Integrating *Clarus* Data with the 511 New York Traveler Information System

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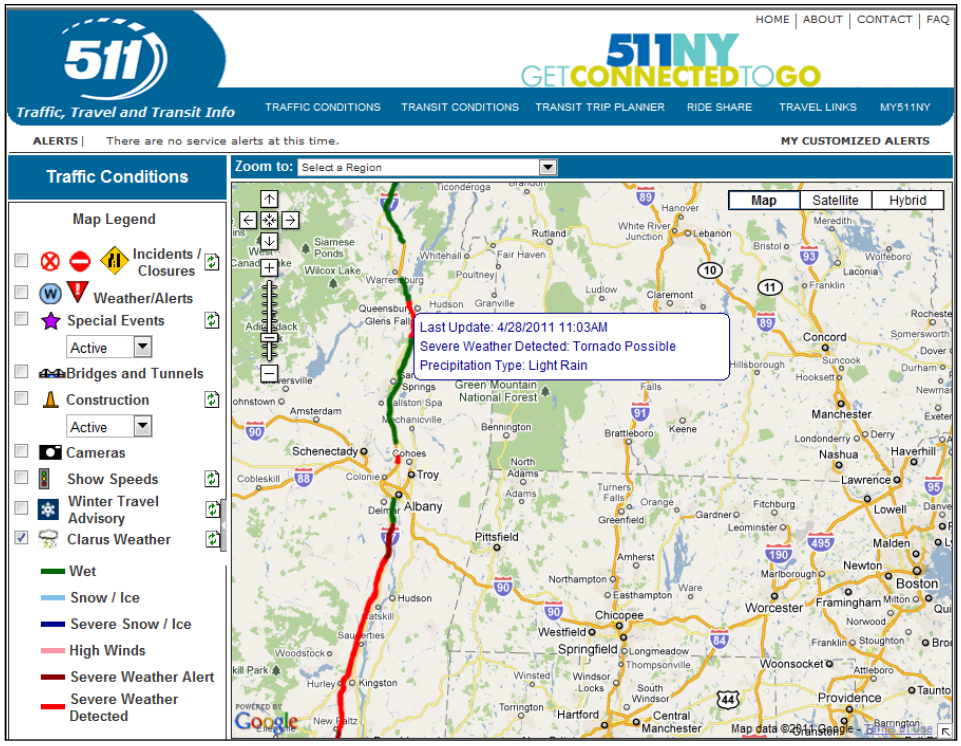

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Notice

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16. Abstract

This document is the final report that describes the process and results of integrating *Clarus* and other weather alert data into the 511 New York Traveler Information System. This project involves the design, development, implementation, and evaluation of an intelligent transportation system that collects real-time *Clarus* Road Weather Information System data and other pertinent weather alert data from various sources on the Long Island Expressway (I-495) and I-87 in New York State and integrates the information for display to the end-user through a modified 511 New York (511NY) traveler information website.

The goal of this project is to demonstrate the feasibility of collecting, integrating, and disseminating various types of current and forecast location-specific weather alert data for use by traffic managers and motorists to help make better travel decisions, reduce congestion, and improve safety.

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Preface / Acknowledgements

This report describes the process and results of integrating *Clarus* and other weather alert data into the 511 New York Traveler Information System. This project was undertaken by the New York State Department of Transportation (NYSDOT) and Telvent USA Corporation with sponsorship and funding by the United States Department of Transportation (USDOT) Federal Highway Administration (FHWA) under Contract DTFH61-10-P-00127.

The project team would like to thank Roemer Alfelor, the FHWA Contracting Officer's Task Manager, for his continued support and technical guidance during this project. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the Federal Highway Administration.

The authors would also like to thank Rexella William and Joe Doherty of NYSDOT for providing the 511 New York Traveler Information System platform for use in this project as well as their support in testing and evaluating the system developed for the project.

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Executive Summary

This document represents the final report for FHWA Contract DTFH61-10-P-00127, Integrating *Clarus* Data with the 511 New York Traveler Information System. This project involves the design, development, and implementation of an intelligent transportation system that collects real-time *Clarus* Road Weather Information System (RWIS) data and other pertinent weather alert data from various sources on selected roadways in New York State and integrates the information for display to the end-user through a modified 511 New York (511NY) traveler information website. The collected data can also be integrated into other traveler information systems such as the New York Connected Vehicle system currently under development.

The goal of this project is to demonstrate the feasibility of collecting, integrating, and disseminating various types of current and forecast location-specific weather alert data for use by traffic managers and motorists to help make better travel decisions, reduce congestion, and improve safety.

The *Clarus* system provides a location-specific data source for road weather information based on state Road Weather Information System sensors scattered across North America. There is concern that some sensors are not evenly distributed; some are within a few miles of each other while others are hundreds of miles apart. To address this problem, the weather information from *Clarus* can be supplemented with additional real-time, location-specific weather data sources to provide a continuous weather picture at various locations.

Through this project, the Telvent project team integrated *Clarus* data into the Telvent road segment alerting engine. This product, called *SiteWatch*, is a patented system that analyzes multiple weather factors against specific road segments along a transportation corridor. If weather conditions exist that can cause issues with the transportation system, an alert is generated for the individual road segments that are affected. These road segment alerts are integrated into the 511NY pre-production system to provide enhanced, detailed, localized road weather condition information, including information from *Clarus*. In addition, the road segment alerts are provided through a data feed for use by the New York Connected Vehicle system.

The coverage area for this project includes the New York transportation corridors of the Long Island Expressway (I-495) and I-87 west of the Hudson River to the Canadian border. Since the number and location of the RWIS sensors along the project corridors are limited, Telvent extended a radius of influence around the locations for eight miles. This means that only road segments within this area will be candidates for *Clarus*-based road weather alerts.

To supplement the RWIS data received from *Clarus*, weather information from a number of other data sources was accessed and integrated into the resulting system, including National Weather Service Surface Observations, Doppler Radar, Storm Corridors, and National Weather Service Bulletins.

System Development Process

A structured System Development Lifecycle (SDLC) approach was used to develop the system created for this project. The first step in the project was to define a set of technical requirements for the system to be developed and maintained during the course of the project. The goal of this effort was to ensure a common understanding between all parties on the expected functionality of the resulting system. The requirements were gathered from the original request for proposal for the project, Telvent's proposal, and additions and clarifications based on discussions between FHWA, NYSDOT, and the Telvent project team.

The next step in the system development lifecycle was to design the system. The Telvent team produced a Design Specification that defines the various sub-systems comprising the overall system and how each of these sub-systems is configured from existing software products and developed for new system functionality.

Development of the system proceeded in accordance with the system design. Although most of the development focused on new system functionality, there were opportunities to utilize existing system tools. For example, the base *SiteWatch* road segment alerting system already included interfaces to existing weather

data sources such as the National Weather Service. In addition, the current 511NY pre-production website infrastructure was used as the base platform to develop the user interface for displaying the weather alerts.

Testing of the resulting applications was conducted in multiple phases. In the first phase (unit testing), each component was individually tested to ensure independent functionality was operating properly, e.g., to test the *SiteWatch* retrieval of RWIS data from the *Clarus* system. Unit testing was performed in a lab/system development environment. The second testing phase (integration/system testing) was performed against a fully integrated system to verify that interactions between all system components operated properly.

The final phase of testing, System Acceptance Testing (SAT), was based on the development of a Test Plan that defines the plans and a set of procedures used to verify that the integration of the *Clarus* data and related weather alerts into the 511NY pre-production website complies with the functional system requirements defined in the Requirements Specification document.

System Description

The 511NY pre-production system configuration is divided into functional groups consisting of data collection, data integration or fusion, and data dissemination. The data collection group requests and receives inbound XML-based data streams from *SiteWatch* on a configurable, periodic basis and forwards the received data flows for data storage and analysis. The data dissemination group distributes the processed information through to the public web platform.

Only RWIS observations that pass both Telvent and *Clarus* quality control checks will be candidates for a weather alert. These RWIS observations are checked against gross and climate ranges, compared to similar sensors in the area, and analyzed against previously reported observations as a way to assess reasonableness and quality.

During the course of the project, Telvent ingested and analyzed numerous incoming NYSDOT RWIS observations from *Clarus* utilizing these quality control checks. Analysis of the data quality shows that some key parameters that would have been candidates for observation-driven weather alerts routinely fail the quality control checks. While there are several other datasets that drive weather alerts, the list of possible RWIS parameters from the NYSDOT RWIS network used to drive these weather alerts is relatively small. In general, only quality pavement temperature readings are routinely available from *Clarus* for the available NYSDOT RWIS stations.

Early in the project, the project team determined that the following *Clarus* RWIS sensor readings would be most applicable for delivery of potential hazardous weather condition alerts:

- Pavement Temperature
- Wind Speed
- Surface Status (i.e., Ice Warning, Snow Warning, Ice Watch, Snow Watch, Frost, Chemically Wet, Wet, Trace, Absorption Dew, Absorption, Dew)
- Precipitation Rate
- Precipitation Situation (i.e., Slight/Moderate/Heavy Unidentified/Snow/Rain/Frozen Precipitation)

The system categorizes the received weather conditions for each roadway segment/link and prioritizes and displays them on the 511NY pre-production website map as a section of roadway color-coded to a specific weather condition category or textually via a tool tip message. The tool tip contains supporting textual information associated with the primary link condition. The selected colors are configurable. The map includes existing pan-and-zoom capabilities with the ability to select a specific 511NY region for display. The integrated data represents a combination of roadside weather alert information including roadway temperature, roadway condition and wind speed, as well as National Weather Service (NWS) alerts and detection of possible severe weather. The weather alerts are depicted through a separate layer on the 511NY pre-production public website map titled "*Clarus* Weather" and categorized as follows:

- Wet
- Snow/Ice

- Severe Snow/Ice
- High Winds
- Severe Weather Alert
- Severe Weather Detected

System Evaluation

A three-month evaluation phase of the resulting system followed immediately upon completion of system acceptance testing in late March 2011. This was the final phase of the project completed in June 2011. This timeframe was selected in order to capture weather alerts from the late winter season through spring 2011.

Evaluation of the system was conducted by FHWA staff, NYSDOT staff, and members of the Telvent project team. The evaluation process consisted of exchanges of observations and feedback through e-mail and teleconferences over the three-month period. To help guide the process, the project team also developed an evaluation survey that was completed by FHWA and NYSDOT staff in early May 2011.

The system produced a wide range of results representing varying weather conditions and alerts during the evaluation phase, although it was observed that a relatively small number of alerts were based on *Clarus* RWIS data. Most of the valid *Clarus* RWIS alerts were only for roadway surface temperatures (e.g., below 33° F) during the late winter and early spring seasons. There were also some valid surface condition readings (e.g., from the Schodack RWIS station), but most other readings were flagged as erroneous by the *Clarus* and *SiteWatch* quality control checks.

In general, the representation of weather alerts on the 511NY pre-production website was accurate, clear, and easy to understand, although there was some concern that some results could be misinterpreted by the public.

The information from the system was also very useful from a traffic management perspective as it can help transportation managers alert motorists of upcoming weather disturbances and provide assistance in readying public safety and incident management staff and resources for impending weather conditions that could negatively affect the transportation system.

During the evaluation phase, a number of recommendations were developed to help improve the usability and effectiveness of the system in terms of alert prioritization, data quality, and information clarity. In addition, the project team defined a series of potential next steps beyond this project including presentation of the project results at upcoming conferences, integrating weather alerts into the NY Connected Vehicle system, and exploring options to integrate weather alerts and related data into the 511NY production system.

1 Introduction

This document represents the final report for FHWA Contract DTFH61-10-P-00127, Integrating *Clarus* Data with the 511 New York Traveler Information System. This project involves the design, development, and implementation of an intelligent transportation system that collects real-time *Clarus* Road Weather Information System (RWIS) data and other pertinent weather alert data from various sources on selected roadways in New York State and integrates the information for display to the end-user through a modified 511 New York (511NY) traveler information website. The collected data can also be integrated into other traveler information systems such as the New York Connected Vehicle system currently under development.

The goal of this project is to demonstrate the feasibility of collecting, integrating, and disseminating various types of current and forecast location-specific weather alert data for use by traffic managers and motorists to help make better travel decisions, reduce congestion, and improve safety.

This document includes the following:

- Background information on the types of data collected and project coverage area;
- The methodology used to design, develop, test, and implement the system;
- A description of the resulting system, including the system architecture, data collection/fusion process, and system outputs; and
- An evaluation of the system detailing the evaluation process, results, and potential areas for improvement and expansion.
- References to supporting documentation produced during the course of the project;

This document was prepared by Telvent for the Federal Highway Administration (FHWA) and New York State Department of Transportation (NYSDOT).

1.1 Project Background

The *Clarus* system provides a location-specific data source for road weather information based on state Road Weather Information System (RWIS) sensors scattered across North America. There is concern that some sensors are not evenly distributed; some are within a few miles of each other while others are hundreds of miles apart. To address this problem, the weather information from *Clarus* can be supplemented with additional real-time, location-specific weather data sources to provide a continuous weather picture at various locations.

Through this project, the Telvent project team integrated *Clarus* data into the Telvent road segment alerting engine. This product, called *SiteWatch*, is a patented system that analyzes multiple weather factors against specific road segments along a transportation corridor. If weather conditions exist that can cause issues with the transportation system, an alert is generated for the individual road segments that are affected. These road segment alerts are integrated into the 511NY pre-production system to provide enhanced, detailed, localized road weather condition information, including information from *Clarus*. In addition, the road segment alerts are provided through a data feed for use by the New York Connected Vehicle system.

