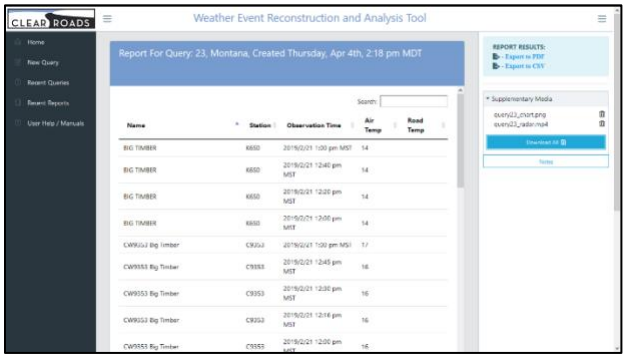
A beta version of the tool was made available to the Clear Roads committee on 12 February 2019.

The following graphics show screenshots of a sample query and report created in the beta version of the web tool.









Task 5: Test and Deliver Web Tool

Task Objective

To ensure that the tool is accessible and functional for use by the Clear Roads member agencies, the objective of Task 5 was to have the Clear Roads committee review the beta version and provide feedback. Three steps were involved in the testing phase:

1. Provide general guidance in order to ensure all users are using the tool to its fullest extent.
2. Have members use the tool and provide feedback on what works well, what needs work, and what is missing or not working at all.
3. Review feedback, make revisions, and perform a second round of testing to ensure the problems have been fixed. Repeat if necessary.

Testing Results

A beta version of the tool was made available to the Clear Roads TAC for testing. Testing was completed two months after beta delivery. The Narwhal team twice solicited feedback from the TAC, and received the following comments and questions in that time; also shown below are Narwhal's responses to the TAC's feedback.

Clear Roads: Will there be a video demonstration on how to use the tool? That could be very helpful.
Narwhal: We are putting together a video tutorial walking through the different steps of the tool. It will be added to the user help/manuals screen soon as the tool is implemented. It should be added in our first round of updates to the deployment.

Clear Roads: Will RWIS stations be included with this, or is it just general weather stations?
Narwhal: This tool does include any RWIS stations where data is shared as public data with MADIS or MesoWest. There are some instances where certain permissions are required to view pavement data through MADIS, and that specific data which requires authentication or verification of the user will not be available. In general, if the data is available at the following URL, the data should be available in the tool: https://mesowest.utah.edu

Clear Roads: Will an iPad work?
Narwhal: The design for this tool was focused on the expected use of a desktop computer. That said, in testing on our end we were able to complete most functionality on an iPad. The only struggle was viewing the .mp4 file created for the radar loop. By default it was not viewable, but if loaded into a third party app made for viewing .mp4 files, it could be viewed.

Clear Roads: NWS Products didn't seem to work.
Narwhal: We found a bug in the test version used by the CR group that prevented the NWS products from being generated. We have fixed that bug in what will be deployed as the working system.

Clear Roads: When a query or report is 'pending,' will that status update on its own?
Narwhal: You must manually refresh the page to get the status of the report or query to update.

Clear Roads: How long should a query take? How long should generating a report take?

Narwhal: These times can vary based on amount of data being gathered, but in general most queries take less than 5 minutes and most reports take less than 10 minutes to generate.

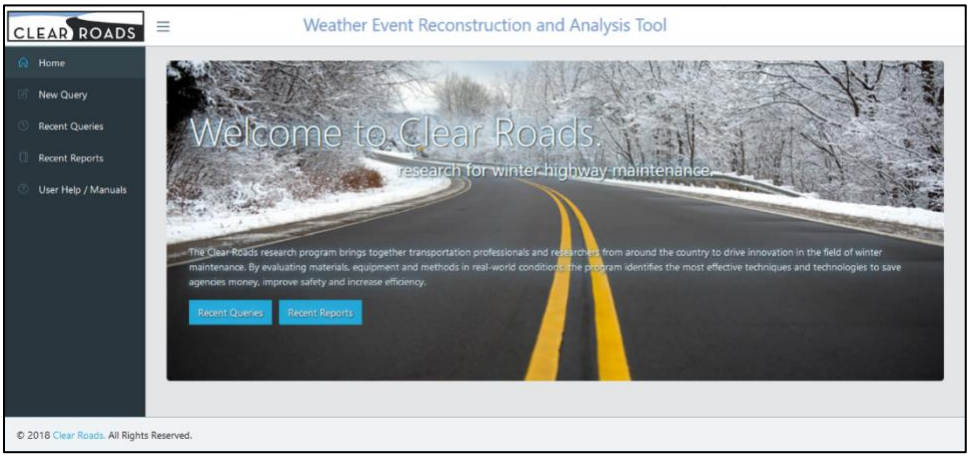
Clear Roads: Where do file downloads go?
Narwhal: The default location for downloads to go on windows computers would be:
Windows 10: This PC > Downloads
Windows 7: C:\Users\<username>\Downloads
Most browsers will direct you to this location when a file is downloaded.

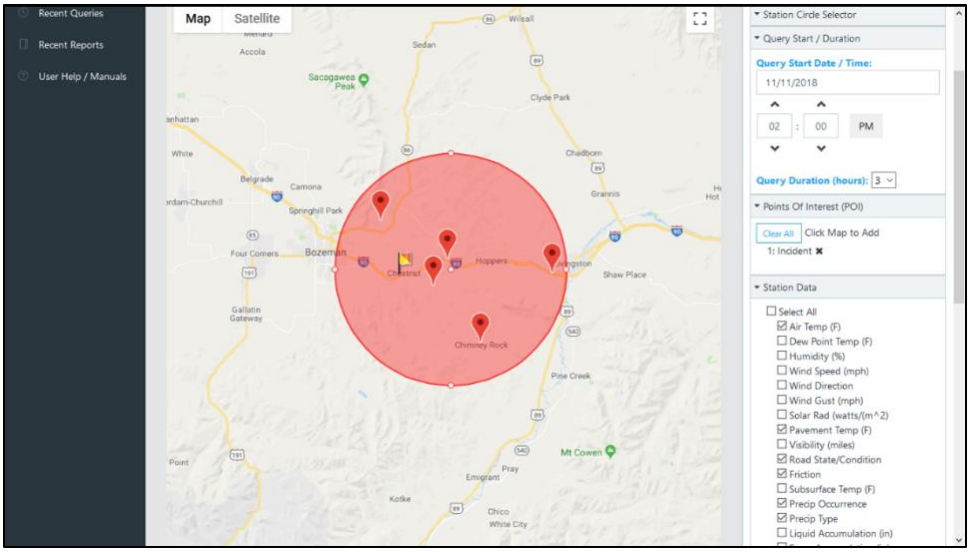
Clear Roads: I clicked 'Download All' on a query page after clicking 'Add Current Map' a couple times, but nothing seemed to happen. Are the files just saved to the report?
Narwhal: By clicking Download All on the query page, you should immediately be able to download the created images. This can be done on this page or on the report page. You can also click on the file name individually to download a specific file. If there was a bug with this in the test version, we do not currently see it in the version that will be deployed.

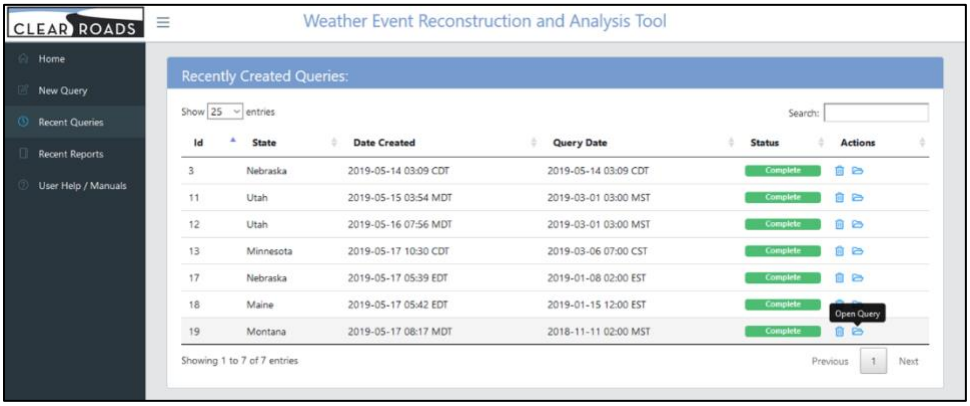
Clear Roads: POI Data didn't seem to show up.
Narwhal: There has been a slight adjustment to some of the RTMA data filenames in the data source we are using to gather this dataset. This specifically impacts the temperature and dew point data for the POI sites for queries February 2019 onward. We need to implement a fix to account for this data source change so that the query will work for queries both before and after the switch occurred. Other variables should have been available the whole time. This fix is being worked on and should be implemented with our first round of updates to the deployment.

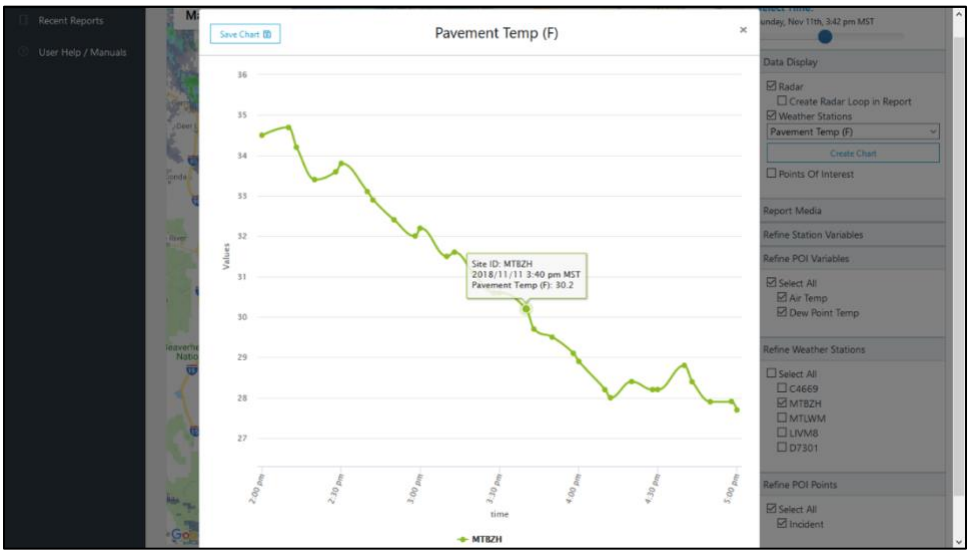
Feedback from the Clear Roads TAC was instrumental in creating a well-functioning final product.

