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Baselining Current Road Weather Information

Final Report

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16. Abstract

This final report contains research findings on the characterization of the quality and value of road weather information resources used by members of the surface transportation community in their decision-making process. The objectives of the project were to identify current road weather information resources, develop a process to measure the quality of road weather information, and establish a baseline metric of the existing resources, and the recommendation of a strategy for an ongoing monitoring program.

The project evaluated the existing sources of road weather information and the methods used by departments of transportation (DOT) to use this information for both internal and external applications. The analysis of weather service provider sources, road weather products, and DOT uses of the data permitted the research team to define six quality attributes that could be used to measure DOT users' perception of road weather data quality and value. The road weather information that DOTs receive/use were separated into product type packages and the basic weather elements within the resource deliverables. The baseline assessment of quality was accomplished through an online survey. DOT personnel who use road weather information routinely as part of their daily operations participated in the survey. The report details the organization of the survey responses into a quality attribute matrix and then analyzes the results of the survey. The report addresses variable user responses within and amongst quality attribute classes that illustrate the strengths and weaknesses of specific products and weather elements. The resulting measures from the survey serve to establish quality markers and point out road weather products or elements that could benefit from improvement.

The technique chosen to characterize the quality of existing road weather information for this study was evaluated as the project evolved to assess its viability for an ongoing quality characterization monitoring program. The team also looked at appropriate time intervals for regular quality assessment, and evaluated the potential impacts of issues that occurred during the quality characterization process. The report evaluates these factors and proposes a strategy for implementing a regular quality assessment monitoring program. Finally, the research report projects the team's anticipated outcomes from an ongoing road weather quality monitoring program.

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Introduction

This report represents the culmination of a study to baseline the quality and availability of road weather information within the US as of early 2008. The study was performed to fulfill research requirements established by the FHWA Road Weather Management Program. The research was done by Booz Allen Hamilton (BAH) and its subcontractors Meridian Environmental Technology, Inc., Iteris, Inc., and the Surface Transportation Weather Research Center at the University of North Dakota. The primary tasks of the study consisted of:

- Identifying the published sources and content of available road weather information;
- Determining the discrete road weather components a department of transportation (DOT) uses to support decision making;
- Selecting quality descriptors used to establish a reproducible measure of quality of the road weather components;
- Querying state DOT stakeholders and end users' opinions regarding road weather quality;
- Synthesis of stakeholder and end users' responses into a quality snapshot; and,
- Recommendation of future quality change monitoring efforts.

OBJECTIVES

The overall objective of this study was to characterize the availability and quality of road weather information to serve as a baseline for future comparisons of enhanced road weather information enabled by the *Clarus* system and other advanced road weather management technologies. The study also focused on the content and usefulness of road weather information.

One primary objective was to provide clear and useful measures of the quality of current road weather information sources in a method effective for continued use to capture changes in the perceived quality of the information. The study provides a catalog and characterization of the pre-*Clarus* road weather information state of practice and recommends strategies to monitor change.

A key element of this study is a review of how change may be reflected through the intrinsic characteristics of road weather information. Fundamental to this is defining a quantifiable measure of road weather information quality such that future change is measurable, and the introduction of *Clarus*-enabled road weather information does not alter the character of the information or require new metrics.

WORKING ASSUMPTIONS

While overall this was not considered to be a particularly high-risk project, there were some potential constraints associated with results of the project.

- The success of stakeholder inputs depended upon the openness of stakeholders' feedback to the information developed in this project. It also relied upon stakeholders' perception of the quality and value of road weather information product

types. Where relevant, particular insight gained by the study team regarding user input and the unique relationships involved in assessing quality are included in the discussion.

The potential Quality Attributes were predefined and provided by FHWA Road Weather Management Team. The final Attributes and their definitions were developed iteratively between the BAH and Road Weather Management teams until there was consensus.

STUDY TASKS

The Baselining Current Road Weather Information study scope of work was organized by tasks. These tasks are summarized in the following synopsis.

Task 1 Project Management

The BAH team developed a Project Management Plan (PMP) that served as a road map for the project. The progress toward meeting the milestones within the PMP was monitored through monthly progress reports and routine conference calls between the research team and the COTM.