The coverage area for this project includes the New York transportation corridors of the Long Island Expressway (I-495) and I-87 west of the Hudson River to the Canadian border. This area is shown by the highlighted roadways in Figure 1-1, below.

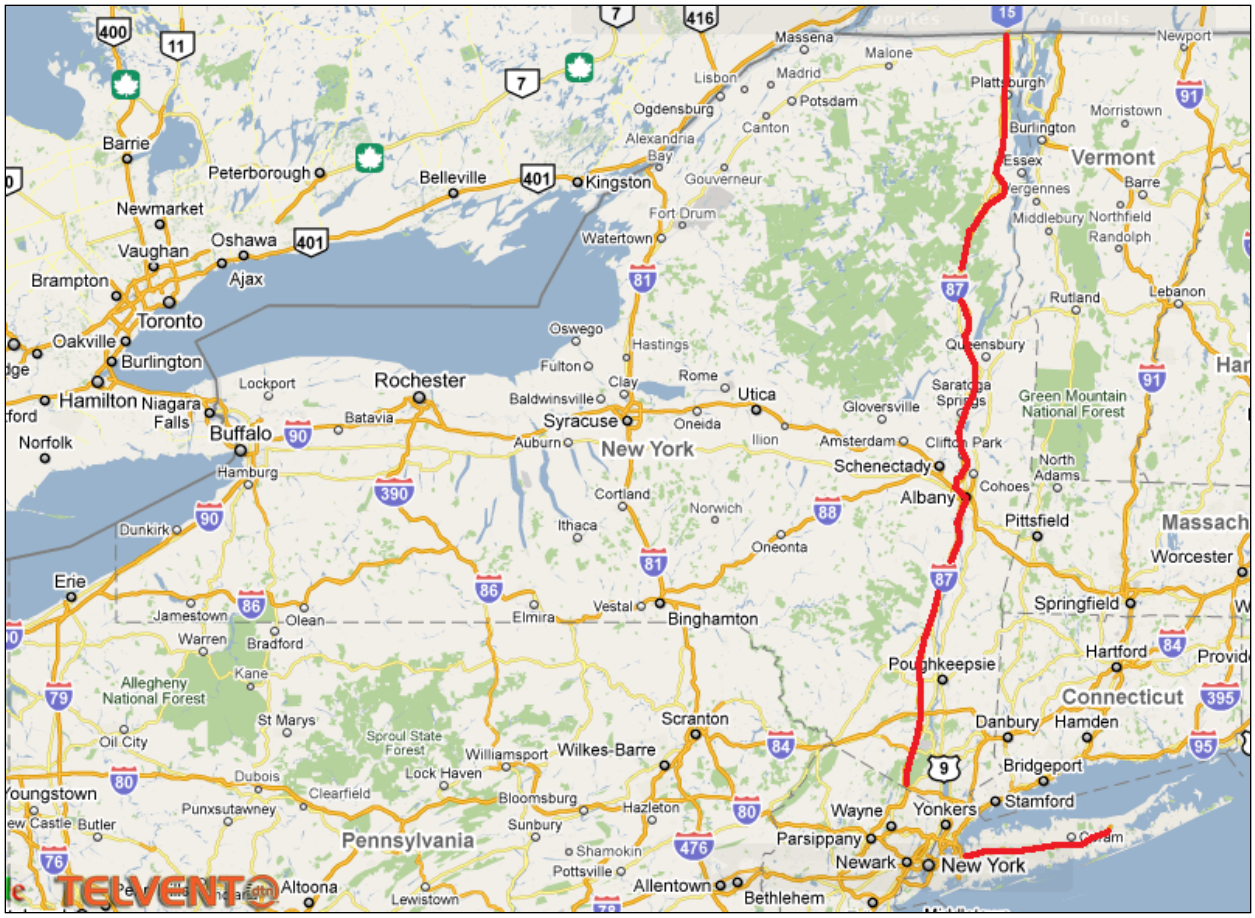


Figure 1-1 – Project Coverage Area
(Source: Telvent)

As mentioned above, *Clarus* utilizes data from RWIS sensors throughout the United States. Figure 1-2, below, is from the *Clarus* website that shows the location of the RWIS sensors in the NYSDOT RWIS network. The five large red circles identify the locations of the RWIS sensors to be used for this project. These locations are as follows:

- Medford
- Greenvale/CW Post
- Schodack
- Albany Toll Plaza
- Clifton Park

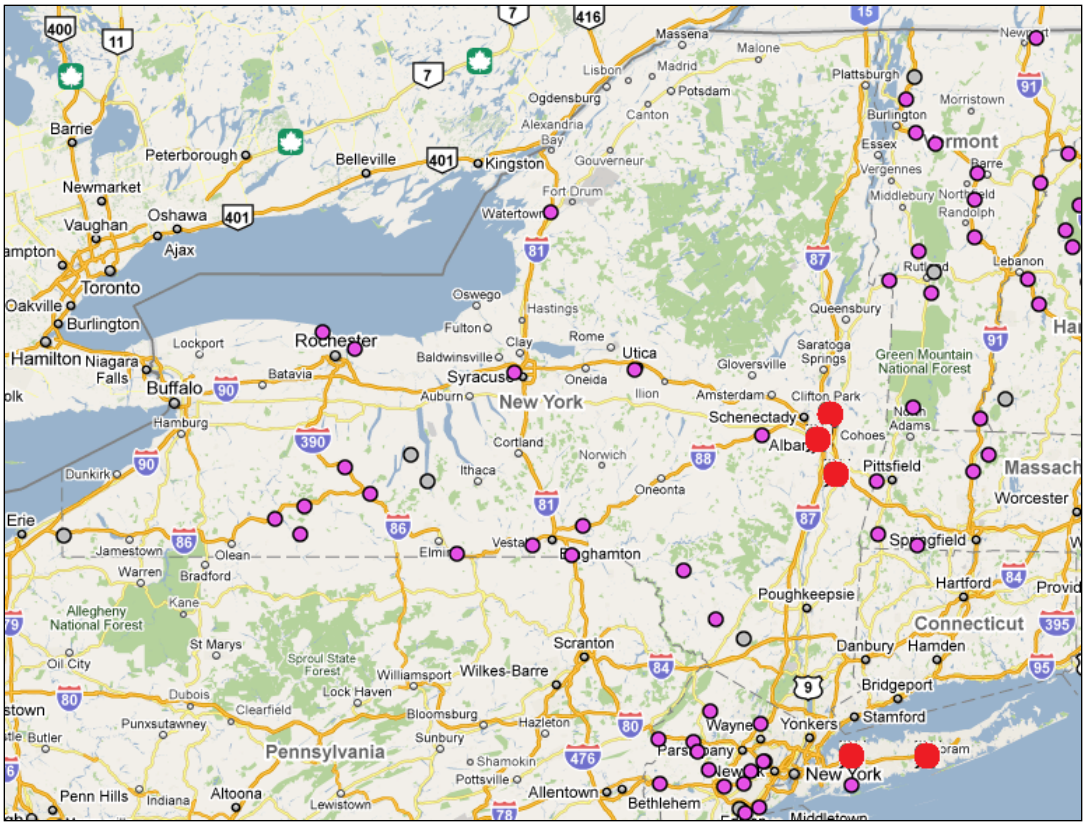


Figure 1-2 – NYSDOT RWIS Network
(Source: www.clarus-system.com)

Since the number and location of the RWIS sensors along the project corridors are limited, Telvent extended a radius of influence around the locations for eight miles. This means that only road segments within this area will be candidates for *Clarus*-based road weather alerts. Below are graphical representations of the eight-mile radius of influence for both the Long Island Expressway and I-87.

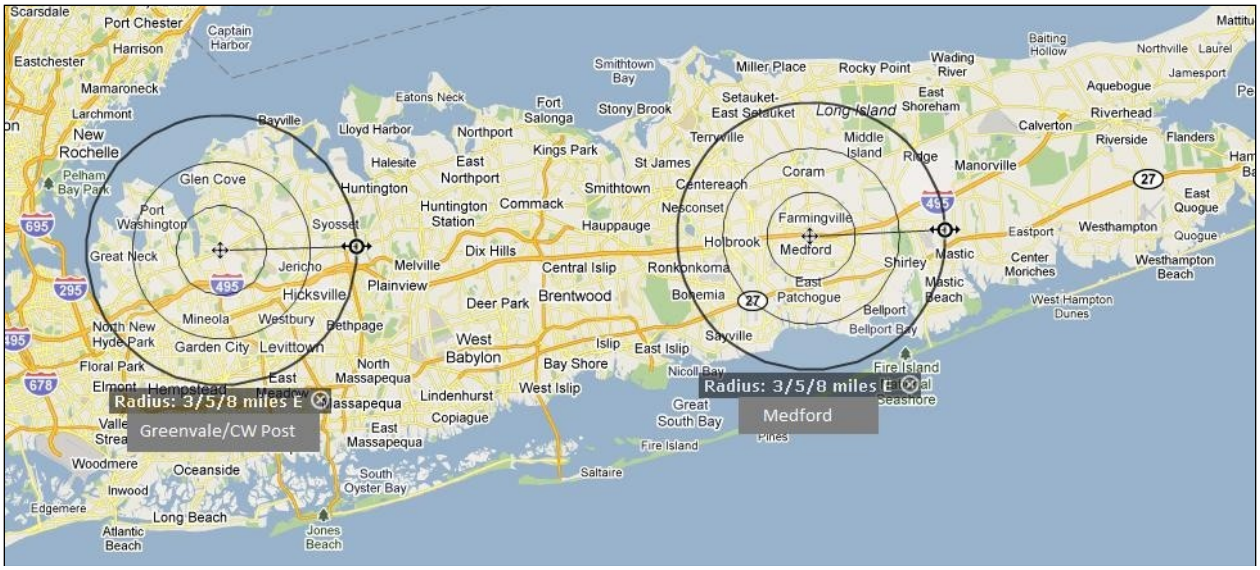


Figure 1-3 – Long Island Expressway RWIS Locations and Area of Influence
(Source: Telvent)

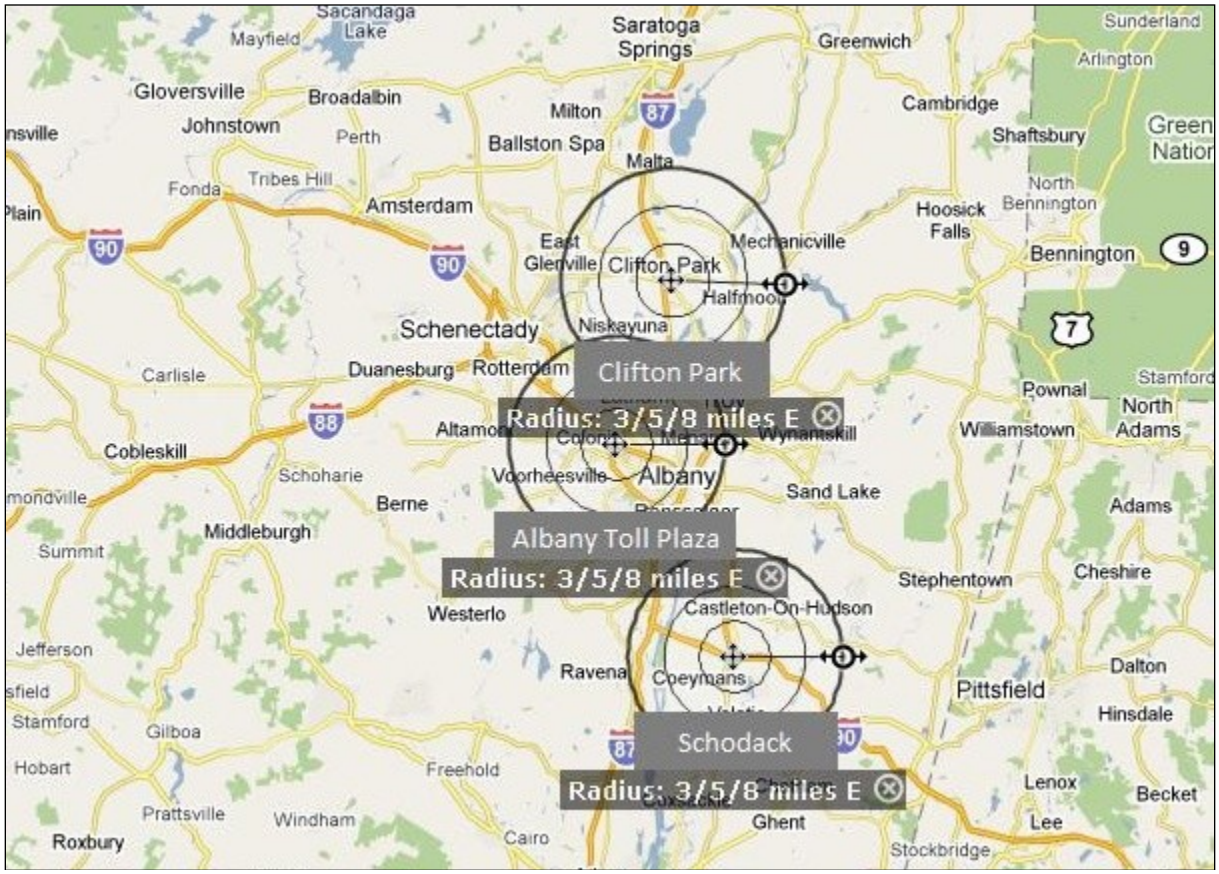


Figure 1-4 – I-87 RWIS Locations and Area of Influence
(Source: Telvent)

To supplement the RWIS data received from *Clarus*, weather information from a number of other data sources was accessed and integrated into the resulting system, including the following:

- National Weather Service Surface Observations
- Doppler Radar
- Storm Corridors
- National Weather Service Bulletins

The specific data captured from all of these systems is described in Section 3.2, Data Collection.