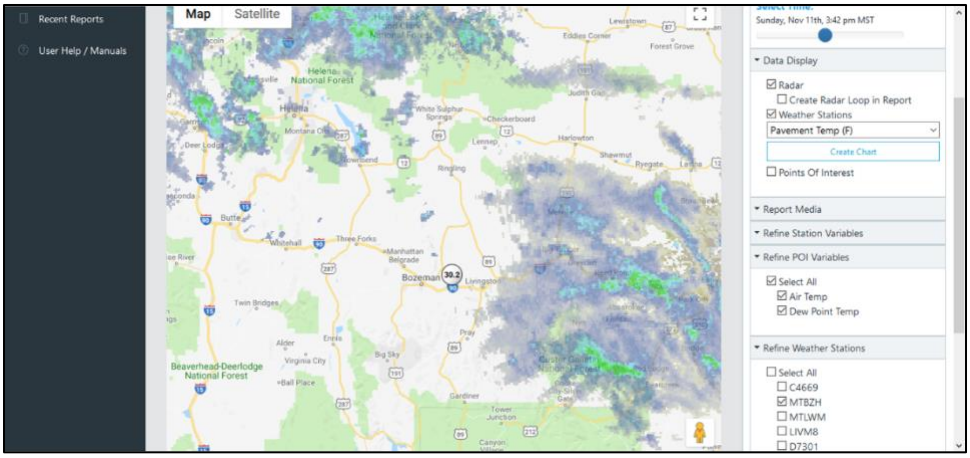
The final version of the Weather Event Reconstruction and Analysis Tool was delivered 6 June 2019 at https://clearroads.org/eventreconstruction. Sample screenshots of the homepage and a basic query being produced and viewed are shown below.




Recent Queries
Recent Reports
User Help / Manuals
Map
Satellite
Station Circle Selector
Query Start / Duration
Query Start Date / Time:
11/11/2018
02 : 00 PM
Query Duration (hours): 3
Points Of Interest (POI)
Clear All
Click Map to Add
1: Incident
Station Data
Select All
Air Temp (F)
Dew Point Temp (F)
Humidity (%)
Wind Speed (mph)
Wind Direction
Wind Gust (mph)
Solar Rad (watts/(m^2)
Pavement Temp (F)
Visibility (miles)
Road State/Condition
Friction
Subsurface Temp (F)
Precip Occurrence
Precip Type
Liquid Accumulation (in)
Bozeman
Chimney Rock
Mt Cowen


CLEAR ROADS
Weather Event Reconstruction and Analysis Tool
Home
New Query
Recent Queries
Recent Reports
User Help / Manuals
Recently Created Queries:
Show 25 entries
Search:
Id
State
Date Created
Query Date
Status
Actions
3 Nebraska 2019-05-14 03:09 CDT 2019-05-14 03:09 CDT Complete
11 Utah 2019-05-15 03:54 MDT 2019-03-01 03:00 MST Complete
12 Utah 2019-05-16 07:56 MDT 2019-03-01 03:00 MST Complete
13 Minnesota 2019-05-17 10:30 CDT 2019-03-06 07:00 CST Complete
17 Nebraska 2019-05-17 05:39 EDT 2019-01-08 02:00 EST Complete
18 Maine 2019-05-17 05:42 EDT 2019-01-15 12:00 EST Complete
19 Montana 2019-05-17 08:17 MDT 2018-11-11 02:00 MST Complete
Open Query
Showing 1 to 7 of 7 entries
Previous
1
Next


Recent Reports
User Help / Manuals
Save Chart
Pavement Temp (F)
Values
time
Site ID: MTBZH
2018/11/11 3:40 pm MST
Pavement Temp (F): 30.2
MTBZH
Data Display
Radar
Create Radar Loop in Report
Weather Stations
Pavement Temp (F)
Create Chart
Points Of Interest
Report Media
Refine Station Variables
Refine POI Variables
Select All
Air Temp
Dew Point Temp
Refine Weather Stations
Select All
C4669
MTBZH
MTLWM
LIVM8
D7301
Refine POI Points
Select All
Incident


Recent Reports
User Help / Manuals
Map
Satellite
Helena National Forest
Bozeman
Beaverhead-Deerlodge National Forest
Sunday, Nov 11th, 3:42 pm MST
Data Display
Radar
Create Radar Loop in Report
Weather Stations
Pavement Temp (F)
Create Chart
Points Of Interest
Report Media
Refine Station Variables
Refine POI Variables
Select All
Air Temp
Dew Point Temp
Refine Weather Stations
Select All
C4669
MTBZH
MTLWM
LIVM8
D7301

Task 6: Production of Guidance and Documentation

Task Objective

The objective of Task 6 was to develop a high-level guidance which walks a user through the tool. The guidance would include many screenshots stepping the reader through each tool choice or function. The document was to be made available as an online-available PDF or as an html document. Complete documentation of the code would also be developed in Task 6, and made available to the Clear Roads TAC.

Guidance Document

The guidance document (user manual) was delivered in PDF format and made available in the tool's user menu. It is located at: https://clearroads.org/eventreconstruction/#/user-help. It is also included in an addendum to this document. As requested by the Clear Roads TAC, a video guide was also developed and is located at the same URL.

Task 7: Technical Support

The objective of Task 7 was for Narwhal staff to provide technical support after finalization of the tool. This support would cover minor bugs, but not major updates. Any changes to the tool would be documented. The support period will end December 2019.

Task 8: Production of Final Report and Project Conclusions

Task Objective

The objectives of Task 8 include the preparation of this final report and the presentation of the final webinar. The report was delivered on 20 May 2019, and the webinar was conducted on a later date.

Project Conclusions

The goal of Clear Roads Project 16-05 was to develop a tool to help transportation agencies more quickly and easily reconstruct winter weather events by drawing from data sources that cover the entire United States. The motivation for such a tool was to help agencies better understand the development and outcomes of hazardous weather events, react appropriately to them in the short and long term, and refine future maintenance decision-making.

Vital to this project was the input of the tool's future users—the Clear Roads TAC—during its production. The TAC's feedback played a crucial role in the selection of data sources and the assembly of the flow and feel of the tool. What resulted was a reasonably efficient way to gather desired data and present it in a straightforward manner.

Appendix A

Table 1A. Final Task 2 spreadsheet showing the source catalog for point, spatial and forecast data.

Point											
Source	**URL**	**Network**	**Available Data Elements**	**Unavailable Data Elements**	**Geographic Coverage**	**Data Latency**	**Archival Longevity**	**How Data is Accessed**	**Download Format**	**API for Downloading?**	**Exporting Images/Animations**
MesoWest	http://mesowest.utah.edu/	NWS/FAA	Air Temperature Relative Humidity Dewpoint Temperature *(and Wetbulb)* Wind Speed & Direction Visibility Precipitation *(Accumulation)* *Most report Weather Conditions/Sky Cover (includes values like freezing rain or fog)*	Solar Radiation Pavement Data	Point; Airports, air fields or military bases	10-15 min (10-15-min incremental data)	Many years	API; Or via tables or graphics available on the web	JSON, GeoJSON, XML, CSV	Yes	Manually download graphical data
		RAWS (Remote Automated Weather Station)	Air Temperature Relative Humidity Dewpoint Temperature *(and Wetbulb)* Wind Speed & Direction Precipitation *(Accumulation)* Solar Radiation	Visibility Pavement Data	Point; Usually more remote; Can be near rural roads	15-90 min (1-hour incremental data)	Many years	API; Or via tables or graphics available on the web	JSON, GeoJSON, XML, CSV	Yes	Manually download graphical data
		RWIS	Air Temperature Relative Humidity Dewpoint Temperature *(and Wetbulb)* Wind Speed & Direction Visibility *(Sometimes)* Precipitation *(Sometimes; usu. in the form of intensity or type)* Solar Radiation *(Sometimes)* Pavement Data *Often, camera image*		Point; Critical locations along the road network	20-60 min (10-60-min incremental data)	Many years	API; Or via tables or graphics available on the web	JSON, GeoJSON, XML, CSV	Yes	Manually download graphical data; Camera image download
Meteorological Assimilation Data Ingest System (MADIS)	https://madis-data.noaa.gov/	(See MesoWest)	(See MesoWest	(See MesoWest)	(See MesoWest)	(See MesoWest)	Many years	API	netCDF; may be others	Yes	No
National Centers for Environmental Information (NCEI; formerly NCDC)	https://www.ncdc.noaa.gov/cdo-web/webservices/ncdcwebservices	US Historical Climatology Network (USHCN)	*Daily Summaries of…* Air Temperature Wind Speed & Direction Precipitation Snowfall Sky Cover Sunshine Weather Type	Relative Humidity Dewpoint Temperature Visibility Solar Radiation Pavement Data	Point; Airports, air fields or military bases	72 hours (daily)	Many years	API or Via tables or graphics available on the web; Or downloading CSV/DAT/PDF file	CSV/DAT/PDF JSON/XML	Yes	No
FHWA's Weather Data Environment (WxDE)	https://wxde.fhwa.dot.gov/	Mobile data *(only available in limited states)*	Air Temperature Relative Humidity Dewpoint Temperature Pavement Temperature	*Other variables possible, but often lacking.*	Finite strip of data along a road	10-15 min via subscription/7 days into archive (1-min incremental data)	2 weeks (subscription)/ A few years (archive)	Subscriptions for multiple vehicles/Manual requests for archived data	CSV	Yes for recent data/Not for archived data	No
Community Collaborative Rain, Hail & Snow Network (CoCoRaHS)	http://www.cocorahs.org/	CoCoRaHS	*Daily…* Precipitation Snowfall General Weather Comments	Air Temperature Relative Humidity Dewpoint Temperature Wind Speed & Direction Visibility Solar Radiation Pavement Data	Point; rural or urban	24 hours (daily total)	19 years (length of archive is state dependent)	Via tables or graphics available on the web	N/A	No	Manually download graphical or image data per state or county