Task 2 Research and Characterize Available Road Weather Information

The research team identified existing road weather data and information sources and evaluated quality attributes that enable the assessment of the current state of the practice. This was accomplished through a scan of existing source road weather information and the characterization of the content within these sources. The scan incorporated active feedback from industry and government stakeholders familiar with road weather information or actively use the information in their daily operations. The primary task was divided into two sub-tasks.

Task 2.1 Scan Road Weather Information Sources

The BAH team characterized the existing road weather information state of the practice by:

- Identifying the full spectrum of road weather observations and forecasts available from public and private providers;
- Listing the communications methods utilized to disseminate road weather observations and forecast information; and,
- Identifying the quality attributes employed by DOT agencies to evaluate the quality of each of the identified sources of road weather information.

The results from a detailed scan of providers and DOT users of road weather information were compiled in two tables, one describing the providers and the content each provider supplied and the second listing each State DOT and their respective advanced traveler information resources. The results were submitted to the FHWA in an interim report.

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Task 2.2 Characterize Road Weather Information

The execution of the baseline road weather information survey and data analysis was accomplished in this sub-task. The final baseline results reflected a series of steps

necessary to design the measurement instrument, collect stakeholder input, and analyze the stakeholder feedback. Key stages in the process were:

- The establishment of quality attributes that define the construct of road weather information quality;
- The selection of a method to create a quality measure that permitted the formation of a baseline metric and a mechanism for future assessment of quality;
- The formation of a summary matrix to consolidate information about the road weather resource components;
- The development and subsequent execution of an online survey to collect stakeholder feedback;
- The consolidation and organization of the survey results in a spreadsheet format to support further analysis of the results;
- Analysis and cross comparisons of the survey results; and,
- Summarization of the results in the Quality Attribute Matrix and related tables.

The processes, the logic behind the chosen methods, and the results were presented in an interim report on the Characterization of Road Weather Information.

Task 3 Recommend Tracking and Comparison Procedures

The results of Task 2 yielded an extensive set of information on the character of road weather. Task 2.2 had provided a baseline measure that could be used for comparison; however, the execution and analysis of the survey results yielded considerable insight into the interrelationships between the product types and elements and the users different assessment of quality across the six attribute categories. Task 3 synthesized the results and formulated recommendations regarding what were deemed the appropriate procedures for a potential ongoing quality assessment program based upon the lessons learned in the baseline study. Specific accomplishments included:

- The establishment of the parameters, quality metrics, and survey mechanism to assess the quality of road weather information;
- The recommendation of an ongoing monitoring and collection method; and,
- The recommendation of an appropriate time interval to execute analyses of road weather information quality.

The results from the study were summarized in a final executive report distributed to a group of DOT individuals who actively use road weather information in their operations. The group included DOT personnel from 40 states with operational responsibilities covering maintenance, traffic operations, and those responsible to issue advisory and control messages. This group responded to a short survey regarding the results of the survey and the need to continue the evaluation as an ongoing program.

Task 4 Recommend Tracking and Comparison Procedures

Task 4 encompassed the preparation and submittal of this final report, a two-page flyer, and the organization of materials for PowerPoint presentations. The results and recommendations were presented at the Transportation Research Board's and American

Meteorological Society's annual meetings, and the materials are available for *Clarus* and related surface transportation meetings.

STUDY PRODUCED REPORTS

The study produced several interim reports addressing specific activities or sub tasks. These included:

- Project Management Plan
- Road Weather Information Sources (Task 2.1)
- Characterization of Road Weather Information (Task 2.2)
- Recommendations for Tracking and Comparing the Characterization of Road Weather (Task 3)
- Baselining Current Road Weather Information: Summary Report (Task 3)

STUDY CONTRIBUTIONS

This study provides a comprehensive evaluation of road weather information. Road weather information encompasses weather, road surface conditions, flooding, camera images, or advisory messages that affect transportation related activities. Road weather information is typically separated into discrete elements for exchange from weather service providers to the ultimate end users. These discrete road weather elements are consolidated and/or reformulated into new products by public and private weather service providers, and then delivered to transportation users in packages of information (products). These packages are collectively called product types, and they have evolved by mutual agreement between the provider sources and the end user transportation community.