2 System Development Methodology

This section provides an overview of the methodology used to develop the system created for this project. The system was developed using a System Development Lifecycle (SDLC) approach based on the following sub-tasks:

- System Requirements Analysis
- System Design
- System Development and Integration
- System Testing and Rollout

A project timeline is also included that depicts the overall schedule for the project.

2.1 System Requirements Analysis

The first step in the project was to define a set of technical requirements for the system to be developed and maintained during the course of the project. The goal of this effort was to ensure a common understanding between all parties on the expected functionality of the resulting system. The requirements were gathered from the original request for proposal for the project, Telvent's proposal, and additions and clarifications based on discussions between FHWA, NYSDOT, and the Telvent project team.

Each requirement was tracked during the course of the project, and any changes were documented and submitted for approval by FHWA. Technical requirements were traced through system design, development, and testing to ensure that each requirement was adequately addressed through the associated project deliverables.

Approximately 35 system/functional requirements were defined covering the following areas:

- System geographic coverage
- Data sources to be used (e.g., *Clarus*, National Weather Service)
- Types of data collected from each data source (e.g., pavement temperature, wind speed, precipitation type and rate)
- Thresholds for weather alerts to be generated (e.g., wind gusts over 40 mph)
- Type of data feed to the 511NY website and NY Connected Vehicle system (e.g., XML)
- Data dissemination method (e.g., web-based map display of roadway segment-based weather conditions)

The detailed requirements can be found in the project Requirements Specification. These functional requirements served as the basis for the design of the system.

2.2 System Design

The next step in the system development lifecycle was to design the system. The Telvent team produced a Design Specification that defines the various sub-systems comprising the overall system and how each of these sub-systems is configured from existing software products and developed for new system functionality.

In particular, the Design Specification addressed several areas including the following:

- System Architecture
    - Architecture diagrams
    - Definition of system components
    - Networking parameters
    - Data flows

    - Security methods
    - Hardware platforms
    - External site connectivity mechanisms

- Data Collection
    - Setup of project roadway segments and data points
    - Definition of *SiteWatch* data streams with external data sources
    - Quality control checks
    - Thresholds for alerts to be disseminated
    - Data update frequencies

- Data Integration
    - Details on data interfaces to dissemination systems (data content, formats, refresh cycles)
    - Sample outputs
    - Data categorization and prioritization
    - Data storage methods
    - Error handling

- Data Dissemination
    - 511NY pre-production website user interface (map display) and functionality
    - Website platform and architecture
    - Interface with NY Connected Vehicle system

The Design Specification was also reviewed to ensure that all identified requirements were fully covered.

2.3 System Development and Integration

Development of the system proceeded in accordance with the system design. Although most of the development focused on new system functionality, there were opportunities to utilize existing system tools. For example, the base *SiteWatch* road segment alerting system already included interfaces to existing weather data sources such as the National Weather Service. In addition, the current 511NY pre-production website infrastructure was used as the base platform to develop the user interface for displaying the weather alerts.

System development included the following tasks:

- Define and collect the roadway segment data on I-495 and I-87 in New York for alerting
- Establish the *Clarus* data stream for the five selected RWIS sensors in the project coverage area
- Ingest the *Clarus* data into the *SiteWatch* system. Note that the *SiteWatch* system resides at the Telvent DTN hosting facility in Omaha, Nebraska.
- Configure *SiteWatch* alerting criteria for the *Clarus* data and other weather data
- Develop the XML web service data interface containing the weather alerts from *SiteWatch* (note that this data interface is for use by the 511NY pre-production system and NY Connected Vehicle system)
- Integrate all weather alert data into the 511NY pre-production system
- Develop updates to the 511NY pre-production website to display the weather alert data
- Configure the 511NY pre-production platform at the Savvis hosting facility in New Jersey to accommodate the modified 511NY website. Note that this platform was segregated from the main 511NY pre-production platform so that each system could be updated and maintained separately in order to prevent conflicts

between the two systems. References to the 511 NY pre-production platform in this document are for the segregated platform.

2.4 System Testing and Rollout

Testing of the resulting applications was conducted in multiple phases. In the first phase (unit testing), each component was individually tested to ensure independent functionality was operating properly, e.g., to test the *SiteWatch* retrieval of RWIS data from the *Clarus* system. Unit testing was performed in a lab/system development environment.

The second testing phase (integration/system testing) was performed against a fully integrated system to verify that interactions between all system components operated properly. For example, tests were conducted to ensure that the data retrieved by the *SiteWatch* system was validated, then passed through the data interface to the 511NY pre-production website, and then properly displayed on the 511NY pre-production website map. Integration/system testing was conducted on the 511NY pre-production platform to identify any potential problems with the system configuration and confirm operation in the destination environment.

To perform these tests, various test scripts were developed to exercise each system function. Both simulated and actual data were used to validate the system under different scenarios.

The final phase of testing, System Acceptance Testing (SAT), was based on the development of a Test Plan that defines the plans and a set of procedures used to verify that the integration of the *Clarus* data and related weather alerts into the segregated 511NY pre-production website complies with the functional system requirements defined in the Requirements Specification document. These tests use a technique in which satisfaction of a requirement is verified by the use of a series of steps to test a component of the system.

The following summarizes the primary areas of focus for the System Acceptance Testing verifications:

- Ingest *Clarus* and related weather data into the *SiteWatch* road segment alerting engine and perform data quality checks
- Publish validated *Clarus* and related weather alert data to the 511NY pre-production system and the NY Connected Vehicle system
- Integrate *Clarus* and related weather alerts from *SiteWatch* into the 511NY pre-production public website via a new map layer

System Acceptance Testing was conducted in the presence of FHWA and NYSDOT representatives according to the procedures in the Test Plan using the operational system on the 511NY pre-production platform. Signoff by FHWA and NYSDOT on each test procedure signified formal acceptance of the system.

Upon acceptance of the system, a three-month evaluation phase was conducted to operate the system and determine its effectiveness. Any problems identified during this phase were addressed and tested by the Telvent team according to the development and testing methodology discussed above. This Final Report was developed during this three-month evaluation period.

2.5 Project Timeline

The *Clarus* Integration projects spanned a period of approximately eight (8) months from November 2010 through June 2011. Below is an overview of the project schedule that delineates the system development tasks discussed above.

ID	Task Name	Duration	Start	Finish	Predecessors	Successors
1	**FHWA Clarus Integration Project**	**164 days**	**Wed 11/3/10**	**Thu 6/30/11**		
2						
3	**Task 1: Project Initiation**	**147 days**	**Wed 11/3/10**	**Tue 6/7/11**		
4	Kick-Off Meetings	1 day	Wed 11/3/10	Wed 11/3/10		19,6
5	**Requirements Analysis and Development**	**27 days**	**Thu 11/4/10**	**Tue 12/14/10**		
6	Develop Draft Requirements Specification	12 days	Thu 11/4/10	Fri 11/19/10	4	7
7	FHWA/NYSDOT Review Draft Requirements Specification	5 days	Mon 11/22/10	Tue 11/30/10	6	8
8	Develop Final Requirements Specification	10 days	Wed 12/1/10	Tue 12/14/10	7	
9	**Monthly Status Reports**	**125 days**	**Tue 12/7/10**	**Tue 6/7/11**		
17						
18	**Task 2: Data Collection**	**33 days**	**Thu 11/4/10**	**Wed 12/22/10**		
19	Collect NY Road Segment Data	5 days	Thu 11/4/10	Wed 11/10/10	4	20
20	Identify Road Segments and Associate Data Points	22 days	Thu 11/11/10	Tue 12/14/10	19	21,25FF,26FF
21	Obtain Clarus Data Stream	1 day	Wed 12/15/10	Wed 12/15/10	20	22
22	Ingest Clarus Data	5 days	Thu 12/16/10	Wed 12/22/10	21	32
23						
24	**Task 3: Design**	**34 days**	**Fri 12/10/10**	**Wed 2/2/11**		
25	Create Output Schema for 511NY	3 days	Fri 12/10/10	Tue 12/14/10	20FF	27,28
26	Create XML Output Schema for IntelliDrive	3 days	Fri 12/10/10	Tue 12/14/10	20FF	
27	Design Data Interface to 511NY System	16 days	Wed 12/15/10	Tue 1/11/11	25	36,29
28	Design 511NY Website Updates	16 days	Wed 12/15/10	Tue 1/11/11	25	37,29
29	Develop Test Plan	15 days	Wed 1/12/11	Wed 2/2/11	27,28	
30						
31	**Task 4: Development and Integration**	**43 days**	**Thu 12/23/10**	**Tue 3/1/11**		
32	Configure Alerting on Clarus Data	10 days	Thu 12/23/10	Tue 1/11/11	22	33,39
33	Push Alert Web Service	6 days	Wed 1/12/11	Thu 1/20/11	32	34
34	Upgrade SiteWatch	1 day	Fri 1/21/11	Fri 1/21/11	33	35
35	Integrate Road Segment Alerting Engine Updates	5 days	Mon 1/24/11	Fri 1/28/11	34	
36	Develop Data Interface to 511NY System	23 days	Wed 1/12/11	Mon 2/14/11	27	38
37	Develop Updates to 511NY Website	23 days	Wed 1/12/11	Mon 2/14/11	28	38
38	Integrate Weather Alert Feed into 511NY System	10 days	Tue 2/15/11	Tue 3/1/11	36,37	43
39	Integrate Weather Alert Feed into IntelliDrive	33 days	Wed 1/12/11	Tue 3/1/11	32	48
40						
41	**Task 5: Testing and Evaluation**	**87 days**	**Wed 3/2/11**	**Thu 6/30/11**		
42	**511NY Pre-Production System**	**21 days**	**Wed 3/2/11**	**Wed 3/30/11**		
43	Install Updates on 511NY Pre-Production Platform	1 day	Wed 3/2/11	Wed 3/2/11	38	44SS
44	Enable Weather Alert Feed to 511NY	1 day	Wed 3/2/11	Wed 3/2/11	43SS	45
45	Test Updates on 511NY	20 days	Thu 3/3/11	Wed 3/30/11	44	46
46	511NY Updates Complete	0 days	Wed 3/30/11	Wed 3/30/11	45	51
47	**IntelliDrive**	**21 days**	**Wed 3/2/11**	**Wed 3/30/11**		
48	Enable Weather Alert Feed to IntelliDrive	1 day	Wed 3/2/11	Wed 3/2/11	39	49
49	Test Weather Alert Feed to IntelliDrive	20 days	Thu 3/3/11	Wed 3/30/11	48	50
50	Weather Alert Feed to IntelliDrive Complete	0 days	Wed 3/30/11	Wed 3/30/11	49	51
51	Analyze Weather Alerts within 511NY & IntelliDrive	66 days	Thu 3/31/11	Thu 6/30/11	46,50	54SS
52						
53	**Task 6: Project Report**	**65 days**	**Thu 3/31/11**	**Wed 6/29/11**		
54	Prepare Draft Final Report	40 days	Thu 3/31/11	Wed 5/25/11	51SS	55
55	FHWA/NYSDOT Review Draft Final Report	10 days	Thu 5/26/11	Wed 6/8/11	54	56
56	Prepare Final Report	15 days	Thu 6/9/11	Wed 6/29/11	55	