Spatial: Model Analyses											
Source	**URL**	**Network**	**Available Data Elements**	**Unavailable Data Elements**	**Geographic Coverage**	**Data Latency**	**Archival Longevity**	**How Data is Accessed**	**Download Format**	**API for Downloading?**	**Exporting Images/Animations**
National Centers for Environmental Prediction (NCEP) FTP Server	http://www.nco.ncep.noaa.gov/pmb/products/rtma/	RTMA (Real-Time Mesoscale Analysis)	Air Temperature Dewpoint Temperature Wind Speed, Direction and Gust Visibility Cloud Cover *(proxy for solar)* Precipitation *(hourly accum.)*	Relative Humidity Precipitation *(type, etc.)*	2.5-km (CONUS), 3-km (Alaska)	Real-time (hourly)	A couple days	.grb2 files via FTP or H	GRIB2	Automate from FTP or HTTP	No
		URMA (UnRestricted Mesoscale Analysis)	Air Temperature Dewpoint Temperature Wind Speed, Direction and Gust Visibility Cloud Cover *(proxy for solar)* Precipitation *(6-hourly accum.)*	Relative Humidity Precipitation *(type, etc.)*	2.5-km (CONUS), 3-km (Alaska)	6 hours (hourly)	A couple days	.grb2 files via FTP or H	GRIB2	Automate from FTP or HTTP	No
NWS FTP Server	http://www.nco.ncep.noaa.gov/pmb/products/rtma/	RTMA	Air Temperature Dewpoint Temperature Wind Speed, Direction and Gust Visibility Cloud Cover *(proxy for solar)* Precipitation *(CONUS only, hourly accum.)*	Relative Humidity Precipitation *(type, etc.)*	2.5-km (CONUS), 3-km (Alaska)	Real-time (hourly)	A couple days	.bin files via FTP	BIN	Automate from FTP	No
		URMA	Air Temperature Dewpoint Temperature Wind Speed, Direction and Gust Visibility Cloud Cover *(proxy for solar)*	Relative Humidity Precipitation	2.5-km (CONUS only)	6 hours (hourly)	A couple days	.bin files via FTP	BIN	Automate from FTP	No
GEMPAK Data Archive (from UNIDATA NOAAPORT Feed)	http://mtarchive.geol.iastate.edu/	RTMA	Air Temperature Dewpoint Temperature Wind Speed, Direction and Gust Visibility Cloud Cover *(proxy for solar)*	Relative Humidity Precipitation	2.5-km (CONUS), 3-km (Alaska)	Real-time (hourly)	2001	FTP	GRIB2	Automate from FTP	No
NOAA's Earth System Research Laboratory (ESRL)	https://www.esrl.noaa.gov/psd/cgi-bin/data/narr/plothour.pl	North American Regional Reanalysis (NARR)	Air Temperature Dewpoint Temperature Relative Humidity Wind Speed, Direction and Gust Visibility Cloud Cover *(proxy for solar)* Precipitation *(3-hourly accum.)* Precipitation *(type, etc.)*		32-km	Months (3-hourly)	1979	Web Interface, Raw files also available via another website (but only since 2015)	NetCDF, GRIB	Yes	Manually from web interface
HRRR Archive at the University of Utah	http://home.chpc.utah.edu/~u0553130/Brian_Blaylock/hrrr_FAQ.html	High-Resolution Rapid Refresh (HRRR)	Air Temperature Dewpoint Temperature Relative Humidity Wind Speed, Direction and Gust Visibility Cloud Fraction *(proxy for solar)* Precipitation *(type, accum.)*		3-km	1 day (hourly)	2015	Manual download or script using wget or curl.	GRIB2	No	No

Spatial: Radar and Satellite											
Source	**URL**	**Network**	**Available Data Elements**	**Unavailable Data Elements**	**Geographic Coverage**	**Data Latency**	**Archival Longevity**	**How Data is Accessed**	**Download Format**	**API for Downloading?**	**Exporting Images/Animations**
NCAR's Earth Observing Laboratory (EOL)	https://data.eol.ucar.edu/dataset/21.093	Stage IV Precipitation Data	Precipitation *(hourly accum.)*	Air Temperature Relative Humidity Dewpoint Temperature Wind Speed & Direction Visibility, Cloud Cover Precipitation *(type, etc.)*	CONUS (4-km resolution)	6 hours (hourly)	2 days	.bufr_d.unblk files via	BUFR	Automate from FTP	No
NOAA Operational Model Archive and Distribution System (NOMADS)	http://nomads.ncep.noaa.gov/pub/data/nccf/com/hourly/prod/	Stage IV Precipitation Data	Precipitation *(hourly accum.)*	Air Temperature Relative Humidity Dewpoint Temperature Wind Speed & Direction Visibility, Cloud Cover Precipitation *(type, etc.)*	CONUS (4-km resolution)	~2 months (hourly)	2002	GRIB data; order & delivered (via email)	GRIB	Automate from FTP	No
National Centers for Environmental Information (NCEI) Radar Archive	https://www.ncdc.noaa.gov/nexradinv/	Level-II (Base) Precipitation Data	Precipication *(location, intensity, progression)*	Air Temperature Relative Humidity Dewpoint Temperature Wind Speed & Direction Visibility, Cloud Cover Precipitation *(type, etc.)*	Local (1-km resolution)	A few hours (5-min)	2007	Web Interface and .GZ files available for download (manual)	.GZ	No	Manually from web interface
Amazon S3 NEXRAD Archive	https://s3.amazonaws.com/noaa-nexrad-level2/index.html	Level-II Precipitation Data	Precipication *(location, intensity, progression)*	Air Temperature Relative Humidity Dewpoint Temperature Wind Speed & Direction Visibility, Cloud Cover Precipitation *(type, etc.)*	Local	Real-time	1991	HTML index	BIN	Yes	Via script download
Iowa Environmental Mesonet (IEM) Archive	http://mesonet.agron.iastate.edu/ogc/ or https://mesonet.agron.iastate.edu/docs/nexrad_composites/	Base Reflectivity	Precipication *(location, intensity, progression)*	Air Temperature Relative Humidity Dewpoint Temperature Wind Speed & Direction Visibility, Cloud Cover Precipitation *(type, etc.)*	National (via local sectors)	Real-time	Years	JSON script	Raster	Yes	Via script download
University Corporation for Atmospheric Research (UCAR) Archives	http://weather.rap.ucar.edu/radar/	Radar Reflectivity	Precipication *(location, intensity, progression)*	Air Temperature Relative Humidity Dewpoint Temperature Wind Speed & Direction Visibility, Cloud Cover Precipitation *(type, etc.)*	Local (single radar radius)	Real-time (4-min)	5 days	Web interface, manual download from images	PNG	No	Manually from web
	or http://www2.mmm.ucar.edu/imagearchive/		Precipication *(location, intensity, progression)*	Air Temperature Relative Humidity Dewpoint Temperature Wind Speed & Direction Visibility, Cloud Cover Precipitation *(type, etc.)*	Regional nationally	Approx. 24 hours (30-min)	1996	Image download via web	GIF	No	Manually from web
IEM Archive	http://mesonet.agron.iastate.edu/ogc/	Satellite Images	IR Satellite Vis Satellite WV Satellite Fog/Low Cloud Channel	Air Temperature Relative Humidity Dewpoint Temperature Wind Speed & Direction Precipitation	National	Real-time	Years	JSON script	Raster	Yes	
UCAR Archives	http://weather.rap.ucar.edu/satellite/	Satellite Images	IR Satellite Vis Satellite WV Satellite	Air Temperature Relative Humidity Dewpoint Temperature Wind Speed & Direction Visibility, Precipitation	Regional nationally	Approx. 1 hour (30-min)	5 days	Web interface, manual download from images	JPEG	No	Manually from web
	or http://www2.mmm.ucar.edu/imagearchive/		IR Satellite Vis Satellite	Air Temperature Relative Humidity Dewpoint Temperature Wind Speed & Direction Visibility, Precipitation	Regional across Plains/Midwest	Approx. 24 hours (30-min)	1996	Image download via web	JPEG	No	Manually from web
NOAA Satellite and Information Service (NESDIS)	https://www.star.nesdis.noaa.gov/smcd/opdb/aviation/fog.html	Fog Satellite Product	Fog Satellite Product	Air Temperature Relative Humidity Dewpoint Temperature Wind Speed & Direction Precipitation	National, regional and select metro close-ups	1-3 hours (hourly)	A few hours	Web interface, manual download from images	GIF	No	Manually from web

Forecast											
Source	**URL**	**Network**	**Available Data Elements**	**Unavailable Data Elements**	**Geographic Coverage**	**Data Latency**	**Archival Longevity**	**How Data is Accessed**	**Download Format**	**API for Downloading?**	**Exporting Images/Animations**
NWS National Digital Forecast Database (NDFD)	http://www.nws.noaa.gov/ndfd/anonymous_ftp.htm	NDFD	Air Temperature[1] Dewpoint Temperature[1] Relative Humidity[1] Wind Speed[1], Direction[1] and Gust[2] Sky Cover[1] Weather[1] Quantitative Precipitation (QPF)[3] Snow Amount[3] Ice Accumulation[3] Hazards[4]	*Visibility (planned)* *Ice Coverage (planned)* *Snow Level (planned)*	National	[1]7 days (1-6-hour) [2]3d(1-3h) [3]3 d (6 h) [4]3 d (1-6 h)	Current	FTP	GRIB2	Via scripts	No
NCEI NDFD Archive	https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/national-digital-forecast-database-ndfd	NDFD	(see above)	(see above)	(see above)	(see above)	2008	FTP, HTTPS, or TDS	GRIB2	Via scripts	No
NOAA Dataport	http://tgftp.nws.noaa.gov/data/	Forecast Discussions (...forecasts/discussion/)	*Text-based, NWS-issued forecast discussions*	*N/A*	National (by NWS forecast office county warning area)	Realtime	Most recent	FTP	Text	No	No
		Watches/ Warnings (...watches_warnings/)	*Text-based, NWS-issued watches and warnings*	*N/A*	National (by NWS forecast office county warning area)	Realtime	Most recent	FTP	Text	No	No
NWS Weather Forecast Office Product Listing	http://forecast.weather.gov/product_types.php?site=NWS	NWS Text Products	*Text-based, NWS-issued products (discussions, advisories, warnings, etc.)*	*N/A*	National (by NWS forecast office county warning area)	Realtime	1 week	Manually searchable or via script	Text	No	No
Iowa Environmental Mesonet (IEM) Archive	http://mesonet.agron.iastate.edu/wx/afos/list.phtml	NWS Text Products	*Text-based, NWS-issued products (discussions, advisories, warnings, etc.)*	*N/A*	National (by NWS forecast office county warning area)	Realtime	2001	Manually searchable	Text	No	No

Appendix B

The user needs outline for the weather reconstruction web tool follows:

- **System will be web based with cross-browser support**
  This is expected to be a web-based system that will be accessed from desktop computers, mobile browser support is not anticipated at this time. The system must be able to be installed on the Clear Roads website.
- **System needs to be open source with Clear Roads able to edit code**
  Since the tool will draw on external web-based data that may change over time, the tool should be open source and built with nonproprietary programming to allow for future revision.
- **Users will be required to use credentials to access**
  Login will serve a few different purposes:
    - Identify which client is logging in as this will be shared by multiple entities
    - Identify access to any special datasets that an entity wants to keep private
    - Identify search history of the logged in client for easy access to past searches
    - Online security
- **User defines time range (date and time)**
    - User will be able to select a time range of interest (start – finish).
    - There should be an option to select a single point in time in which case data from within X minutes on either side is returned (snapshot of the weather at a given time).
    - Preference would be for start/end to be selected using a calendar and time list (in whole hours).