RELEVANCE TO CLARUS

According to the *Clarus* Initiative web site,

> *Clarus* is a Federal Highways Administration research and development initiative to demonstrate and evaluate the value of "Anytime, Anywhere Road Weather Information" that is provided as an integral part of the road weather support packages delivered to the spectrum of transportation users and operators. The goal of the initiative is to create a robust data assimilation, quality checking, and data dissemination system that can provide near real-time atmospheric and pavement observations from the collective state's investments in road weather information system (RWIS) environmental sensor stations (ESS) as well as mobile observations from Automated Vehicle Location (AVL) equipped trucks.
> (http://www.clarusinitiative.org/background.htm)

Transportation system operators and weather service providers utilize the basic elements from the road weather sources. These data processing organizations include entities responsible for gathering the raw road weather observations, adding value to observations by generating derived information from the observations, and using the raw information to generate decision-making guidance. Figure 1 illustrates the processes involved in the transfer of raw road weather information from its sources through the primary service providers to the eventual end users.

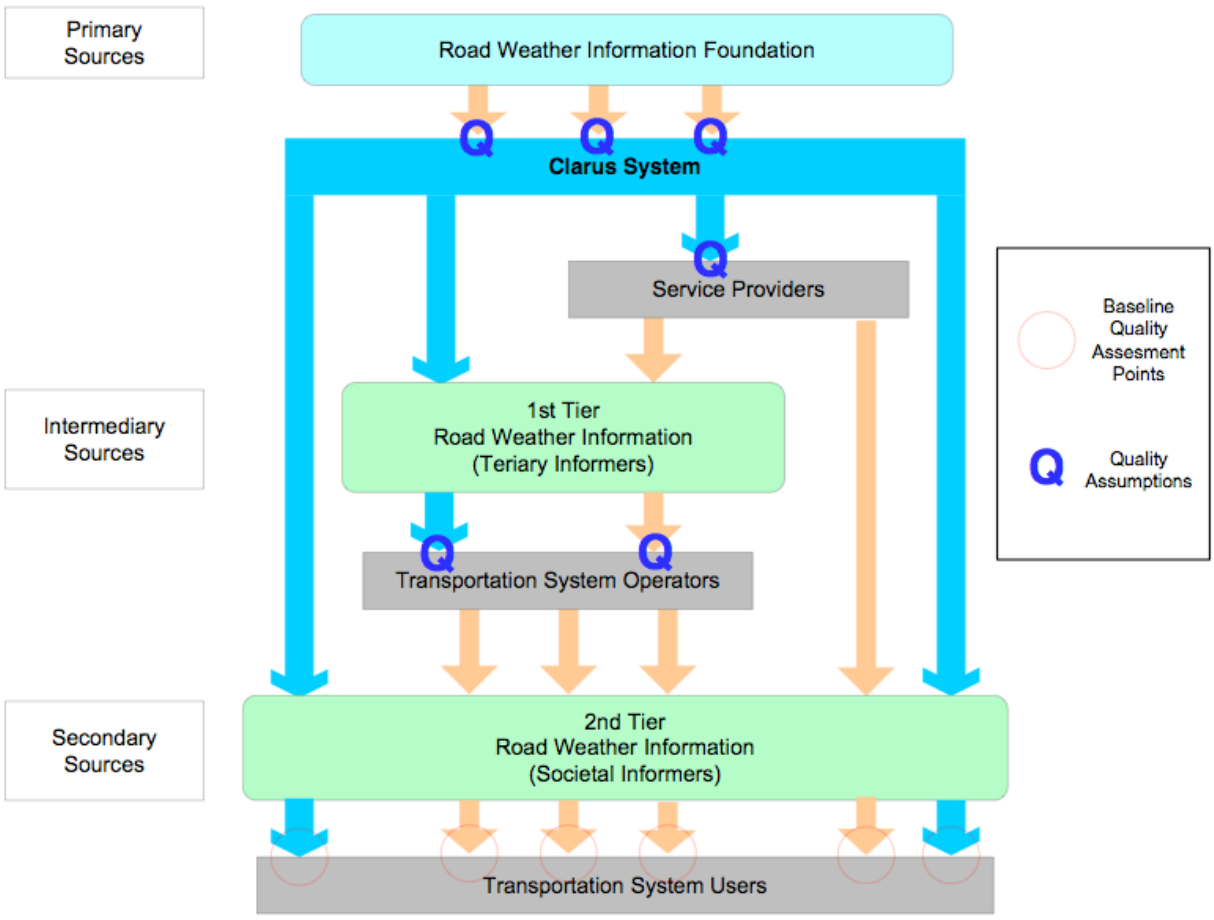
Transportation system operators and users responsible for decisions impacted by weather benefit from the resulting road weather information. The transfer or transition of raw road weather data from its raw format to a form that end users may use to support their own decision process is often a complex process that incorporates a number of transformations or reorganizations of the original data sources. Thus, there are a number of intermediate steps in the road weather data delivery process that either formulate the data as new parameters or recompose the raw information into a more readily usable format.