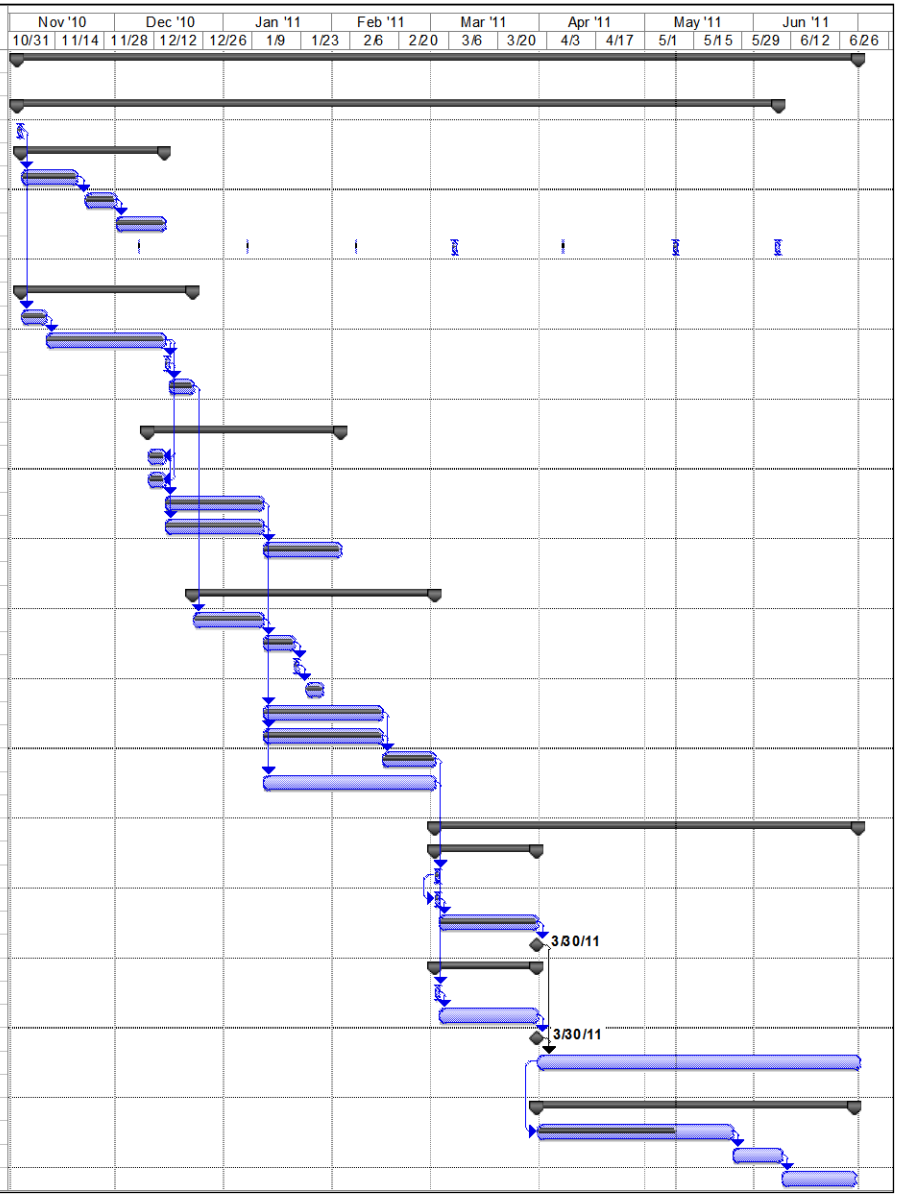


Figure 2-1 – Project Timeline
(Source: Telvent)

3 System Description

A description of the system that was developed for the *Clarus* Integration project is provided in this section. It defines the different components of the system and how they interact. The system description is organized as follows:

- System Architecture
- Data Collection
- Data Integration
- Data Dissemination

Additional details are provided in the project Design Specification.

3.1 System Architecture

The architecture for the project is divided into two primary sub-systems: the *SiteWatch* road segment alerting engine and the 511NY pre-production public website. The two diagrams below depict the architecture of each of these sub-systems.

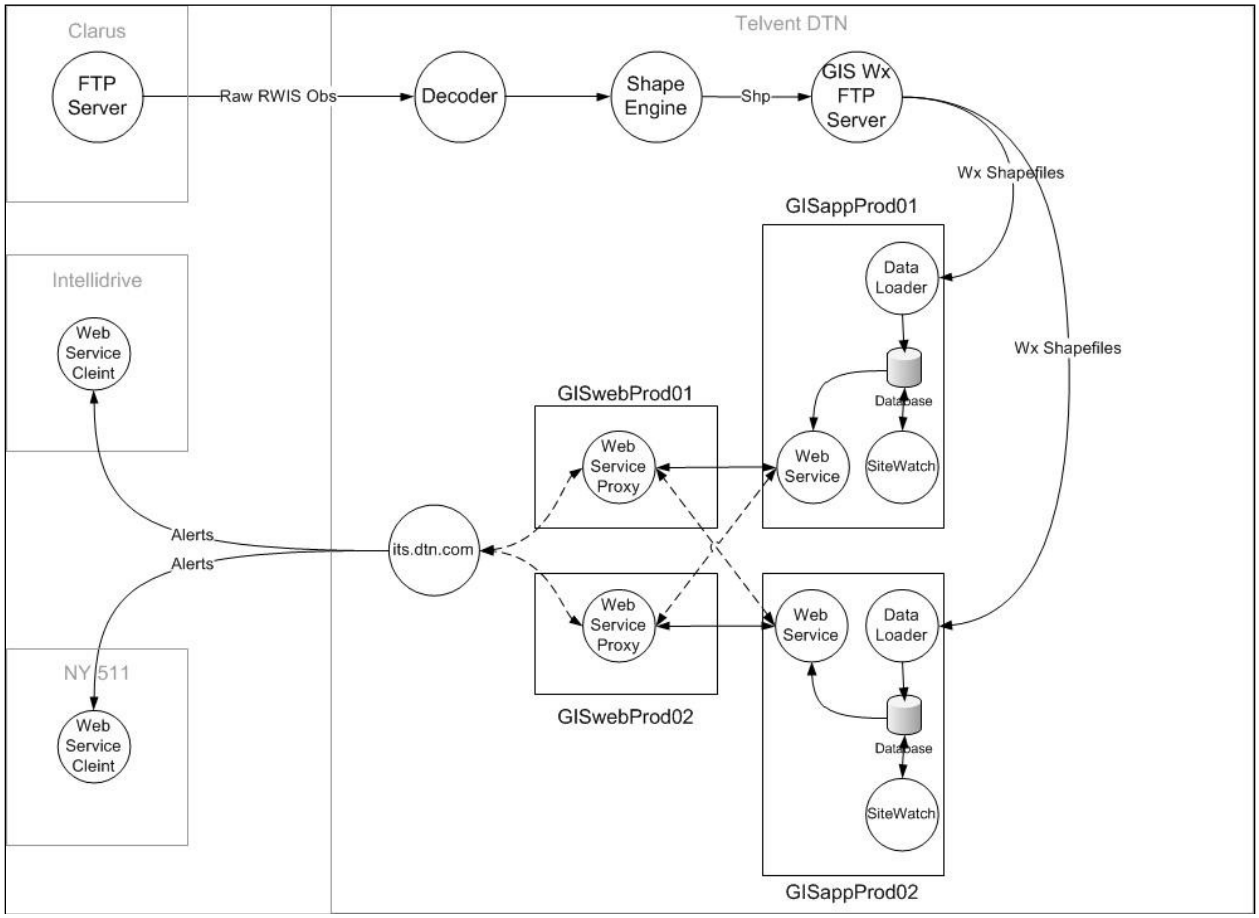


Figure 3-1 – *SiteWatch* Architecture
(Source: Telvent)

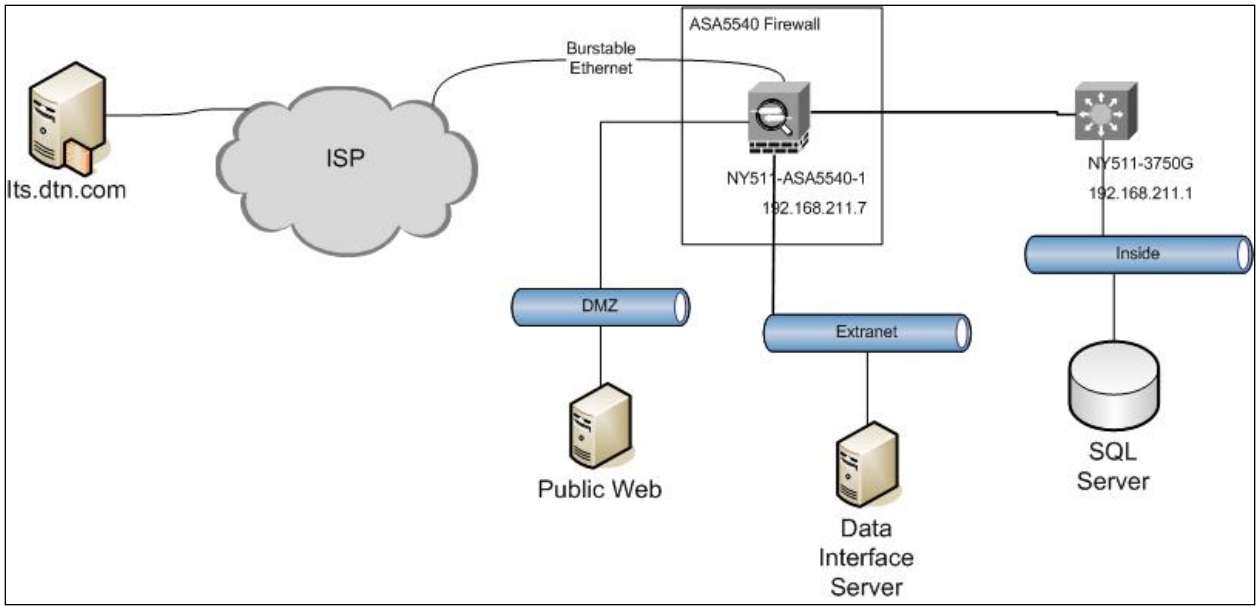


Figure 3-2 – 511NY Pre-Production Platform Architecture
(Source: Telvent)

Initially, GIS weather data shapefiles are periodically acquired from an FTP server and automatically loaded into a geodatabase. These shapefiles are retrieved from a number of sources including NWS (National Weather Service) Doppler Radar, storm corridors based on NWS Doppler Radar, NWS bulletins, surface weather observations, and Roadway Weather Information Systems (i.e., *Clarus* System data) and are processed by the Telvent alerting engine, *SiteWatch*. At the completion of *SiteWatch* processing, the information is made available at the http://its.dtn.com site for the 511NY and Connected Vehicle clients to process.

The 511NY pre-production system configuration is divided into functional groups consisting of data collection, data integration or fusion, data dissemination, and administrative areas. The data collection group is responsible for termination of any inbound data streams from external data sources such as http://its.dtn.com and forwards the received data flows to the SQL server for storage of the data. The data dissemination group distributes the processed information through to the public web platform.

3.2 Data Collection

The Data Collection module is based on the Telvent alerting engine, *SiteWatch*, where interstate highways (i.e., assets) as well as reference points (i.e., roadway nodes/landmarks) were added to the system's geodatabase. The roadway nodes were initially defined based on the I-87 and I-495 roadway segments established in the 511NY system. The assets and landmarks are factored into the *SiteWatch* processing of GIS Weather data shapefiles at Telvent's operations center in Omaha, Nebraska.

Only RWIS observations that pass both Telvent and *Clarus* quality control checks will be candidates for a weather alert. These RWIS observations are checked against gross and climate ranges, compared to similar sensors in the area, and analyzed against previously reported observations as a way to assess reasonableness and quality.

During the course of the project, Telvent ingested and analyzed numerous incoming NYSDOT RWIS observations from *Clarus* utilizing these quality control checks. Analysis of the data quality shows that some key parameters that would have been candidates for observation-driven weather alerts routinely fail the quality control checks. While there are several other datasets outlined in this document that drive weather alerts, the list of possible RWIS parameters from the NYSDOT RWIS network used to drive these weather alerts is

relatively small. In general, only quality pavement temperature readings are routinely available from *Clarus* for the available NYSDOT RWIS stations.

Early in the project, the project team determined that the following *Clarus* RWIS sensor readings would be most applicable for delivery of potential hazardous weather condition alerts:

- Pavement Temperature
- Wind Speed
- Surface Status (i.e., Ice Warning, Snow Warning, Ice Watch, Snow Watch, Frost, Chemically Wet, Wet, Trace, Absorption Dew, Absorption, Dew)
- Precipitation Rate
- Precipitation Situation (i.e., Slight/Moderate/Heavy Unidentified/Snow/Rain/Frozen Precipitation)

Below is a sample of the Schodack RWIS sensor data from the *Clarus* website used for the project. In this example, a red X indicates that the *Clarus* quality control checks identified invalid data for Surface Status and Precipitation Rate. Note that only two of the five RWIS stations (Schodack and Albany Toll Plaza) are equipped to collect all of the above readings; the remaining three stations can only provide pavement temperature.