  NOTE: It is requested that we add a reminder on screen (helpful hint) that users should ensure that the entire length of storm *impacts* is included.
- **User defines geographic extent of data (geographic area)**
    - The user should be able to define a region/area (or point) of interest that will be the extent of data loaded into the system
    - *Possible* options listed for user selection include:
        - Option 1: Provide a clickable map. If a single point is clicked, a circle of X radius is chosen. Radius is also editable.
        - Option 2: Provide a map over which a selection box can be dragged.
        - Option 3: Allow a city or county to be input, the geographic boundaries of which are the same as the political boundaries.
        - Option 4: Allow a state to be input, the geographic boundaries of which are the same as the political boundaries.

  NOTE: It is requested that we add a reminder on screen (helpful hint) reminding users that it is important to view a storm from a regional perspective.
- **User defines desired observation data**
  Users should be able to select one or more variables from the following list for display on the interactive map and in any exported reports. Variables based on available data found in Task 1.
    - Atmospheric Data
        - Air temperature (point or spatial)
        - Dew point temperature (point or spatial)
        - Relative humidity (point only)
        - Wind speed (point or spatial)
        - Wind direction (point or spatial)
        - Visibility (direct, point or spatial)
        - Solar radiation (point, cloud cover for spatial)
    - Pavement Data (all Point data)
        - Pavement temperature
        - Eutectic point
        - Road state/condition
        - Friction
        - Salinity
        - Subsurface temperature
    - Precipitation Data
        - Occurrence (point)
        - Type (point)
        - Intensity (point)
        - Accumulation, liquid (point or spatial)
        - Accumulation, snow (point)

        - Radar, reflectivity (spatial)
    - Satellite Data (all Spatial data)
        - Visible satellite
        - Infrared satellite
        - Water vapor satellite
        - Fog satellite product

      NOTE: It is requested that we add a helpful hint next to each data option explaining the product and why it is useful (text found in Task 1 spreadsheet).
- **User defines desired forecast data**

  Users should be able to select one or more variables from the following list for display on the interactive map and in any exported reports. Variables based on available data in Task 1:
    - NDFD Variables (all spatial or point data)
        - Air Temperature
        - Dew Point
        - Relative Humidity
        - Wind Speed, Direction, Gust
        - Sky Cover
        - Weather
        - Quantitative Precipitation (QPF)
        - Snow Amount
        - Ice Accumulation
        - Hazards
    - Text-based NWS Products

      All Text-Based NWS products issued for the selected region for the selected timeframe should be available.
- **Map-based Data Viewer**
    - It is expected that the primary interface with any data would be an interactive map (Google, Openlayers, or similar).
    - Spatial data will be viewable on the map
    - Point data will be viewable in graph form from clicking on the map/clicking on available point locations
    - Point data for one variable can be displayed for a given time on the map for all sites available
    - Multiple time sliders may be necessary
        - Time slider for observed data within the user selected time range
        - Time slider for forecast data which shows what the given available forecast was at the specific time within the user selected time range.
    - NWS text products available through map click for given map time
- **User can generate reports**

  The user should be able to output data from the given time frame into report form with options to view as web-based report, .pdf report and .csv file option for tabular point data.
    - Report contains observational point data;

      Point data in the report should be available in both tabular and graphical form.
    - Report contains observational spatial data;

      Spatial data in the report should be either an animation (gif, mp4, etc.) or a series of images. On the pdf report it is expected that multiple still images would be necessary. In some cases with either a large timeframe or large temporal resolution a large number of images would be needed.
    - Report contains forecast point data;

      Point data in the report should be available in both tabular and graphical form.
    - Report contains forecast spatial data;

      Spatial data in the report should be either an animation (gif, .mp4, etc.) or a series of images. On the pdf report it is expected that multiple still images would be necessary. In some cases with either a large timeframe or large temporal resolution a large number of images would be needed.
    - Report contains NWS Text Products;

      Any NWS text products issued for the selected area over the given time should be included in the report.
- **Query history saved for user account**

  Query history is maintained per user account so that the user can recall past queries easily.

- **User can add Notes to a search**
  A user should be able to add customized text notes to a storm search that will be saved in the query history.

Addendum: Weather Event Reconstruction and Analysis Tool User Manual

Clear Roads Weather Event Reconstruction and Analysis Tool

User Manual

Table of Contents

1) Overview

Welcome to the Clear Roads Weather Event Reconstruction and Analysis Tool User Manual. This document will guide you through the steps of the tool, how to use each part, and the data that you can expect the tool to return. The overall goal of the tool is to bring several data sources together to recreate weather events without having to visit several sites to gather data.

The following key terms will be used in this manual:

Media – Any file generated from the tool. This could be a screenshot, chart/graph, or movie file of a radar loop.

Query – Settings for data to be gathered from outside sources using the Tool. The user will select date/time and certain information to collect from the available data systems. That information is stored in the system as the query.

Report – Generation of files from the system. When the user saves a report, all files associated with the query are generated and made available for download.

2) General Layout

The Reconstruction and Analysis Tool has been set up to make all of the controls easily accessible in both right- and left-side menus. Figure 1 shows an example of the user interface (UI) layout. On the left side of the UI, you will see a navigation menu that will move you through the UI to different sections. On the right side, you will find an actions menu that will allow you to control the data being displayed, and make selections of certain data to save or discard.

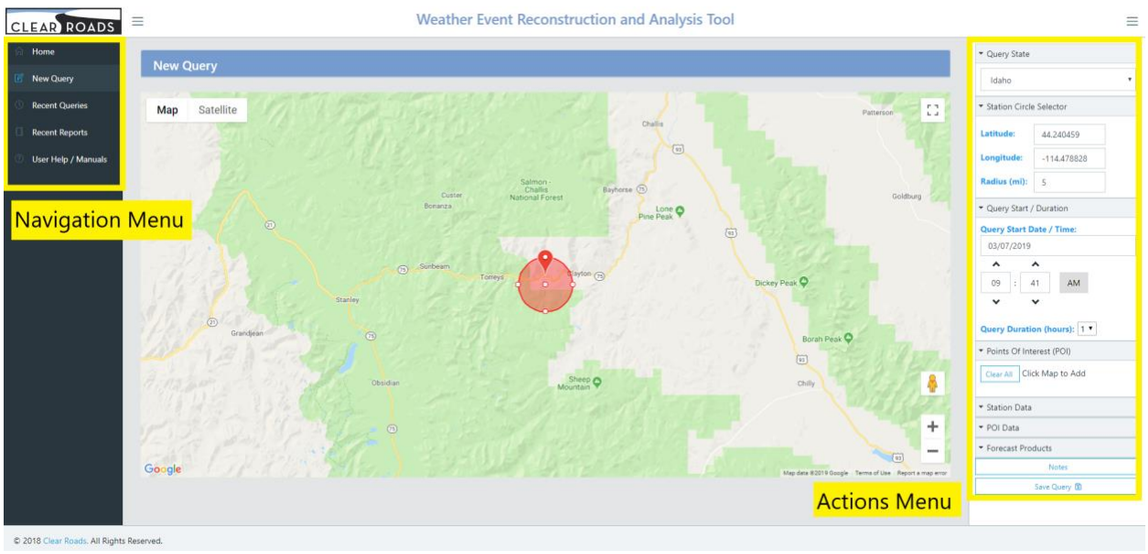


Figure 1: Overview of the layout of the UI

3) New Query

The first step in using the tool is to create a query. Here you will choose which date/time and types of data you are interested in viewing. Select 'New Query' from the navigation menu to get to the create-a-query screen. Controls to create the query will be found on the right side in the Actions Menu. The following lists all controls from top to bottom and how each control impacts your query.

- **Query State –** This dropdown allows you to select a state to start your query. When you select a state from the dropdown, the map will automatically center on the state selected. The other function of this dropdown is that when queries are saved, the name given to the query will be the state name.

- **Station Circle Selector –** This section lists the latitude and longitude of the center of the selection circle displayed on the map, along with the circle's radius (in mi). The selection circle will include the observation sites desired for your query (see Figure 2). You can edit the location/size of the circle by manually typing in the text boxes in the Actions Menu, or you can click and drag the center of the circle to change the location, or the edges of the circle to expand or decrease the radius of the circle.
  Note: when you move the ring, the possible available sites within that ring will be displayed. To undo changes made to the circle, click the gray arrow that appears at the left side of the circle.

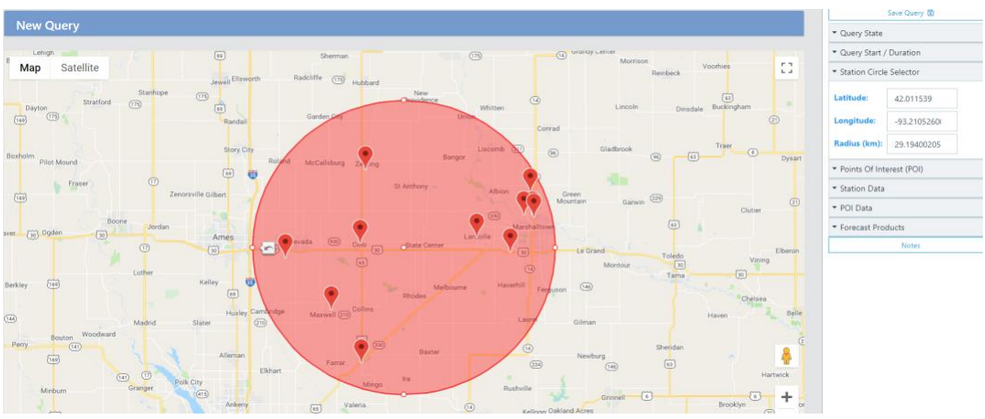


Figure 2: Example query circle

- **Query Start / Duration –** In this section you will select a starting date/time for your query. Note that the time you enter will be in local time for the center of your query circle. You also need to select a Query Duration in hours (see Figure 3). You can select up to a six hour query.

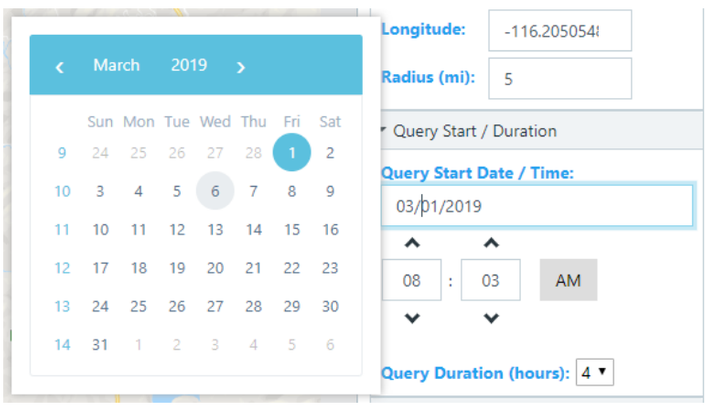


Figure 3: Example of Starting date/time for your query

- **Points of Interest (POI) –** One of the more powerful features of this interface is the ability to highlight certain weather conditions at a given point of interest. This data is generated from the National Weather Service's Real-Time Mesoscale Analysis (RTMA), an interpolated dataset. It is not direct observational data, but an analysis of the observations made near the point of interest, and it will provide a sense of the weather that likely occurred at that point.