A source may be a starting place where data are observed or generated, such as ESS observations, numerical weather model output, or maintenance vehicle treatment actions. A source may also be reformatted data or new resources derived from multiple data elements to create new services (e.g., forecasts, watches/warnings, advisory messages). Modified data formats are designed to meet the specific needs of the decision-maker consumer.

The flow of information in Figure 1 emphasizes the role *Clarus* plays in the transfer process. The points where the road weather data reaches the end users are denoted with circles and represent Road Weather Baseline Quality Assessment Points. Points where assumptions must be made by the intermediate data users about the quality of the data are also highlighted. These are the points in the flow where data quality has a fundamental influence on the quality of the road weather information reaching the end user; that is, the use by a weather service provider assumes the data is of acceptable or high enough quality to pass the data or create a reformatted product. The confidence of the intermediate users directly relate to their assumptions about the data quality at these points.

The process of Baselining Current Road Weather Information actually occurs at the bottom of the diagram in Figure 1 where the open red circles exist. The raw weather and pavement observations are input values at the top of the diagram. Essentially all of the raw data is modified or reconfigured before users gain access to the data from Secondary Sources. The Intermediary Sources are primarily the recipients of the raw data and these sources become the primary providers of the road weather information that is being evaluated in this study. How these Intermediary Sources package and deliver the raw road weather data significantly impacts the way end users evaluate the quality of road weather information. This fundamental construct influences many factors in the establishment and interpretation of the road weather information baseline process discussed in the remainder of this report.

Figure 1. Illustration of the processes involved in the transfer of raw road weather data, value added data, and decision guidance to users.



Definitions Figure 1

The term source has dual meanings that are applicable in this study. A source can be a starting place or foundation; it can also be an informer or spokesperson. The starting places of road weather information are the roadside weather, pavement conditions, and traffic observations along with forecasting guidance from other origins. This we term the **primary source**. Another source of road weather information is the method or technology used as an informer to the traveler or driver such as 511, DMS, HAR, etc. We term this the **secondary source**. Weather service providers serve as **intermediary sources** to transportation system operators by creating road weather forecasts and decision support.

Identification of Weather Service and Road Weather Service Providers

An important objective of this project was to identify the road weather data and information sources available within the road weather community. Task 2.1 of the study involved the identification of current stakeholders in the weather enterprise, and the isolation of those entities in the weather enterprise that provide products and services supporting the road weather community. This effort involved the canvassing of available publicly listed information sources to prepare a comprehensive list of weather providers.

An initial comprehensive list of weather service providers was filtered to remove weather providers demonstrating a marginal relationship to the weather provider enterprise and/or had no relevance to the road weather user community. In the scan of providers, 192 weather service providers were identified with only 14 classified as road weather service providers. The list of 14 disregards companies who provide only instrumentation products, no forecasting or information services, and those companies that employ their own meteorologists to provide forecasting and weather consulting for internal use only. This constitutes 7.3% of the entire weather service provider community. All providers are listed and classified in Appendix A.

The road weather information user community was considered to include two general categories of users. The first was the road transportation agencies that provide direct support to the transportation infrastructure and support for the traveling public through the use of road weather products and services. This group primarily included state transportation divisions such as maintenance organizations and traffic management. The second road weather information user community was focused on those entities that provide direct support for travelers.

Using these definitions of the road weather information user community, a comprehensive scan was made to identify the information provided to each and to collect basic characterization information.