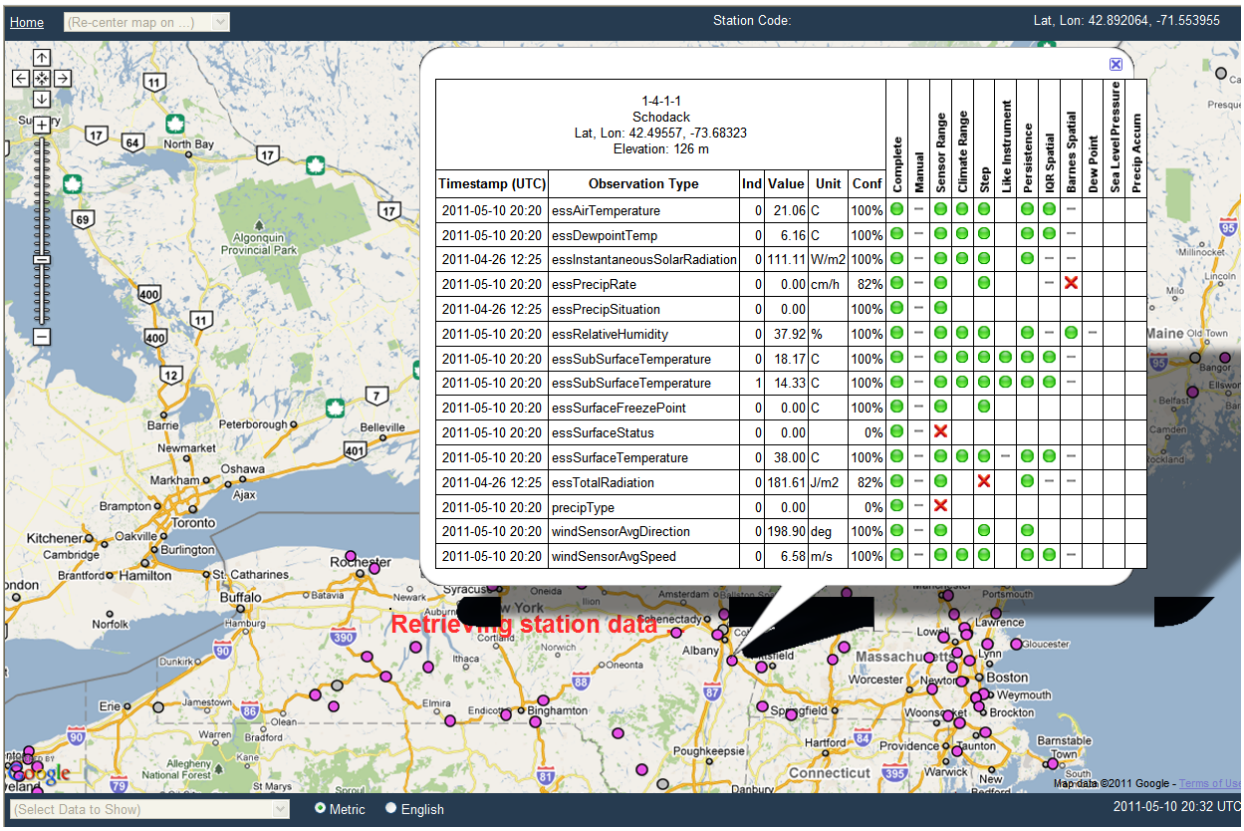


Figure 3-3 – NYSDOT RWIS Data from *Clarus*
(Source: www.clarus-system.com)

As new weather data arrives, *SiteWatch* spatially intersects this new weather with known assets, i.e., the 511NY roadway segments and landmarks. If weather conditions at these intersections exceed predetermined thresholds, *SiteWatch* generates an alert (e.g., hazardous pavement temperatures) for each asset (e.g., I-87) and weather data type (e.g., RWIS observations) combination. These thresholds are shown in Table 3-1, below. Note that there are gaps in the thresholds between light, moderate, and heavy precipitation in this table as these readings are only provided in 5 dbz increments.

Table 3-1 – *SiteWatch* Weather Alert Thresholds

Weather Alert	Threshold
HAZARDOUS WIND SPEED	>= 40 mph
LIGHT RAIN	15-25 dbz
LIGHT MIXED PRECIP	15-25 dbz
LIGHT SNOW	5-15 dbz
MODERATE RAIN	30-40 dbz
MODERATE MIXED PRECIP	30-35 dbz
MODERATE SNOW	20-30 dbz
HEAVY RAIN	45+ dbz
HEAVY MIXED PRECIP	40+ dbz
HEAVY SNOW	35+ dbz
HAZARDOUS PAVEMENT TEMP	<=33^{o}F

When an alert is created, it remains active until the weather condition no longer exists (plus a brief delay to ensure the condition does not reappear). Note that the weather alerts are not direction-specific within the asset/roadway.

When an alert is created, *SiteWatch* also creates an XML alert message. This XML message is combined with other active alert messages, and made available through a web service to remote clients. For the *Clarus* Integration project, the 511NY pre-production system and NY Connected Vehicle system act as remote clients. Both systems receive the same XML message from *SiteWatch*.

The system has built in redundancies to ensure that alerts are available when needed as shown in the *SiteWatch* Architecture diagram, Figure 3-1.

Below is a table of frequencies of generation of weather alerts from *SiteWatch*. Information on the categorization and prioritization of alert types for display in the 511NY pre-production website are provided in Section 3.3, Data Integration, and Section 3.4, Data Dissemination.

Table 3-2 – *SiteWatch* Alert Frequencies

Alert Category	Alerts	Data Update Frequency
Clarus Alerts for types affecting roadways or vehicles (Wind, Precipitation Rate)	HAZARDOUS WIND SPEED HAZARDOUS PRECIP RATE	Available at roughly 15-20 minute intervals
National Weather Service Observed Wind Alerts	HIGH WINDS	Available (mostly) hourly, but can be unsolicited
Precipitation Alerts from NWS Doppler Radar – Rain/Mix/Snow	LIGHT RAIN LIGHT MIXED PRECIP LIGHT SNOW MODERATE RAIN MODERATE MIXED PRECIP MODERATE SNOW HEAVY RAIN HEAVY MIXED PRECIP HEAVY SNOW	Available at five minute intervals

Alert Category	Alerts	Data Update Frequency
Storm Cell Alerts (priority within is high to low (Tornado, Mesocyclone, Severe Hail, Hail))	TORNADO POSSIBLE SEVERE THUNDERSTORM POSSIBLE HAIL POSSIBLE	Expected within next 30 minutes
Clarus Alerts for types affecting roadways or vehicles (Pavement Temperature, Surface Status, Precipitation Situation)	HAZARDOUS PAVEMENT TEMP HAZARDOUS PAVEMENT CONDITION HAZARDOUS PRECIP TYPE	Available at roughly 15-20 minute intervals
NWS Bulletins of all types	TORNADO WARNING SEVERE THUNDERSTORM WARNING FLOOD WARNING FLASH FLOOD WARNING DENSE FOG ADVISORY HIGH WIND WARNING WINTER STORM WARNING HEAVY SNOW WARNING BLIZZARD WARNING ICE STORM WARNING	Unsolicited data – Unscheduled update frequency

3.3 Data Integration

A data interface (DI) application was developed that receives the XML output stream from *SiteWatch* and stores the information in a database for display on the 511NY pre-production public website. This same XML output stream can also be retrieved by the NY Connected Vehicle system at a specific frequency for its own processing and display purposes. Although the integration of the weather alert data into that system was originally part of the project scope, in late February 2011, NYSDOT indicated that they would not be ready to integrate the data into the NY Connected Vehicle system until 2012 or later. Therefore, it was decided that integration and analysis of this data within the NY Connected Vehicle system would not be conducted as part of this project, but possibly as a future effort.

The 511NY Weather DI application requests information from the *SiteWatch* web service. The web service then returns an XML feed with the details of the weather alert. The Weather DI application then parses the XML response and creates, updates, and/or removes alerts as indicated by the difference between the prior XML feed processing and the current feed. The alerts are maintained in the 511NY pre-production database.

Based on a frequency parameter, the Weather DI application requests and receives data at a regular interval. The default interval is set to two (2) minutes. Once received, the data is processed to extract the event, effective date, expiration date, headline, and geocode information from the XML data stream. An alert will be removed from the database when it no longer appears on the feed, signifying that the alert no longer applies. In addition, if the feed is not available for a period of time, alerts may be removed from the database based on the alert expiration date.

All weather alerts marked for load go through a translation process. Translation of the weather alerts initially includes a verification that the alert is for the project geographic definition. Any failures in the verification process will result in the information being logged and the alert discarded. This verification occurs by examining the received asset identifier and ensuring that it is for either I-87 or the Long Island Expressway (I-495). The Weather DI then examines the asset impact localization to determine if the provided location (point ID, latitude, and longitude) is on the specified asset. The definition of what is on the asset is a set of points that correspond with the “link” definition of the asset. There may be cases where the “from” and “to” points (nearest landmark) are the same. In these cases, the asset-impact-localization geolocations are

examined to determine where the actual event occurred in relation to the specified landmark, and the corresponding link(s) are then identified with the weather alert.

Next, the Weather DI examines the provided weather condition and verifies that it is a known condition. The table below lists the alert types and how the weather conditions are categorized and displayed on the 511NY pre-production website map as a section of roadway colored to a specific weather condition category or textually via a tool tip message.

Table 3-3 – Weather Alerts and Display Categories

Alert	511NY Website Display Category
HAZARDOUS PAVEMENT TEMP	Tooltip
HAZARDOUS PAVEMENT CONDITION	Tooltip
HAZARDOUS PRECIP RATE	Tooltip
HAZARDOUS PRECIP TYPE	Wet, Snow/Ice, Severe Snow/Ice
HAZARDOUS WIND SPEED	High Winds
HEAVY MIXED PRECIP	Severe Snow/Ice
HEAVY RAIN	Wet
HEAVY SNOW	Severe Snow/Ice
LIGHT MIXED PRECIP	Snow/Ice
LIGHT RAIN	Wet
LIGHT SNOW	Snow/Ice
MODERATE MIXED PRECIP	Snow/Ice
MODERATE RAIN	Wet
MODERATE SNOW	Snow/Ice
TORNADO WARNING	Severe Weather Alert
SEVERE THUNDERSTORM WARNING	Severe Weather Alert
FLOOD WARNING	Severe Weather Alert
FLASH FLOOD WARNING	Severe Weather Alert
DENSE FOG ADVISORY	Severe Weather Alert
HIGH WIND WARNING	High Winds
WINTER STORM WARNING	Severe Weather Alert
HEAVY SNOW WARNING	Severe Snow/Ice
BLIZZARD WARNING	Severe Snow/Ice
ICE STORM WARNING	Severe Snow/Ice
HAIL POSSIBLE	Severe Weather Detected
SEVERE THUNDERSTORM POSSIBLE	Severe Weather Detected
TORNADO POSSIBLE	Severe Weather Detected
HIGH WINDS	High Winds

The Weather DI stores the following information for the validated weather alerts in a relational database for display on the 511NY pre-production public website.

- Roadway segment(s) affected by the weather alert
- Weather alert type
- NWS Bulletin warning type
- NWS Bulletin warning expiration time

- Wind speed
- Precipitation type
- Pavement temperature
- Pavement condition

The weather alerts are depicted through a separate layer on the 511NY pre-production public website map titled "*Clarus* Weather". The possible values for the legend of this map layer are listed below and also shown in the categorization scheme in Table 3-3, Weather Alerts and Display Categories, above.

- Wet
- Snow/Ice
- Severe Snow/Ice
- High Winds
- Severe Weather Alert
- Severe Weather Detected

3.4 Data Dissemination

As mentioned previously, the existing 511NY pre-production public website was used as the base platform to disseminate the collected weather alert data, although a separate copy of the website was created for this project so that each system could be updated and maintained separately in order to prevent conflicts between the two systems. The 511NY pre-production hardware platform resides at the Savvis hosting facility in New Jersey. Note that references to the 511NY pre-production platform in this document are for the segregated platform.

The 511NY pre-production public website was augmented to display link based (i.e., road segment based) weather conditions on the existing Google based map. The website map page includes various layers of information already received by the 511NY system. The new layer added is called the "*Clarus* Weather" layer since *Clarus* weather data integration is the focus of the project and to differentiate it from other weather related layers, although it is important to note that this layer contains weather alerts from various sources, not just *Clarus*. The new layer represents a combination of roadside weather alert information including roadway temperature, roadway condition and wind speed, as well as NWS alerts and detection of possible severe weather.

The *Clarus* Weather layer includes color coded, graphical link coverage for I-87 west of the Hudson River and the Long Island Expressway (I-495) as well as tool tip coverage for the same roadways to indicate current weather alerts. The selected colors are configurable. The map includes existing pan-and-zoom capabilities with the ability to select a specific 511NY region for display. A sample screen with the new *Clarus* Weather layer depicting actual, real-time weather conditions is provided below. This screen shows Light Snow along the northern portions of I-87 toward Canada. The tool tip appeared by hovering the mouse over the colored section of roadway near Albany, NY revealing that the pavement is Wet and below 29 °F in that area as of 3/7/11 at 10:10am. In this example, the Light Snow precipitation data was provided by NWS Doppler Radar, and *Clarus* was the source of the Pavement Temperature and Pavement Condition readings.

Additional tool tip information is provided near the end of this section.