    - **Add a POI** – To add a POI, simply click within the circle selector on the map. The UI will prompt you to enter a name for the POI. Once you enter a name and click 'ok,' the point will be added to the map as a flag (see Figure 4). Note that POI names are limited to 50 characters.

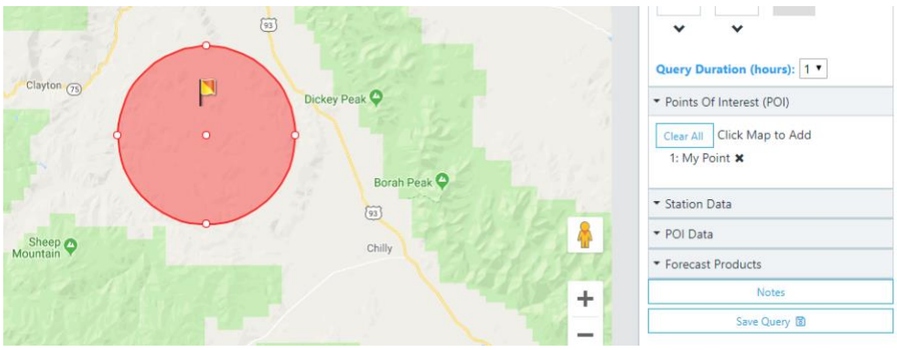


Figure 4: Example of a POI on the map

    - **Delete a POI** – To remove a POI already added to the map, simply click on the x next to the POI name in the Actions Menu (see Figure 5).

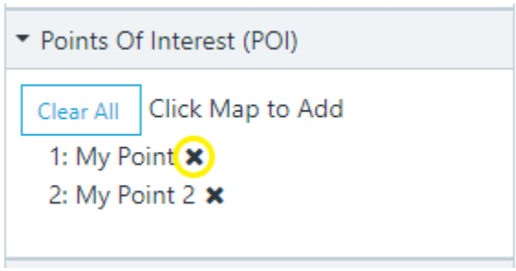


Figure 5: Click the X to remove a POI from the map

    - **Clear All** – To remove all POIs from the map, click the Clear All button in the Actions Menu (see Figure 6).

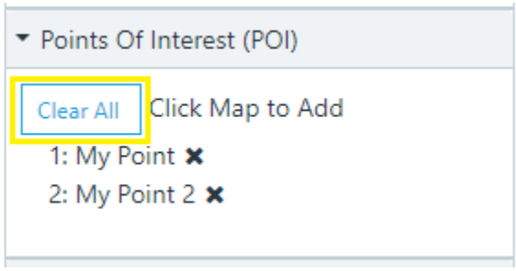


Figure 6: Click the Clear All button to clear all of the POIs from the map

- **Station Data –** This section allows you to pick and choose variables of interest for the observation sites (i.e., RWIS, ASOS/AWS and RAWS) the system will query (see Figure 7). It is not guaranteed that all variables will be available for all sites. The data that is available is the data made available to MADIS and Synoptic Labs by the owners of each data network. You can select any or all variables from this list. **Note:** Weather station dataset availability varies widely depending on the network. Some data may be available as far back as 1997, while other datasets may have been shared for a shorter amount of time.

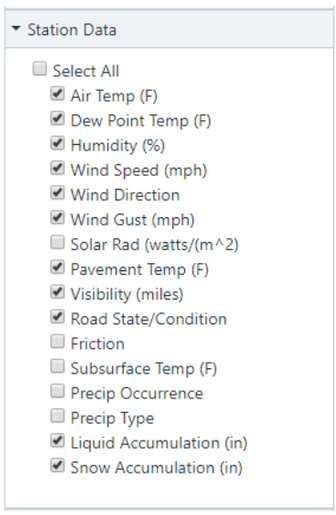


Figure 7: Example of variables in Station Data

- **POI Data –** Similar to the Station Data section, this section allows you to select variables of interest for any POI that has been created (see Figure 8). These variables would be available to any POI created. **Note:** The RTMA data source used for POIs is valid from 2012 onward, with some data available as far back as 6/1/2011.

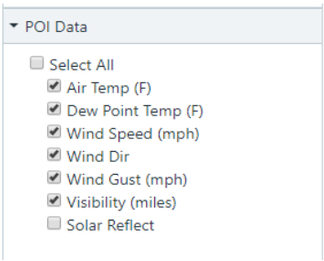


Figure 8: Example of Variables in POI Data

- **Forecast Products –** This selection allows you to select whether or not to include text products issued by the National Weather Service (NWS). If you would like to do this, select the products of interest, and set a Forecast Date (see Figure 9).

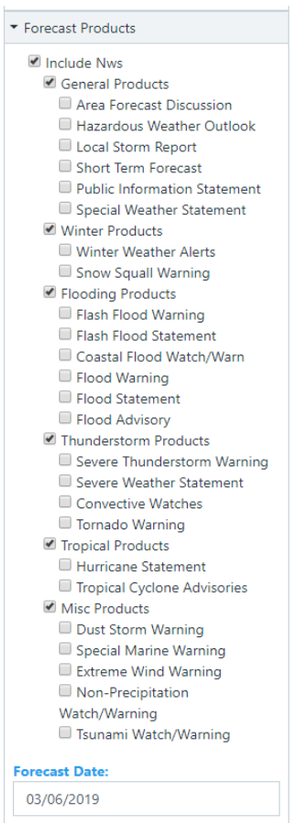


Figure 9: Example of products from the NWS that may be available.

A few additional notes about this section follow:

- The query uses the latitude/longitude coordinates at the center of your query circle as the point to decide which NWS office products to search.
- The Forecast Date will be used by the query to find all NWS products selected from the list that were issued at any point during the selected Forecast Date.
- You can change the Forecast Date to capture NWS products from dates leading up to the query date.
- The NWS products dataset is valid from 2008 forward. Some data, though possibly incomplete is available as far back as 1996.

- **Notes** – This section allows you to add user notes to a given query (see Figure 10). When you click the 'Notes' button, a text box will pop up. Enter whatever text you would like to associate with the query such as notes about an incident. This text will eventually be displayed in the report, and can be edited at later steps. Once you have entered text, simply click away from the text box. The written text will automatically be saved. Query notes are limited to 3000 characters.

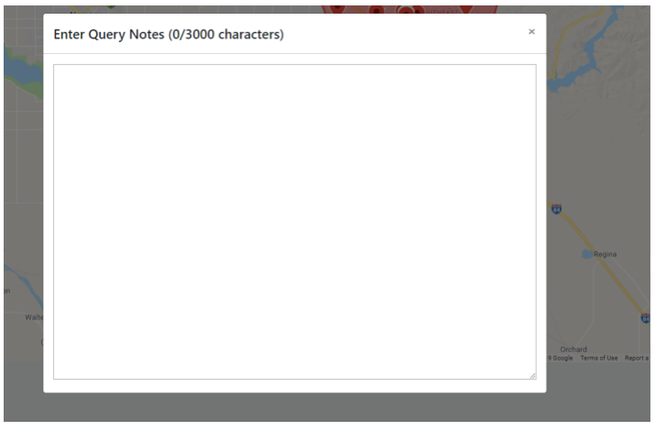


Figure 10: Example of pop up text box for Notes

- **Save Query –** Click the "Save Query" button at the bottom of the window to save the query to the database. This is the last step in creating the query. You will then be directed to the 'Recent Queries' page and can see the status of your query.

4) Recent Queries

The recent queries page (see Figure 11) shows a list of queries recently saved, when the query was created, the date of the query's data, and the status of the given query. An identification number (Id) is assigned to the query based on the order that it is created. Once a query is marked complete, open it by clicking on the folder in the Actions column. More about viewing the query is explained in the next section. If you no longer need a query, or for some reason the query errored out, you can delete the query by clicking on the trash can in the Actions column.

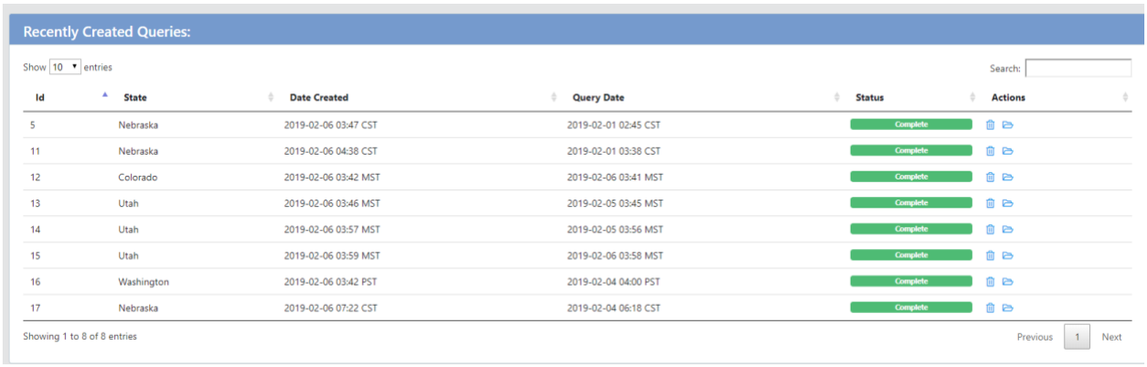


Figure 11: Example list of recently created queries

5) View Query

Once you have created a query, open the query from the 'Recent Queries' page by clicking on the folder icon in the Actions column of the table. This will open an interactive screen (see Figure 12) for viewing available data associated with a query. With the query open, you have several options to look at the data and save information. The following lists all controls in the Actions menu from top to bottom and how each control impacts your query.

Note: Only one report can be associated with a query at a time. If a report has already been generated the Generate Report button will not be shown. To create a new report you must delete the old report first.