The research team performed a review of literature from TRB, state department of transportation studies, and university research reports. Particular benefit was gained in a review of a study completed for the Utah Department of Transportation (UDOT) by the Western Transportation Institute (WTI) (i.e. “Evaluation of the UDOT Weather Operations/RWIS Program: Phase I”, published July 2007). In the UDOT study, a survey of road weather service providers was conducted by WTI that provided significant content relevant to the present scanning activity. The literature review of previous and/or ongoing FHWA RWMP projects yielded a limited amount of information. The dominant source of information was acquired through direct review of state agencies and the services they acquire and/or use.

In the scanning of road weather content utilized by transportation agencies, a particular focus was directed to the availability and use of road weather observations. This information was

primarily focused on ESS data collected and utilized by state agencies. Additional services scanned include the road weather forecast information; for example, pavement conditions, pavement temperature, precipitation timing, etc. Besides road weather observations and forecasts, the sources and types of non-road weather observations and forecasts used by transportation agencies were collected. This information most often includes the use of weather radar, weather satellite, surface observations, and related resources that are often used in road weather decision-making.

For the scan of road weather services available to the traveling public, considerable effort was expended to review public web pages and the direct use of advanced traveler information system services provided by telephone; for example, 511 and other agency provided toll and toll-free telephone numbers.

The consolidation of the scan information is provided in Appendix B. For this effort, the elements of ESS data that were generally consistent across the agencies were not included in the tables to reduce the size of the tables. This was deemed prudent as all state departments of transportation utilize these data at varying levels except for the Mississippi Department of Transportation (DOT). The ESS content found to be generally uniform is provided in Appendix C.

Road Weather Information Characterization

An objective of the Baselining study was the determination of the perception of the end users towards the quality and value of the road weather information. In Task 2.2 of the study, the instrument developed to assess this receptivity and organize the results was the Quality Attribute Matrix (QAM).

PRODUCT TYPES, ELEMENTS, AND QUALITY ATTRIBUTES

The QAM assessment tool was developed around Product Types (packages of information representing the discrete resources that have evolved in the transfer of weather content from the meteorological community to the end user transportation community) that decision makers receive from various weather service providers (public and private). These "standard" packages typically contain observed or forecasted values for a number of distinct weather parameters. Transportation users normally need information on a number of discrete weather elements, and they generally understand which weather support packages contain the elements desired.

An additional effort in the baseline development process was the assessment of the quality of the discrete weather elements or weather representations derived from the raw elements (e.g., watches and warnings are considered a road weather element in this study even though it is a resource derived from several raw observed and forecasted meteorological elements). The intent of the "element approach" was the desire to ascertain the relative quality of the various basic weather parameters (reported, forecasted, or derived) used by transportation users to support their subsequent decision support needs. The Element approach fuses information resources from different time scales into one evaluation of the quality of the specific parameter. The Product Types and discrete Elements are listed in Table 1.

Table 1. Product Type and Element Categories Used in the Survey

Road Weather Information	
Product Types	**Elements**
Camera Images	Precipitation start time
Current Conditions	Pavement temperature
Flood Warning	Probability of deck and road frost
History Listing	Percent probability of deck and road frost
Local / Regional Forecast	Probability of precipitation
MDSS	Pavement condition
Pavement Forecast	Dew point temperature
Regional Map of Road Weather Parameter	Flow rate
Road Condition Report	Cloud cover
Road Weather Alert	Freeze point temperature
Route Specific Forecast	Air temperature

Verbal Forecast	Chemical concentration
Watches and Warnings	Dense fog advisories
Weather History (Site Specific)	Flood potential
Weather Summary	Maximum Air Temperature
Zone Forecast	Precipitation type
	Minimum Air Temperature
	Flood watches/warnings
	Flood stage
	Estimated amount of precipitation in ranges
	Probability of precipitation types
	Precipitation end time
	Rain accumulation
	Rain amount or liquid equivalent amount
	Rain rate
	Relative humidity
	River stage
	Road closures
	Road conditions by highway segment
	Severe thunderstorm watches/warnings
	Snow accumulation
	Snow Amount
	Snow rate
	Treatment recommendation
	Type of precipitation or Y/N precipitation indicator
	Type of Weather
	Type of weather & precipitation
	Type of weather condition
	Visibility
	Wind advisories/watches/warnings
	Wind direction
	Wind gust
	Wind speed
	Winter advisories/watches/warnings

The Product Type QAM provides a framework for the evaluation of product quality and value, as viewed from the end user's perspective. It includes a summary of the following attributes for each of the Product Types:

1. Accuracy/precision assessed by the user;
2. The completeness of the information;
3. The currency/latency of the information (relative to when they are received by the user);
4. Relevance to user's needs;

5. Timeliness of the information and reliable delivery of the required information; and,
6. Ease of use of the information to be accessed and applied to the required situation, including the visual effectiveness of the data presentation.