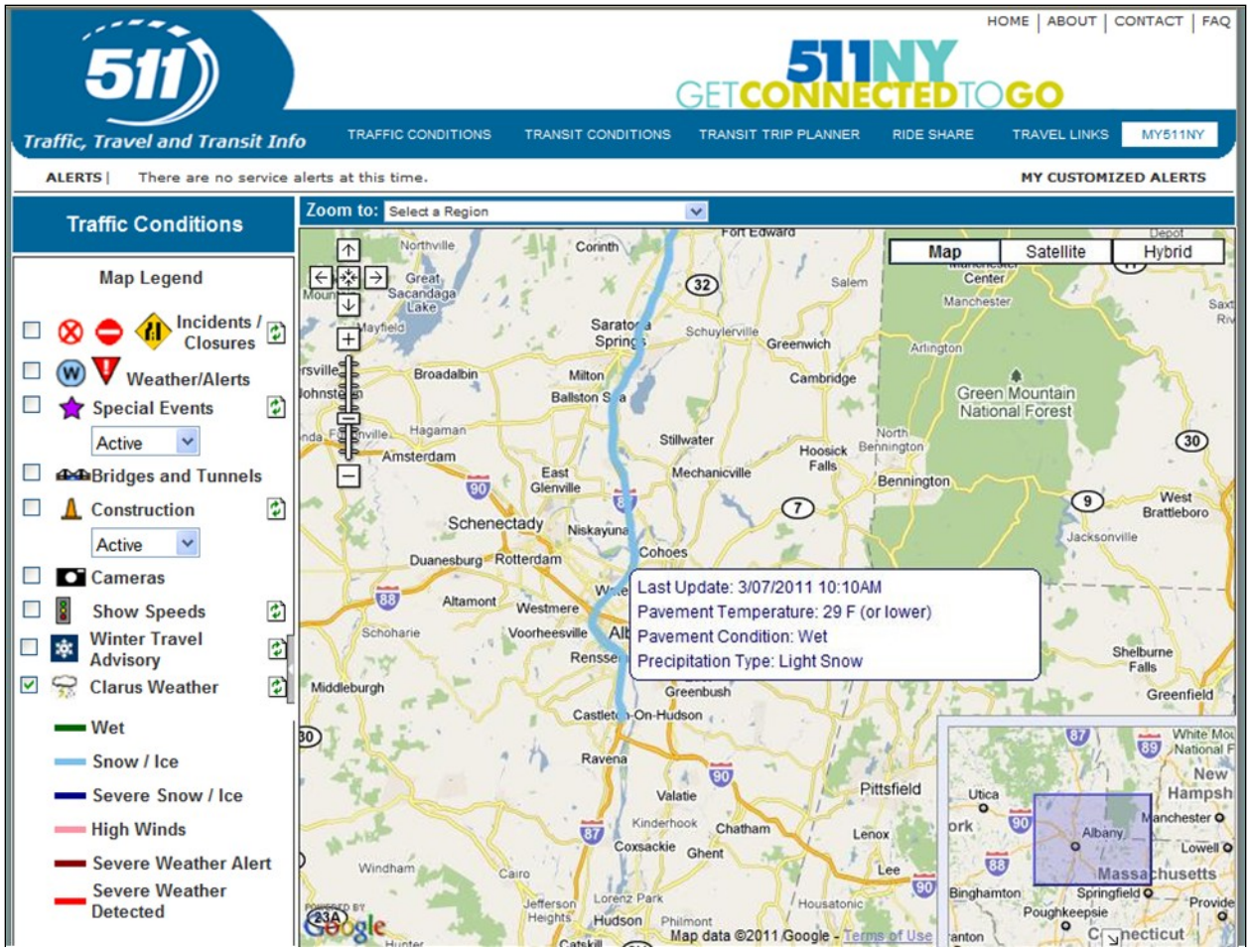
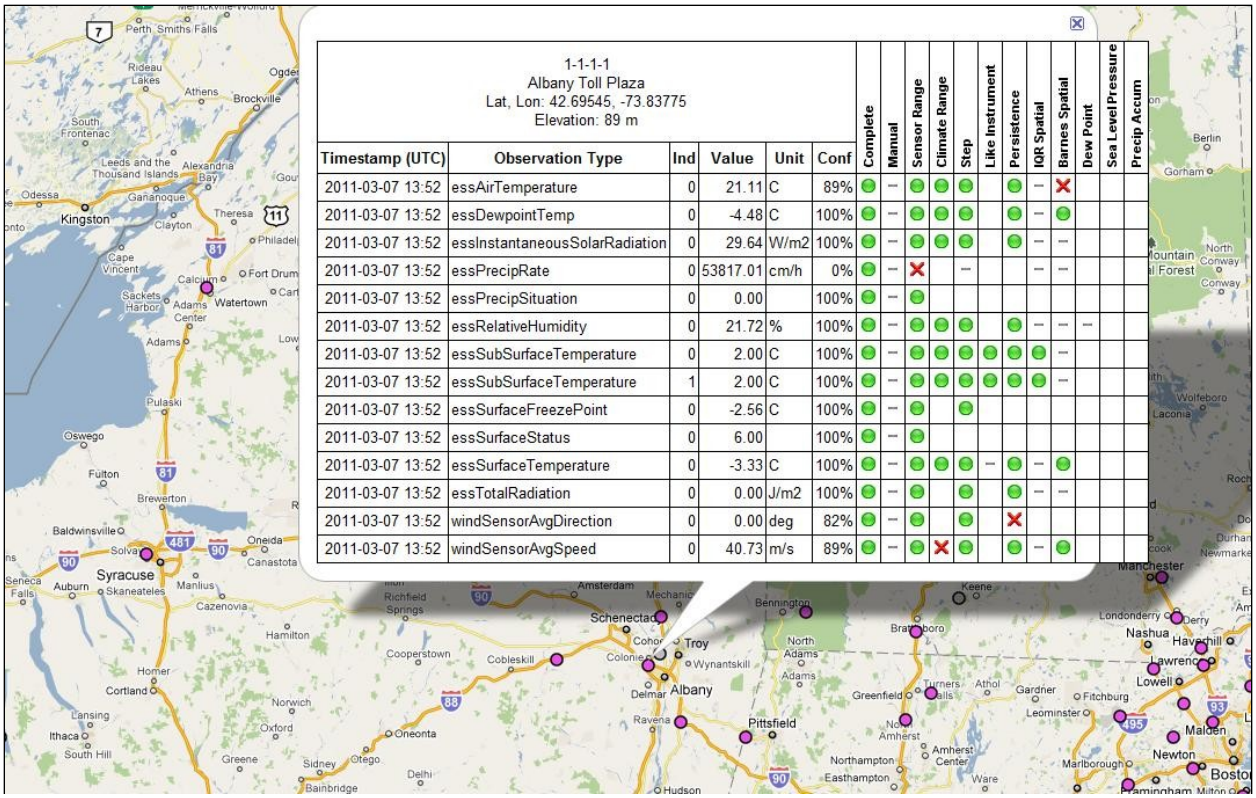


Figure 3-4 – 511NY Pre-Production Website Map Page with *Clarus* and Doppler Radar Alerts (Source: Telvent)

Figure 3-5, below, depicts the source *Clarus* readings that resulted in the pavement-related alerts in the website map, above. In particular, *Clarus* provided an essSurfaceTemperature value of -3.33 °C (26 °F) and a coded essSurfaceStatus reading of 6.00 that corresponds to a pavement condition of Chemically Wet (or just Wet for end-user purposes).

In Figure 3-6, below, Doppler Radar shows a large area of light to moderate snow rotating through eastern New York, affecting I-87 from Albany north to the Canadian border. This activity was responsible for the light blue shading of the I-87 road segments north of Albany in the 511NY website map.



Timestamp (UTC)	Observation Type	Ind	Value	Unit	Conf	Complete	Manual	Sensor Range	Climate Range	Step	Like Instrument	Persistence	IQR Spatial	Barnes Spatial	Dew Point	Sea Level Pressure	Precip Accum
2011-03-07 13:52	essAirTemperature	0	21.11	C	89%	●	–	●	●	●		●	–	✗			
2011-03-07 13:52	essDewpointTemp	0	-4.48	C	100%	●	–	●	●	●		●	–	●			
2011-03-07 13:52	essInstantaneousSolarRadiation	0	29.64	W/m2	100%	●	–	●	●	●		●	–	–			
2011-03-07 13:52	essPrecipRate	0	53817.01	cm/h	0%	●	–	✗		–			–	–			
2011-03-07 13:52	essPrecipSituation	0	0.00		100%	●	–	●									
2011-03-07 13:52	essRelativeHumidity	0	21.72	%	100%	●	–	●	●	●		●	–	–	–		
2011-03-07 13:52	essSubSurfaceTemperature	0	2.00	C	100%	●	–	●	●	●	●	●	–				
2011-03-07 13:52	essSubSurfaceTemperature	1	2.00	C	100%	●	–	●	●	●	●	●	–				
2011-03-07 13:52	essSurfaceFreezePoint	0	-2.56	C	100%	●	–	●		●							
2011-03-07 13:52	essSurfaceStatus	0	6.00		100%	●	–	●									
2011-03-07 13:52	essSurfaceTemperature	0	-3.33	C	100%	●	–	●	●	●	–	●	–	●			
2011-03-07 13:52	essTotalRadiation	0	0.00	J/m2	100%	●	–	●		●		●	–	–			
2011-03-07 13:52	windSensorAvgDirection	0	0.00	deg	82%	●	–	●		●		✗					
2011-03-07 13:52	windSensorAvgSpeed	0	40.73	m/s	89%	●	–	●	✗	●		●	–	●			

Figure 3-5 – Albany Toll Plaza RWIS Data from *Clarus*
(Source: www.clarus-system.com)

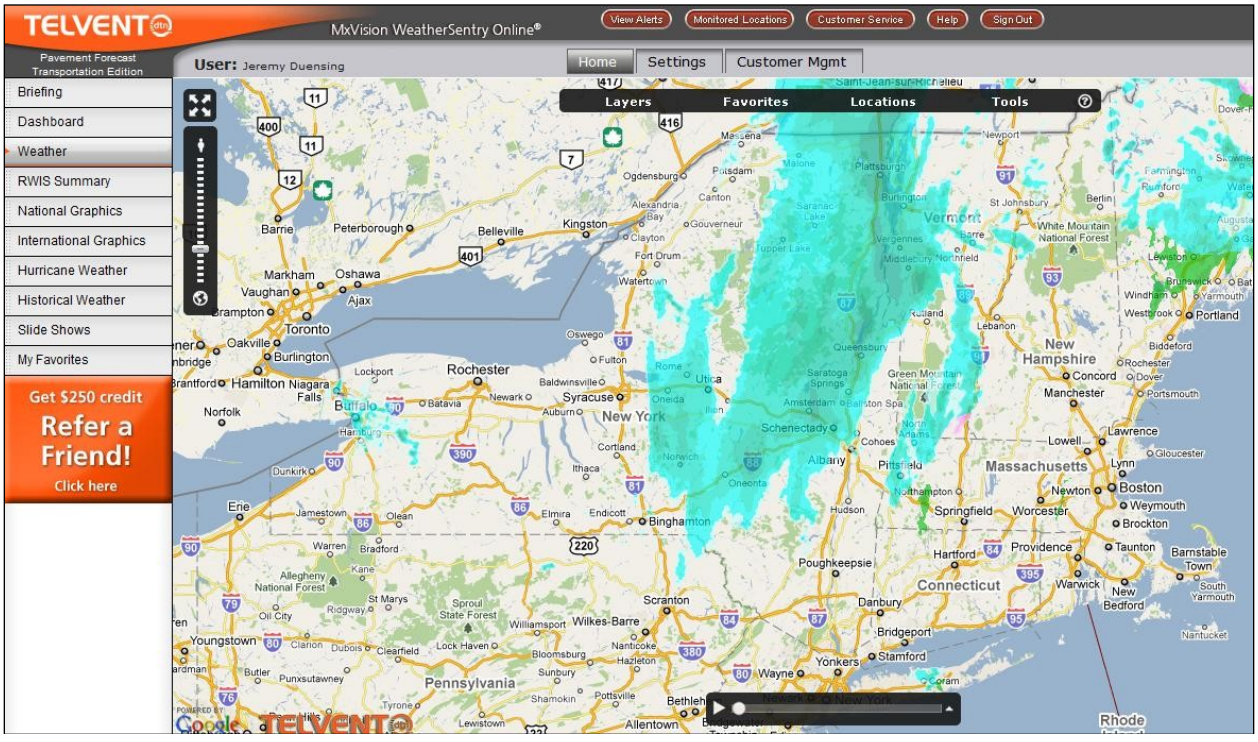


Figure 3-6 – Doppler Radar Showing Light/Moderate Snow Affecting I-87 North of Albany
(Source: Telvent)

Another sample screen with the new *Clarus* Weather layer is shown in Figure 3-7, below. Here, several different types of weather alerts occurred along most portions of I-87, including Wet warnings, Severe Weather Alerts, and Severe Weather Detected. Through the tool tip, the red section of I-87 near Glens Falls, NY indicates a possible tornado along with Light Rain in the area. Since the Severe Weather Detected alert is a higher priority than Light Rain, the coloring was red and not green as per the legend. Information on alert priorities can be found in Table 3-5 on page 24. This alert occurred because Doppler Radar detected a storm cell that contained characteristics that often generate tornados. Note that this did not mean a tornado hit the ground, but that all conditions are right for a tornado to form resulting in a dangerous condition for motorists.