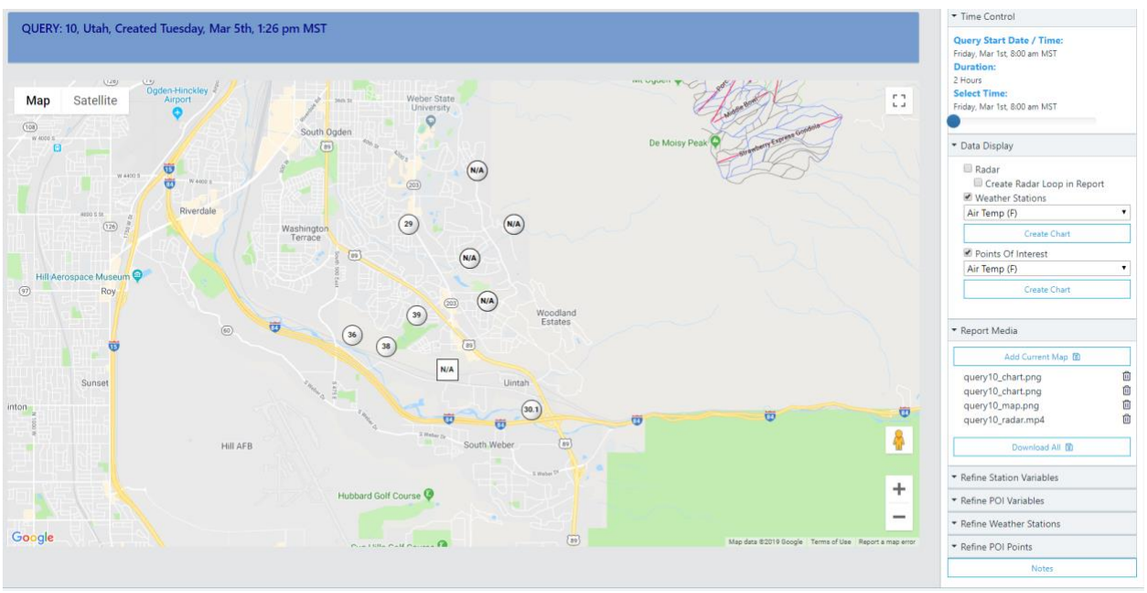


Figure 12: Example of Recent Query

- **Time Control –** This section shows information on the start time of the query along with duration. There is also a time slider that allows you to scroll through any available data for the length of the query. Click and drag the slider to move through the data to find the time you want (see Figure 13). Alternately, you can use the arrows on the keyboard to slide the timer by hitting the TAB key until the slider is selected, then clicking the arrows.

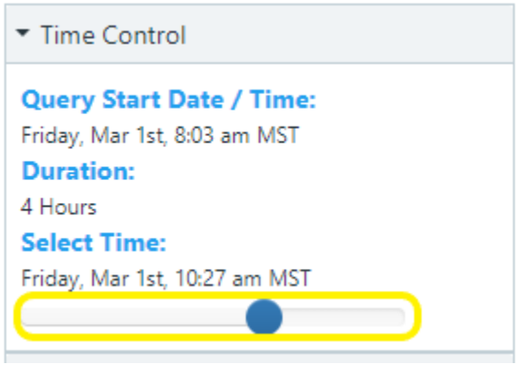


Figure 13: Time Control time slider

- **Data Display –** This section controls what data is being displayed on the map. Below outlines the choices and what can be done with each (see Figure 14).

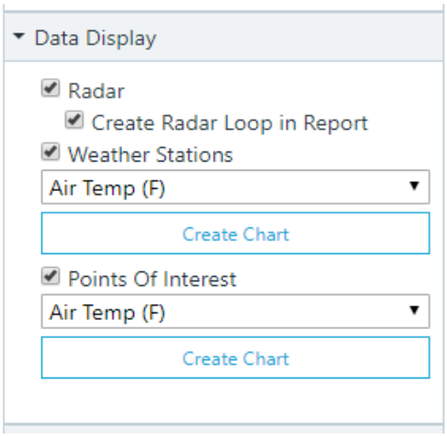


Figure 14: Example of Data Display

  - **Radar –** Overlay radar imagery for the given time on the map (see Figure 15). This is simply on or off.

    Create Radar Loop in Report – If you are interested in saving a .mp4 loop of radar imagery for the given query, check this box. That file will be generated as part of the report and will be downloadable below in Report Media (see Figure 29 for an example).

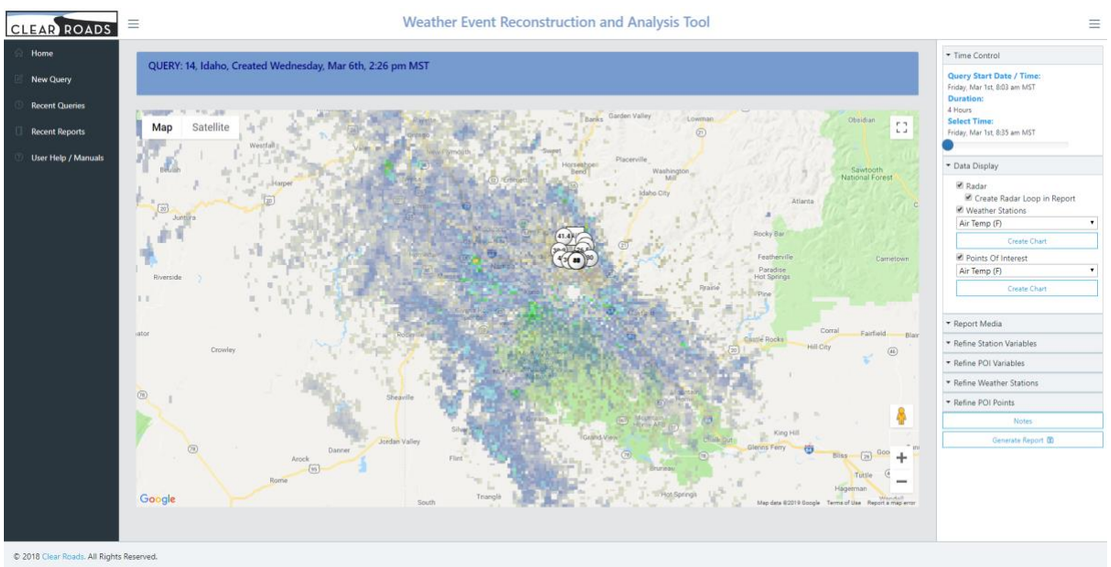


Figure 15: Example of radar imagery

- **Weather Stations –** This overlay will show any weather stations with available data for the given time period. Toggle on/off to display this layer. When it is on, the data is shown inside of circles on the map at the location of the sites. Change which variable is displayed on the map by selecting a different variable from the dropdown menu.

- **Points of Interest –** This overlay will show any POIs that were created with the query. Toggle on/off to display this layer. When it is on, the data is shown inside of squares on the map located at the selected POI location. Change which variable is displayed on the map by selecting a different variable from the dropdown menu.

- **Create Chart –** Both Weather Stations and POIs give the option of creating a chart of all of the sites for a given variable. For instance, if you have Air Temp (F) selected as the Weather Stations variable and click Create Chart, a chart of air temperatures for all available weather stations is generated (see Figure 16). This chart spans the length of the query and shows all weather stations that are part of the query. The following are tips for manipulating the chart:

    - To hide Weather Stations or POIs from the chart, click on the site ID at the bottom (you can see in Figure 16 that the hidden sites have been crossed off).
    - You can hover over the points on the chart to see specific values.
    - Click the Save Chart button at the top left to save this image to be downloadable later on, and to be included in the report document.

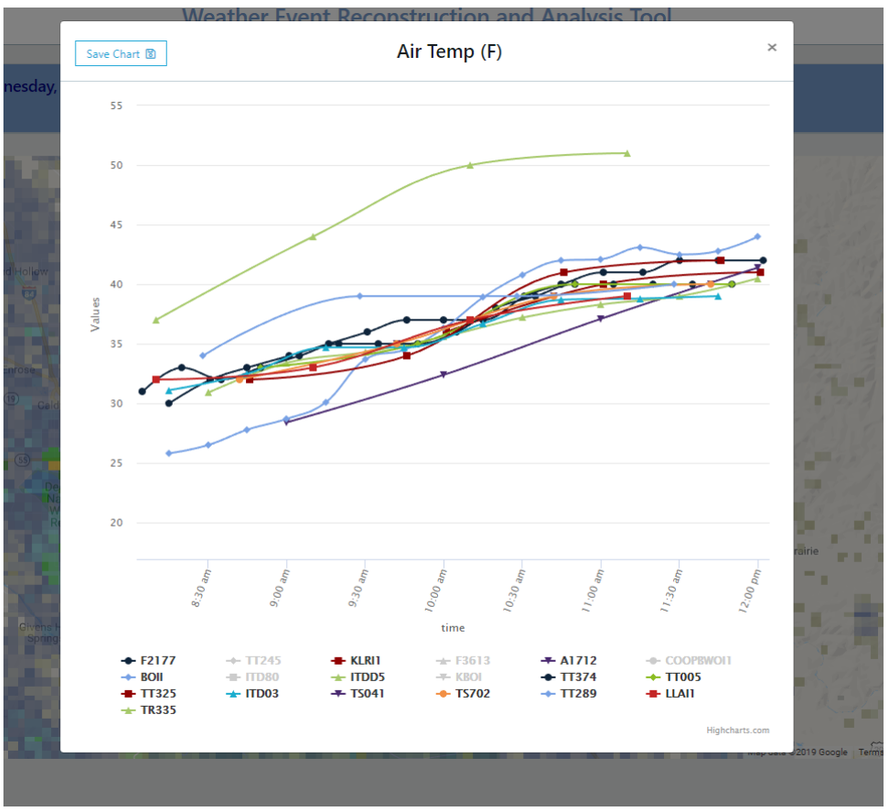


Figure 16: Example chart created from weather station data

- **Report Media –** This section allows you to create and manage additional media that will be saved with the query as part of the report (see Figure 17). There are a few things that can be done from this section, as follows:

    - **Add Current Map –** Clicking this button will save the current map view as a screenshot image. All layers that are visible on the map will be shown in the image.
    - **List of Included Media –** These will range from map screenshots and chart screenshots, to the included radar loop. If you want to remove a media file click the trash can next to it and confirm.

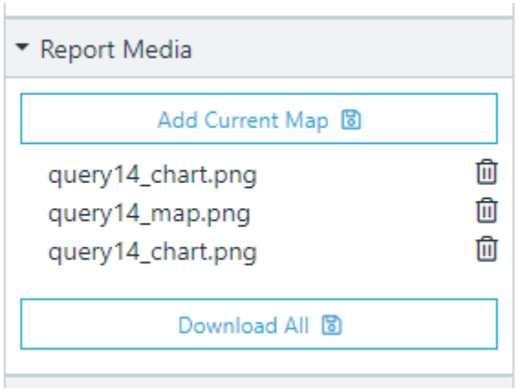


Figure 17: Example of Media you can download to Report

- **Refine Station Variables –** This section shows a list of the weather station variables (see Figure 18) that you initially opted to search for in your query. If you decide that you do not need all of them, simply uncheck them to not include them in the final report.

    Tip: Remove as many variables that are not needed to declutter the final report. Data tables with unneeded or empty variables take up space in the pdf version of the report; they can add to the length of the document and make it harder to read.