The format of QAM is presented in Appendix D. The specific definitions of the heading columns include:

- **Road Weather Information Class:** Type of weather information: W = weather information only; RW = weather and pavement condition information
- **Road Weather Information Type:** Name given to the product type
- **Description:** Information contained in the product type
- **Provider:** The source of the product type: NWS = National Weather Service; DOT = Department of Transportation; STWSP = surface transportation weather service provider
- **Informer:** Agent delivering the product
- **Delivery format:** Mechanism for transferring the product to the end user
- **Consumer:** The end user
- **Road Weather Elements:** The weather or pavement condition elements in the product type
    - CC = cloud cover
    - Cond = representation of the snow, ice, water, and deicer layer on the road
    - C% = percentage of chemical
    - DP = dew point temperature
    - FP = freeze point temperature of road surface layer
    - P = precipitation type
    - Pamt = liquid precipitation accumulation
    - PavT = pavement surface temperature
    - POP = probability of precipitation
    - Prate = intensity of liquid precipitation
    - P(Y/N) = precipitation type as YES or NO
    - RC = road condition reported by the DOT
    - Samt = snow accumulation
    - Srate = intensity of snowfall
    - T = temperature
    - Tmax = maximum temperature
    - Tmin = minimum temperature
    - TR = treatment recommendation
    - WD = wind direction
    - Wgust = wind gust
    - Winds = a textual combination of wind speed, wind direction, and gusts
    - WS = wind speed
    - Wx = type of present weather or precipitation type
    - %Frost = probability of frost conditions
- **Quality Attributes:** Described in previous paragraph
- **Composite Measure:** A weighted average of all quality attribute responses
- **Scan Reference:** Source of the quality attribute data in the QAM

- **Cost:** Users' perceived cost of acquiring the data: 1 = cost to agency; 0 = free
- **Perceived Benefit to Cost:** 1= great benefit; 0 = no benefit

A slightly modified version of the QAM was created for the Element quality assessment.

The questions that would provide the information for the QAM were consolidated into a Quality Attribute survey instrument that addressed both the quality of road weather packages and the quality of the discrete weather elements.

The goals of the survey instrument were to sample users according to their use of weather information in particular road weather management strategy actions (i.e., advisory, control, and treatment). The survey was divided into three sections. The first section collected general information on the respondent for use in survey analysis, and to gain an understanding of the respondent's experience and awareness of road weather. The second section contained questions related to individual road weather elements. Finally, the third section contained questions related to road weather packages or weather product types.

The majority of the questions solicited responses using a five-point Likert scale to permit a numerical evaluation of user responses. Additional questions were asked with answers requiring specific categorical responses.