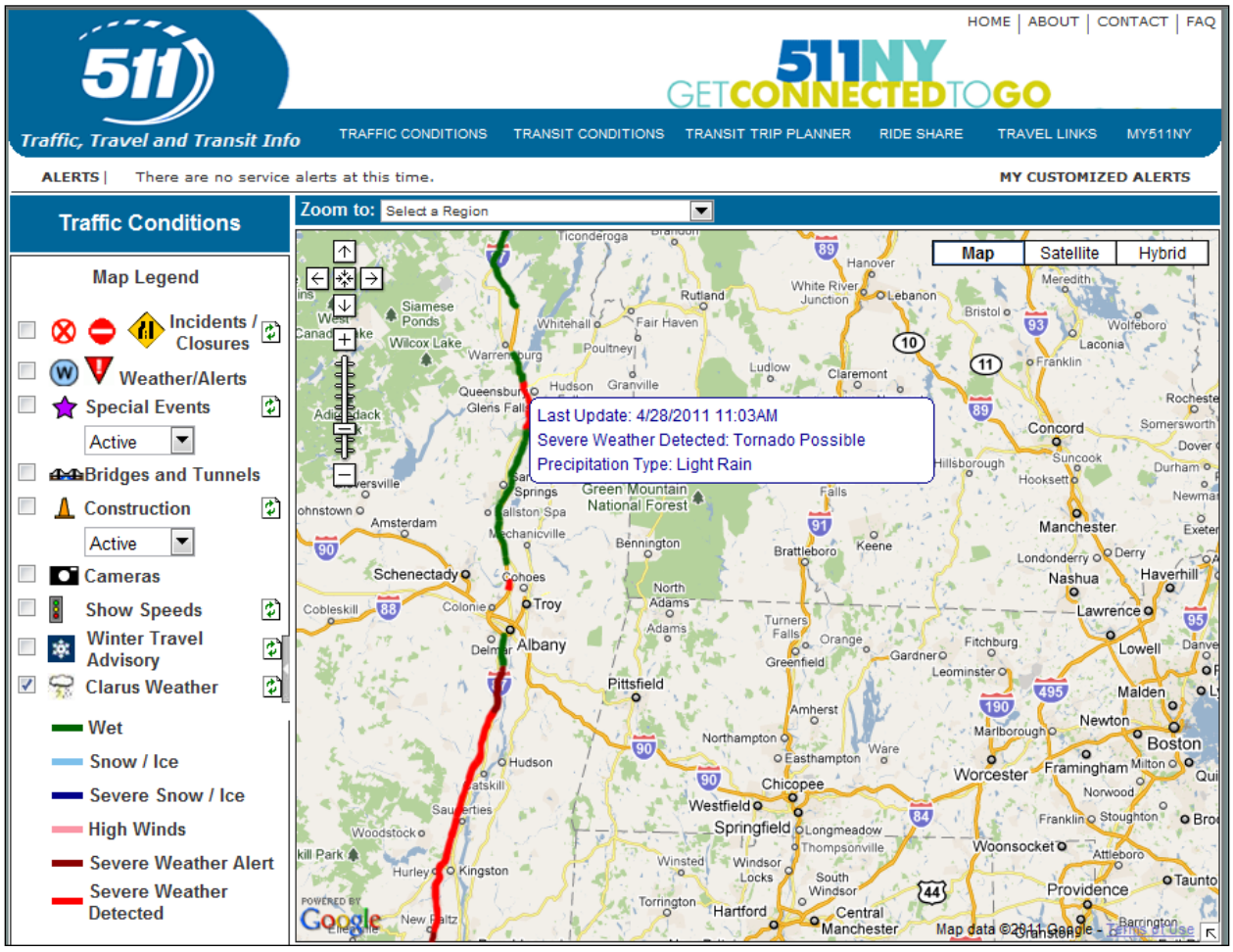


Figure 3-7 – 511NY Pre-Production Website Map Page with Various Alerts (Source: Telvent)

Below are screen samples from the National Weather Service and Doppler Radar at the same time showing the source of the information presented on the 511NY website map, above. The first screen shows the National Weather Service Warnings issued for the area. This data generates the burgundy/brown road segment alerts on the 511NY website map. The second screen shows Doppler Radar with storm corridors, which generates the red road segment alerts in 511NY.

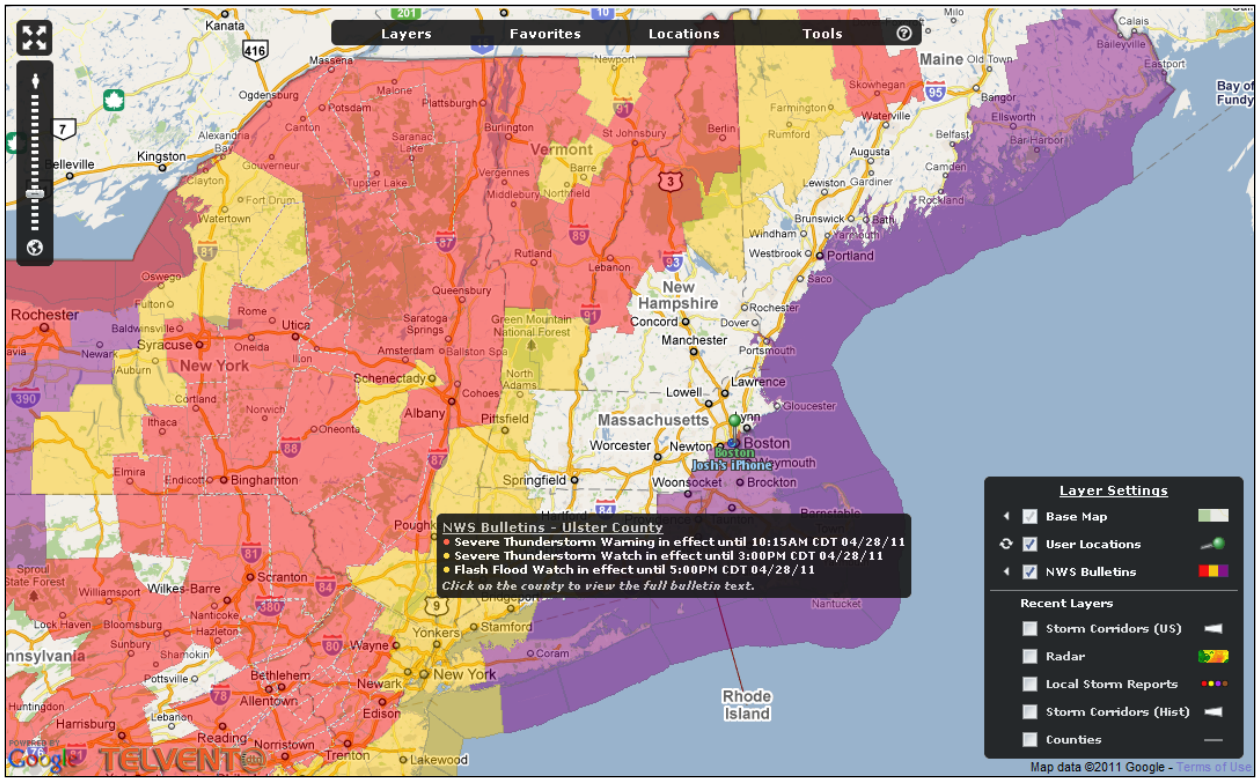


Figure 3-8 – National Weather Service Warnings
(Source: Telvent)

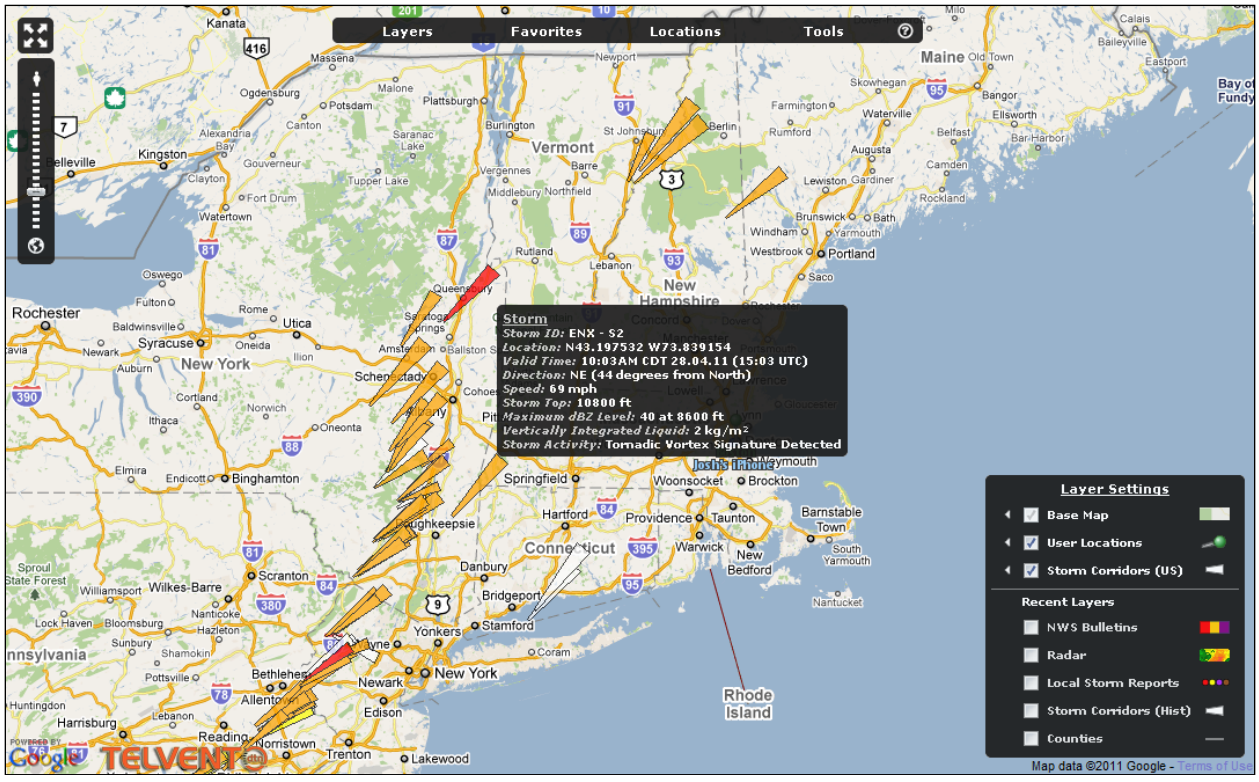


Figure 3-9 – Doppler Radar with Storm Corridors
(Source: Telvent)

The existing layers on the 511NY website map page provide additional information as it is received by the 511NY pre-production system. If the *Clarus* Weather layer is toggled on (through a user selected checkbox), the Winter Travel Advisory layer (which contains winter roadway conditions manually reported by maintenance staff) and the Show Speeds layers will both be automatically toggled off. The existing layers and the *Clarus* Weather layer are described below:

Including the existing map layers, the website map page includes the following layer selections:

- Incidents/Closures
- Weather/Alerts (received from the National Weather Service)
- Special Events (Active and Planned Special Events)
- Bridges and Tunnels (travel times)
- Construction (Active and Planned Construction Events)
- Cameras (CCTV camera displays)
- Show Speeds (Link based speeds)
- Winter Travel Advisory (New York State roadway plow beat conditions)
    - No Report
    - Generally Clear and Dry Conditions
    - Wet Conditions
    - Snow / Ice Conditions
    - Severe Snow / Ice Conditions
    - Closed
    - Closed Portions
- *Clarus* Weather (primary weather alert for a link)
    - Wet
    - Snow/Ice
    - Severe Snow/Ice
    - High Winds
    - Severe Weather Alert
    - Severe Weather Detected

In addition to the color coded link representation of weather alerts, each color coded link includes a tool tip that contains supporting textual information associated with the primary link condition. Note that information for all weather alerts for the selected link appears in the tool tip. The tool tip is invoked when the mouse cursor hovers over a color coded link.

The following tooltip information accompanies a link with a current weather condition, in addition to an update time.

Table 3-4 – 511NY Website Map Tool Tip Information

Tool Tip Label	Possible Conditions
Pavement Temperature:	33° F (or lower)
Pavement Condition:	Snow | Ice | Wet
Precipitation:	Heavy Mix | Heavy Rain | Heavy Snow | Moderate Mix | Moderate Rain | Moderate Snow | Light Mix | Light Rain | Light Snow
Wind Speed:	40 mph (or higher)
Severe Weather Alert:	Tornado Warning | Severe Thunderstorm Warning | Flood Warning | Flash Flood Warning | Dense Fog Advisory
Severe Weather Detected:	Hail Possible | Severe Thunderstorm Possible | Tornado Possible

The system determines the highest priority condition based on the prioritization scheme in Table 3-5, below, and this condition determines the color of the roadway link. In cases where there are overlapping conditions, secondary conditions are included in the tool tip. For example, if severe weather is detected and high winds are reported by the RWIS for a specific link, the color of that link would be red since severe weather detection is a higher priority (lower map display priority number) than high winds.

Table 3-5 – 511NY Website Map Weather Alert Layer Priority

Weather Alert Layer Value	Map Display Priority
Wet	6
Snow/Ice	3
Severe Snow/Ice	2
High Winds	5
Severe Weather Alert	4
Severe Weather Detected	1

4 System Evaluation

4.1 Evaluation Process

A three-month evaluation phase of the resulting system followed immediately upon completion of system acceptance testing in late March 2011. This was the final phase of the project completed in June 2011. This timeframe was selected in order to capture weather alerts from the late winter season through spring 2011.

Evaluation of the system was conducted by FHWA staff, NYSDOT staff, and members of the Telvent project team.

The evaluation process consisted of exchanges of observations and feedback through e-mail and teleconferences over the three-month period. These observations are summarized in Section 4.2. To help guide the process, the project team also developed an evaluation survey that was completed by FHWA and NYSDOT staff in early May 2011. The survey results are provided in Section 4.3. Potential areas for improvement and expansion are included in Section 4.4.

4.2 Observations/Results

The system produced a wide range of results representing varying weather conditions and alerts during the evaluation phase, although it was observed that a relatively small number of alerts were based on *Clarus* RWIS data. Most of the valid *Clarus* RWIS alerts were only for roadway surface temperatures (e.g., below 33° F) during the late winter and early spring seasons. There were also some valid surface condition readings (e.g., from the Schodack RWIS station), but most other readings were flagged as erroneous by the *Clarus* and *SiteWatch* quality control checks. For example, the wind sensors at the Schodack and Albany Toll Plaza stations reported abnormally high winds on March 31, 2011 that failed a *Clarus* validation check; this was also corroborated by normal wind readings from other weather sources in those areas at that time. It is recommended that the sensors on all five RWIS stations used for this project be checked to ensure all equipment is in operating order. Note that NYSDOT is currently in the process of developing contracts for ongoing maintenance and calibration of the RWIS sites in New York.