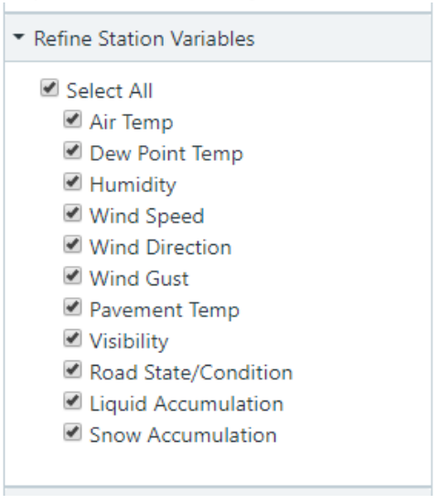


Figure 18: Example of Weather Station variables.

- **Refine POI Variables -** This section shows a list of the POI variables (see Figure 19) that you initially opted to search for in your query. If you decide that you do not need all of them, simply uncheck them to not include them in the final report.

  Tip: Remove as many variables that are not needed to declutter the final report. Data tables with unneeded or empty variables take up space in the pdf version of the report; they can add to the length of the document and make it harder to read.

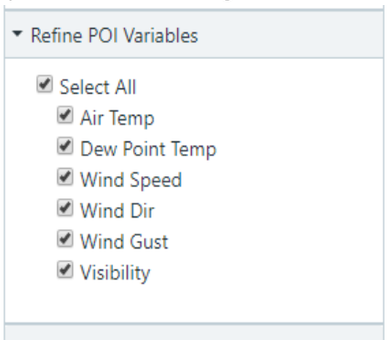


Figure 19: Example of POI variables

- **Refine Weather Stations –** This section shows all of the station IDs returned for a given query. If there are stations that you do not want to include in the report, simply uncheck the ID (See Figure 20).

  Tip: Unchecking the ID will remove the station from the query view map. You can remove unwanted stations before taking map screenshots. Also having unwanted stations in the report will add length to the pdf report.

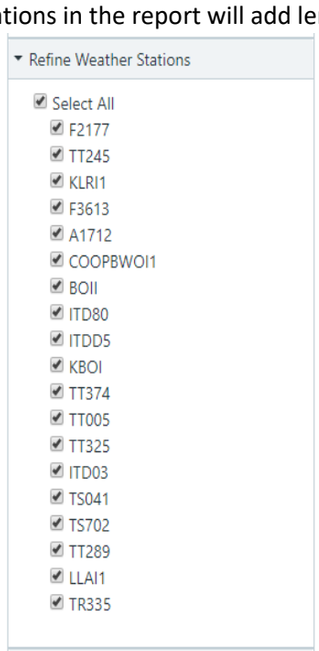


Figure 20: Example of refining Weather Stations for your report.

- **Refine POI Points –** This section shows all of the POIs created for a given query. If there are POIs that you do not want to include in the report, simply uncheck the ID (see Figure 21).

  Tip: Unchecking the ID will remove the POI from the query view map. You can remove unwanted POIs before taking map screenshots. Also having unwanted POIs in the report will add length to the pdf report.

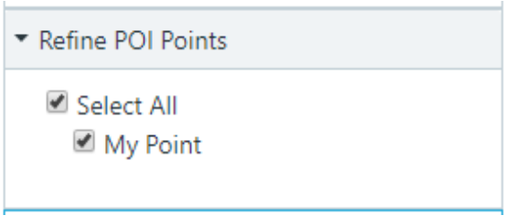


Figure 21: Example of refining POI points for your report.

- **Notes** – This section allows you to add user notes to a given query, or edit the previously created notes. When you click the 'Notes' button, a text box will pop up. Enter or edit whatever text you would like to associate with the query such as notes about an incident. This text will

eventually be displayed in the report, and can be edited at later steps. Once you have entered text, simply click away from the text box. The written text will automatically be saved. Query notes are limited to 3000 characters.

- **Generate Report** - This button at the top is the button you will click to create a report, which will be saved to the database (Figure 22). This is the last step on this page with this button being clicked after all settings below have been refined, and any supplementary media has been saved. Once the button is clicked, you will be redirected to the 'Recent Reports' page and can see the status of your report. **Note:** Only one report can be associated with a query at a time. If a report has already been generated the Generate Report button will not be shown. To create a new report you must delete the old report first.

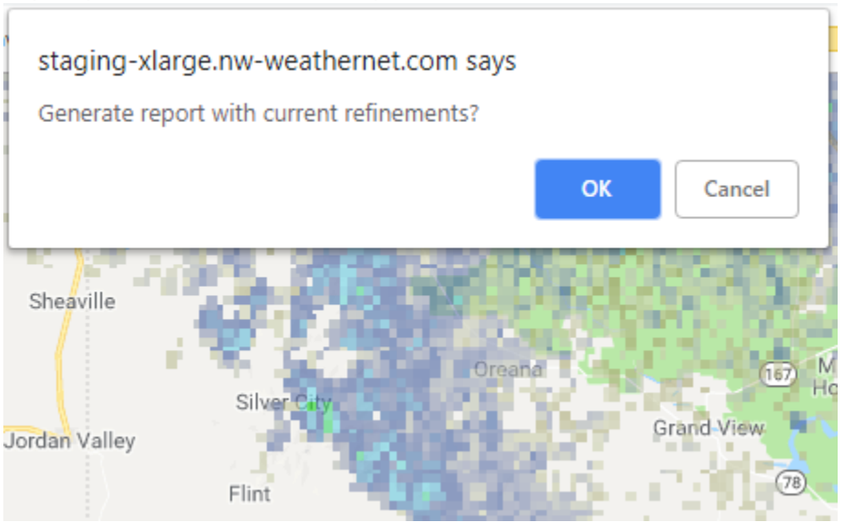


Figure 22: The last step to Generate Report

6) Recent Reports

The recent reports page shows a list of reports recently saved (shown in Figure 23), when the report was created, the report date, and the status of the given report. Once a report is marked complete, open it by clicking on the folder in the Actions column. If you no longer need a report, or for some reason the report errored out, you can delete the report by clicking on the trash can in the Actions column. Note that only one report is allowed per query by the system. To create a new report for a query, you must first delete the old report.

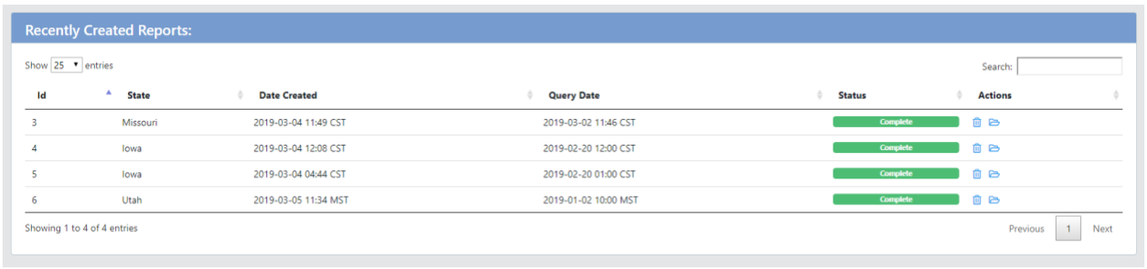


Figure 23: Example of Recent Reports

7) View Recent Report

Once you have created a report, you can open the report from the 'Recent Reports' page by clicking on the folder icon in the Actions column of the table. Once the report is open you have several options to download the data, report, and files. The following lists all controls shown in the Actions Menu from top to bottom and what you can do with them (see Figure 24).

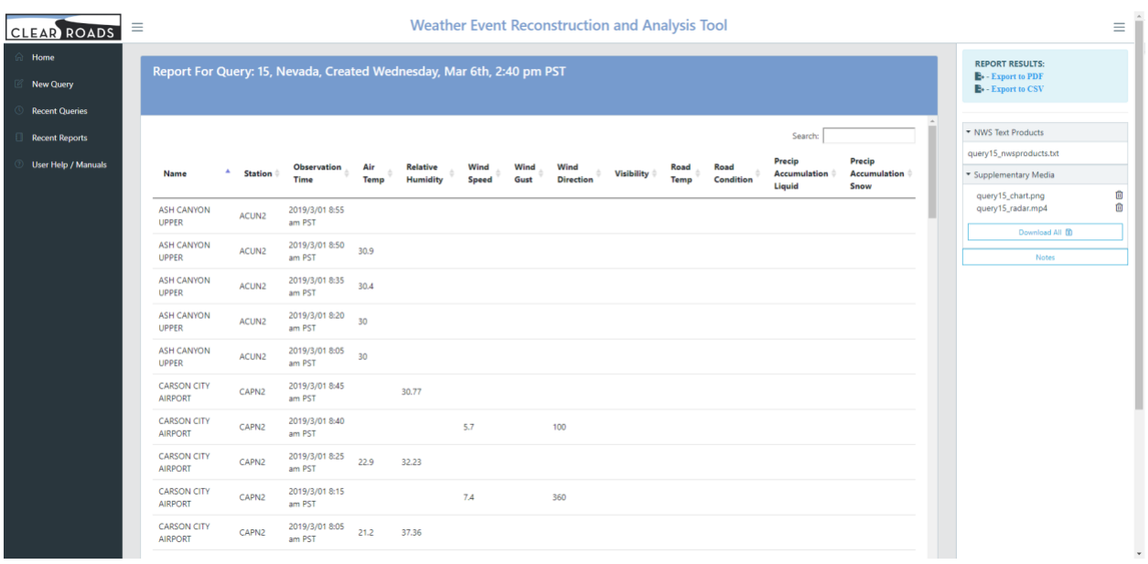


Figure 24: Example of Report for Query

- **Export to PDF –** Click this item to download the full .pdf report (shown in Figures 25 & 26).

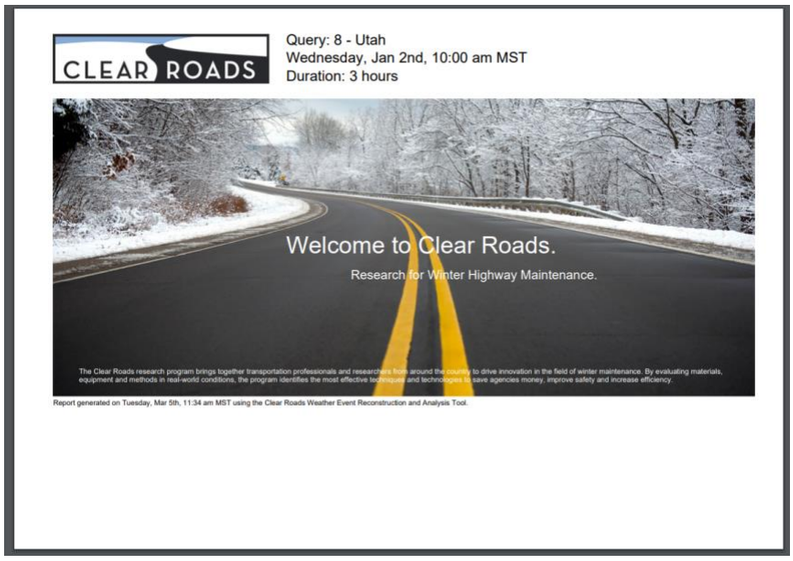
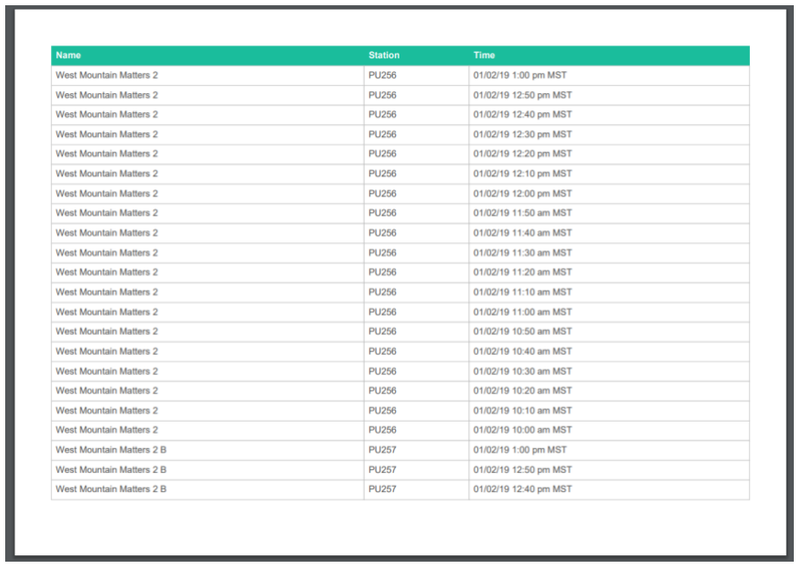


Figure 25: Example of downloaded .pdf report



Name	Station	Time
West Mountain Matters 2	PU256	01/02/19 1:00 pm MST
West Mountain Matters 2	PU256	01/02/19 12:50 pm MST
West Mountain Matters 2	PU256	01/02/19 12:40 pm MST
West Mountain Matters 2	PU256	01/02/19 12:30 pm MST
West Mountain Matters 2	PU256	01/02/19 12:20 pm MST
West Mountain Matters 2	PU256	01/02/19 12:10 pm MST
West Mountain Matters 2	PU256	01/02/19 12:00 pm MST
West Mountain Matters 2	PU256	01/02/19 11:50 am MST
West Mountain Matters 2	PU256	01/02/19 11:40 am MST
West Mountain Matters 2	PU256	01/02/19 11:30 am MST
West Mountain Matters 2	PU256	01/02/19 11:20 am MST
West Mountain Matters 2	PU256	01/02/19 11:10 am MST
West Mountain Matters 2	PU256	01/02/19 11:00 am MST
West Mountain Matters 2	PU256	01/02/19 10:50 am MST
West Mountain Matters 2	PU256	01/02/19 10:40 am MST
West Mountain Matters 2	PU256	01/02/19 10:30 am MST
West Mountain Matters 2	PU256	01/02/19 10:20 am MST
West Mountain Matters 2	PU256	01/02/19 10:10 am MST
West Mountain Matters 2	PU256	01/02/19 10:00 am MST
West Mountain Matters 2 B	PU257	01/02/19 1:00 pm MST
West Mountain Matters 2 B	PU257	01/02/19 12:50 pm MST
West Mountain Matters 2 B	PU257	01/02/19 12:40 pm MST

Figure 26: Example of downloaded .pdf report

- **Export to CSV –** Click this item to download all of the included site data in .csv format (Shown in figure 27).

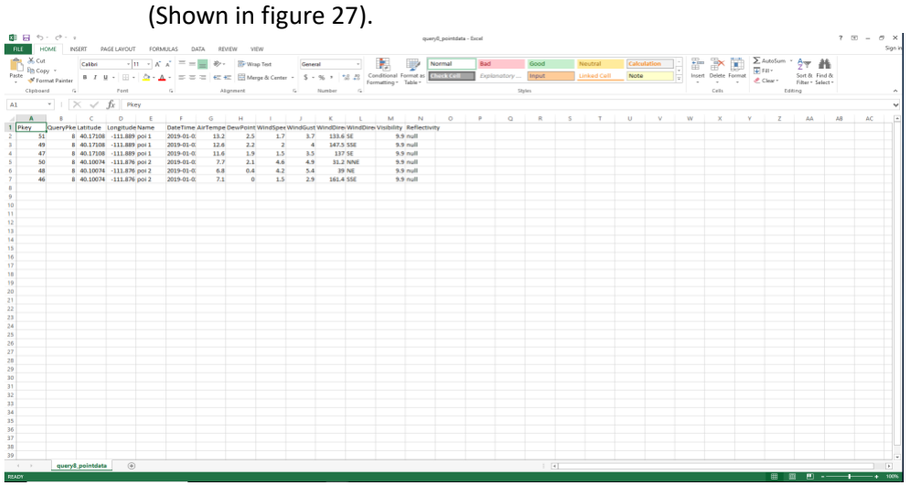
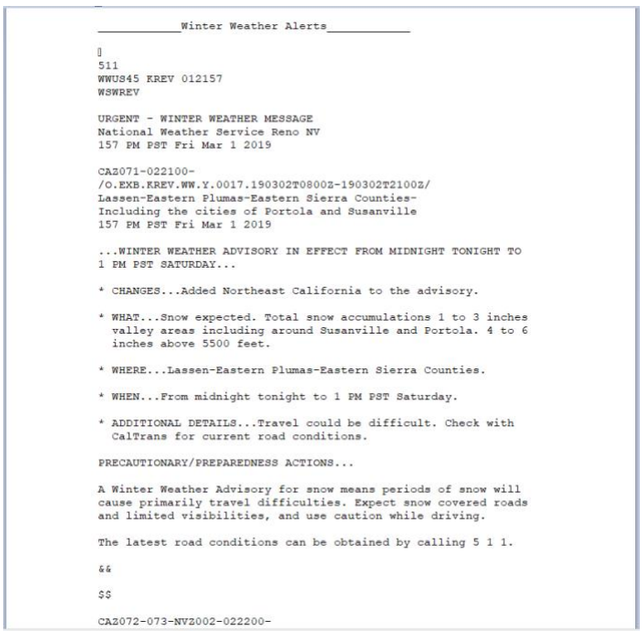


Figure 27: Example of downloaded .csv format

- **NWS Text Products –** All NWS text products that are returned with the query are grouped into a downloadable file. Click on the file to download. If no products exist for a selected alert type, a file is still created. The created file will contain an error message stating that it could not find a specific product type.

  Note: to maintain readable formatting, you should open the .txt file that is created in a program that is more sophisticated than Notepad (e.g., Microsoft Word or Wordpad; see Figure 28).



```
__________Winter Weather Alerts__________

[]
511
WWUS45 KREV 012157
WSWREV

URGENT - WINTER WEATHER MESSAGE
National Weather Service Reno NV
157 PM PST Fri Mar 1 2019

CAZ071-022100-
/O.EXB.KREV.WW.Y.0017.190302T0800Z-190302T2100Z/
Lassen-Eastern Plumas-Eastern Sierra Counties-
Including the cities of Portola and Susanville
157 PM PST Fri Mar 1 2019

...WINTER WEATHER ADVISORY IN EFFECT FROM MIDNIGHT TONIGHT TO
1 PM PST SATURDAY...

* CHANGES...Added Northeast California to the advisory.

* WHAT...Snow expected. Total snow accumulations 1 to 3 inches
  valley areas including around Susanville and Portola. 4 to 6
  inches above 5500 feet.

* WHERE...Lassen-Eastern Plumas-Eastern Sierra Counties.

* WHEN...From midnight tonight to 1 PM PST Saturday.

* ADDITIONAL DETAILS...Travel could be difficult. Check with
  CalTrans for current road conditions.

PRECAUTIONARY/PREPAREDNESS ACTIONS...

A Winter Weather Advisory for snow means periods of snow will
cause primarily travel difficulties. Expect snow covered roads
and limited visibilities, and use caution while driving.

The latest road conditions can be obtained by calling 5 1 1.

&&

$$

CAZ072-073-NVZ002-022200-
```

Figure 28: Example of NWS text product opened in Wordpad

- **Supplementary Media –** This is a list of all of the media files that were saved as part of the report. You can click Download All to download every media file, or you can click on the individual files to download them one at a time. If you want to remove a media item from the saved report click on the trash can next to that item.
  Note: When viewing Radar Loop .mp4 or radar imagery use VLC media player for best results (see Figure 29).

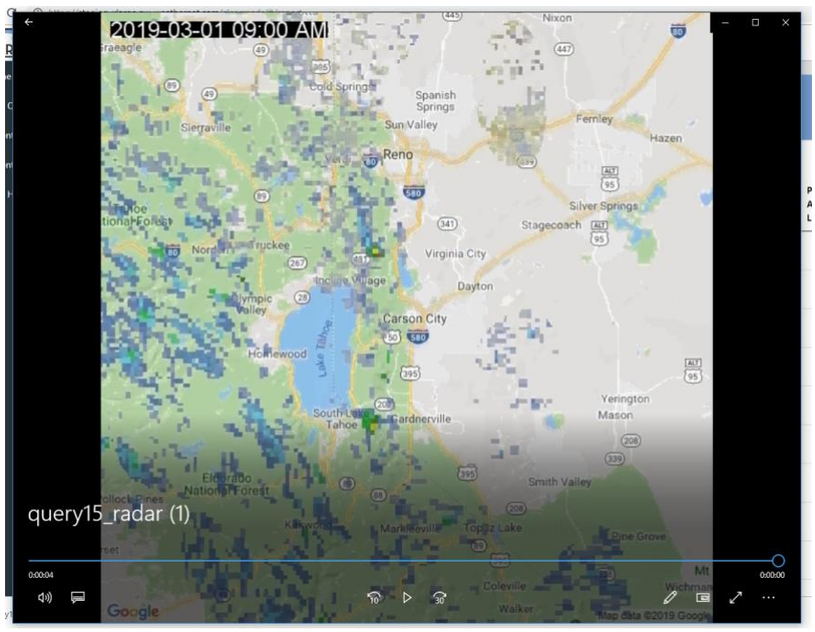


Figure 29: Example of Radar Loop

- **Notes –** Click on Notes to edit/add any notes that you would like to associate with this report.

research for winter highway maintenance

Lead state:

Minnesota Department of Transportation
Research Services
395 John Ireland Blvd.
St. Paul, MN 55155