In general, the representation of weather alerts on the 511NY pre-production website was accurate, clear, and easy to understand, although there was some concern that some results could be misinterpreted by the public. For example, in late April 2011, a Flood Warning (from a NWS Bulletin categorized as a Severe Weather Alert) appeared along the entire section of I-87 north of Albany, NY, but it was difficult to determine if this meant that the highway could become flooded or just the surrounding areas. In this case, when the National Weather Service issues a Flood Warning, it indicates that the river has the potential to exceed flood stage and that flooding could cover roads and highways, although interstates very seldom experience flooding. These Flood Warning alerts are usually for rivers and low-lying roads along them, and generally do not affect interstates, so there is the potential for some of the indicators to be misleading. Since the weather alerting system was designed to be very configurable, it can be adjusted to include only the types of warnings that actually affect the road segment and help travelers make decisions, versus those that do not actually apply and could cause confusion or be misleading. For example, it might be more meaningful to the traveling public to alert on a Flash Flood Warning (short-term localized event) and downplay or not post alerts from a Flood Warning (long-term widespread event). Additional explanations of each of the alert types on the 511NY website would also help avoid potential confusion.

The information from the system was also very useful from a traffic management perspective as it can help transportation managers alert motorists of upcoming weather disturbances and provide assistance in readying public safety and incident management staff and resources for impending weather conditions that could negatively affect the transportation system. For example, in late April 2011, the 511NY pre-production website

showed a dense fog advisory on the eastern portion of the Long Island Expressway. This alerted NYSDOT staff who then looked at traffic cameras in the area and confirmed that visibility was very poor. This information could be used in conjunction with the traffic management system to alert eastbound motorists via dynamic message signs, highway advisory radio, e-mail/text message alerts, etc. of the situation and suggest alternate routes if available. The potential tornado near Glens Falls, NY in late April 2011, as shown in Figure 3-7 on page 21, is another example of a significant weather alert that could be proactively disseminated to the public through various means.

Additional observations are provided on the following page as captured through the feedback survey provided to FHWA and NYSDOT.

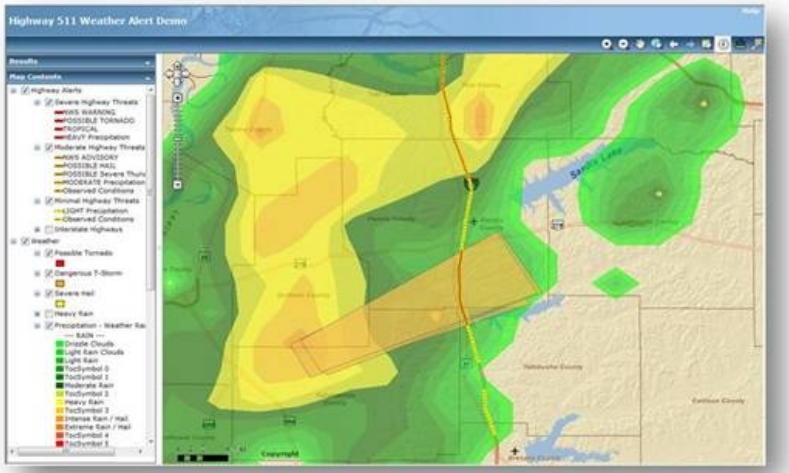
4.3 Survey Results

The project team prepared the following project survey to help evaluate the effectiveness of the system. The responses shown are from FHWA and NYSDOT project evaluation staff.

Table 4-1 – Project Evaluation Survey Results

Survey Question	Survey Response
1. Is the new *Clarus* Weather layer intuitive and easy to use within the 511 New York system?	Yes. My only concern is that most of the weather info/alerts come from the NWS and not *Clarus*, so the heading "*Clarus* Weather" is not necessarily true.
2. Does the new *Clarus* Weather layer provide clear, appropriate and timely information for the traveling public?	Yes and No. Generally it does; however, a very good point was raised on April 26th when a flooding warning was displayed for I-87. An end user would not be able to discern if the highway was flooded or if areas surrounding the roads were flooded. The weather layer does provide appropriate and timely info for the traveling public. Some users may need to know the differences between 'regular' and 'severe' snow/ice, or between severe weather detected and severe weather alert. Same with the different levels of wetness (light rain, moderate rain, heavy rain) or what high winds mean. It will be useful to provide some short explanations on the website about what these conditions are and the associated thresholds (in some cases, it may be better to display the specific measurements).

Survey Question	Survey Response
3. Do the *Clarus* Weather layer categories clearly represent potential travel hazards?  (Source: Telvent)	It may be useful for travelers to know if the roads are wet and at the same time it is raining, or if the roads are wet but the rain has stopped. Similarly for snow, it will be useful to know how much snow has fallen on the ground and whether the snow is still falling. The degree of travel hazard depends upon these combinations of road and weather conditions.
4. Are the colors used to symbolize *Clarus* Weather layer categories appropriate?	Yes. Eventually the colors should be standardized nationwide. The colors used seem appropriate. NYSDOT will have to decide which colors to use on the production system.
5. Is the information provided in the pop-up boxes when you hover over a colorized road segment clear and appropriate?	Yes, but lines and coloring should come off in a more timely manner when warnings expire. The information is clear and appropriate but need to make sure that it's up to date.
6. In many cases, a road segment may be affected by several types of weather conditions. Did the priority weather condition, i.e., the one that determined the color of the road segment alert, represent what the traveler wants/needs to know the most?	Yes, but we should consider a way to display all alerts, not just the #1 priority. All weather conditions affecting a road segment need to be displayed on the website.

Survey Question	Survey Response
7. Would a layer showing radar data and storm corridors add to the context and functionality to the weather alerts (see example below)?  (Source: Telvent)	Yes, we think something more visual is user friendly and easier to understand. Yes, because it shows the location, extent and severity of the weather events.
8. Is there anything you wish to see changed?	We need to understand what our QA tools are – if an RWIS detector conflicts with other sources of data, would it notify the right person? (Note that functionality to provide these types of individual notifications is outside the scope of this project.)
9. Are there other related features or information that you would like to be added?	Projected Times – providing approximate times along road segments of when severe weather is expected to hit.
10. Do you have any other comments?	What's the difference between 'Winter Travel Advisory' and '*Clarus* Weather'? There are clearly overlaps among the information provided for these two sections of the website, but it's not clear which one the user should refer to for winter weather conditions. Also, the colors used are different for the same weather condition (e.g., for wet road – light blue for winter travel advisory and green for '*Clarus* Weather'). This can be very confusing to the users. (Note: Winter Travel Advisory represents winter road conditions based on reports manually collected from New York State roadway plow-beat drivers, whereas *Clarus* Weather data is from *Clarus* and other electronic sources

Survey Question	Survey Response
	described in this report. The Winter Travel Advisory layer only appears during winter months, typically from November 1 through April 30, and does not represent summer weather conditions such as high winds, heavy rain, fog, flooding, thunderstorms/tornados/hail/hurricanes, etc. The *Clarus* Weather layer is designed for year-round use.)

4.4 Potential Areas for Improvement and Expansion

During the evaluation phase, a number of recommendations were developed to help improve the usability and effectiveness of the system. These recommendations are categorized and summarized below.

Alert Prioritization

- Prioritize radar-driven weather alerts (e.g., Wet, Snow/Ice, Severe Snow/Ice) higher than Severe Weather Alerts since the former alerts indicate actual current conditions and the latter alerts represent predicted conditions. As the system was designed to be configurable, changes such as these could be accommodated with minimal work.

Data Quality

- This project shows that RWIS observations provided through *Clarus* can successfully be integrated to drive road segment-specific alerts. Using *Clarus* observations in this way underscores the importance of RWIS data quality and reliability. By improving the reliability of the RWIS sensor equipment across the road network covered in this project, additional RWIS parameters can be used for alert generation. For example, this could provide reliable road surface conditions (e.g., Ice Warning, Snow Warning, Wet) which is critical information to motorists, especially during the winter season.

Information Clarity

- Provide additional information about the definition of each type of weather alert. For example, the system could explain that a Flood Warning pertains more to surrounding roads than to the interstate. Given the potential for confusion on long-fused Flood Warnings that were encountered as part of this project, it may be prudent to drop the usage of Flood Warnings altogether and only use Flash Flood Warnings to drive alerts.

- Explain the differences between "Snow/Ice" and "Severe Snow/Ice" as well as light/moderate/heavy precipitation, e.g., using threshold values.

- Determine a method to show all weather alert conditions easily, rather than just the highest priority condition. For example, this could be improved by simultaneously overlaying radar and storm corridor imagery on the website map.

- Standardize on colors and terminology used for different types of weather alerts. Note that this issue is not limited to this project, but rather a nationwide issue. Within the 511NY website map, different colors are also used between similar conditions shown in the Winter Travel Advisory layer and *Clarus* Weather layer. Further discussion and research is needed here to develop the necessary standards. Recently, the Transportation Association of Canada developed some guidelines on winter road condition terminology that should be explored – see http://www.tac-atc.ca/english/bookstore/pdfs/winter-feb2011.pdf.

- Based on project feedback from both NYSDOT and FHWA personnel, a more simple and concise road segment colorization scheme should be used to communicate weather alert information to the travelling public. It is suggested that a simple red/yellow/green colorization scheme be used based on the severity of the weather situation and its effect on the roadway. Table 4-2 and Table 4-3, on the following page, provide one possible method for simplifying the color scheme on the 511NY website map. This scheme uses a total of three road overlay colors, one set for *Clarus* and another set for Non-*Clarus* weather conditions. The colors would be configurable to easily allow for changes as the system evolves.

Table 4-2 – Simplified Website Map Color Scheme for *Clarus* Data

Color	Meaning	Pavement Condition	Pavement Temperature (Celsius)	Precipitation Rate (mm/hr)	Precipitation Type/Intensity	Wind Speed (mph)
Red	Significant Threat	Ice Warning Snow Warning Frost		> 8.0	snowHeavy frozenPrecipitationHeavy snowModerate unidentifiedHeavy	
Yellow	Moderate Threat	Ice Watch Snow Watch	< 0.0	< 8.0 and > 3.0	rainHeavy frozenPrecipitationModerate unidentifiedModerate	> 40.0
Green	Low Threat	Wet Trace Chemically Wet Absorption Absorption Dew Dew	< 0.56 and > 0.0	> 0.0	unidentifiedSlight snowSlight rainModerate frozenPrecipitationSlight	

Table 4-3 – Simplified Website Map Color Scheme for Non-*Clarus* Data

Color	Meaning	Radar Precipitation Type/Intensity	Storm Corridors	Wind Observation	NWS Bulletin
Red	Significant Threat	HEAVY SNOW HEAVY MIXED PRECIP	TORNADO POSSIBLE		Tornado Warning Severe Thunderstorm Warning Flash Flood Warning Winter Storm Warning Heavy Snow Warning Blizzard Warning Ice Storm Warning
Yellow	Moderate Threat	HEAVY RAIN MODERATE MIXED PRECIP MODERATE SNOW	SEVERE THUNDERSTORM POSSIBLE HAIL POSSIBLE	HIGH WINDS	Dense Fog Advisory High Wind Warning
Green	Low Threat	MODERATE RAIN LIGHT MIXED PRECIP LIGHT SNOW			Flood Warning

4.5 Next Steps

Possible next steps beyond this project include:

- Present the project results at (1) the *Clarus* MDSS meeting in September 2011 and (2) the 2012 International Conference on Winter Maintenance and Surface Transportation Weather.
- Integrate weather alerts into the NY Connected Vehicle system.
- Explore opportunities to improve/expand the system as discussed in Section 4.4, Potential Areas for Improvement and Expansion.
- Explore options to integrate weather alerts and related data into the 511NY production system for both the public/mobile website and IVR Telephone System. Note that transitioning this information to a telephone-based system may require extensive design and development efforts due to the constrained format of that type of system compared with a more visual environment such as a website. Although challenging, various types of weather alerts have been integrated into IVR telephone systems for other projects, and examples are available for reference.

References

There are a number of project documents that define management processes and other technical aspects of the system created for this project. Relevant documents include:

- Telvent Proposal Response to FHWA RFP DTFH61-10-R-00015, Research on *Clarus* System RFP – Telvent Proposal, April 14, 2010
- Minutes from Project Schedule Review Meeting with FHWA – Telvent, November 12, 2010
- FHWA Contract DTFH61-10-P-00127 Requirements Specification, Version 1.1 – Telvent, December 6, 2010
- FHWA Contract DTFH61-10-P-00127 Design Specification, Version 1.2 – Telvent, February 11, 2011
- FHWA Contract DTFH61-10-P-00127 System Acceptance Test Plan, Version 1.0 – Telvent, February 4, 2011

List of Acronyms

Acronym	Description
CCTV	Closed Circuit Television
DBZ	Decibels of Z
DI	Data Interface
FHWA	Federal Highway Administration
FTP	File Transfer Protocol
GIS	Geographic Information System
MDSS	Maintenance Decision Support System
MPH	Miles per Hour
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
NYSDOT	New York State Department of Transportation
QA	Quality Assurance
RFP	Request for Proposals
RWIS	Roadway Weather Information System
SAT	System Acceptance Test
SDLC	Software Development Lifecycle
SQL	Structured Query Language
WTA	Winter Travel Advisory
XML	Extensible Markup Language

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