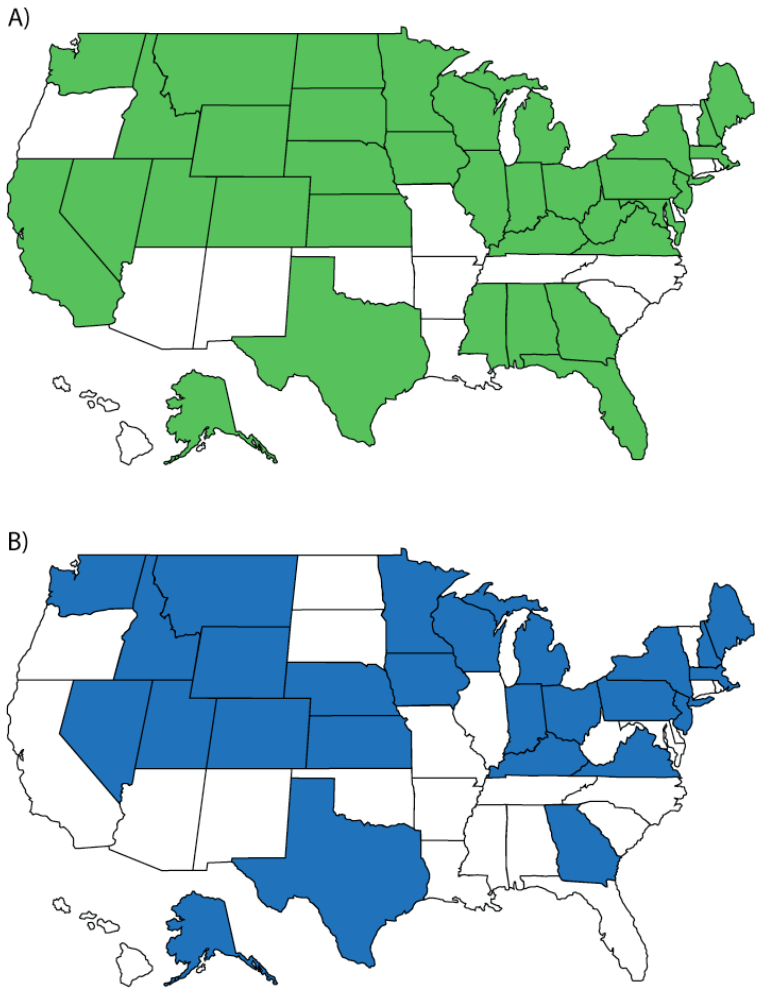
The study team feels that mental assessment of quality is done on a continuous spectrum ranging from no-quality to a maximum perceived quality. In the Baseline survey, it was assumed that all respondents in the sample were in a position to assess quality. People have difficulty transforming their mental impression of quality into the specific point on the continuum of possible quality values, but they can express their comprehension of quality in discrete categories that best represent the segment of the entire range that covers their assessed quality rank. Because people rebel against test queries offering too many options, the Likert categories were set to five to capture quality measure responses. To represent the discrete segment responses to the quality continuum, the research team opted to use common variance statistics. The transformation of discrete response values to a continuous representation is a common practice of variance statistics. The details of the data transformation can be found in the "Characterization of Road Information" report.

A commercial web-survey tool was employed to apply the survey instrument. This tool permitted respondents to skip questions that were not applicable to their experience. The survey instrument included a capability to provide a free form response to every question. Additionally, there were separate surveys for respondents in each of the three road weather management responsibility areas. The separate surveys were necessary due to the variability in road weather utilization across the advisory, control and treatment management strategies. While this resulted in a fracturing of the overall respondent pool, it was deemed necessary to better qualify the road weather characteristics in terms of the end user's responsibilities.

The acquisition of input from the DOT end user community was done in two ways: phone interviews and the survey instrument. The project team contacted individuals in each of the

road weather management strategy areas (Advisory, Control, and Treatment) in thirty-five (35) state Departments of Transportation to identify their willingness to participate in the QAM development. An awareness of varying types of road weather conditions across differing geographical areas was considered in identifying these DOTs. This resulted in a diverse geographical distribution of DOTs in the survey efforts (Figure 2A). Of the original list of DOTs agreeing to complete the survey, twenty-six (26) DOTs completed the survey (Figure 2B).

Figure 2. Map A indicates contacted states; Map B indicates participating states



In the development of the QAM for Product Types, the term 'Importance' was used in two different ways in the analysis: one associated with the quality attribute survey and the other dealing with the perceived worth of the individual elements that are contained within a given product. To differentiate the two meanings in this report, the former were called Attribute Importance and the latter named Element Importance. Attribute Importance reflects a critical character of a user's quality response. This ensures quality responses for attributes that are very important to the user in the evaluation of that particular product type receive greater

weighting in the overall quality rating of that product type. The Element Importance delineated which of the elements within the product type were of greatest value to the respondent. The QAM facilitated the entry of the quality and attribute importance responses for each Attribute/Product Type pair. The Quality and Attribute Importance averages for a given Product Type were placed on separate rows. The number of responses incorporated in the quality and attribute importance averages were added as the third row within each quality attribute cell. In the QAM results for Product Types in Appendix D, the values in the light yellow/cream-colored cells are the Quality results for a given Product Type. The numbers in cells directly below that row with no fill are the attribute importance computations. These attribute importance average values are above the number of survey responses for the quality attributes for that product type. The scale for both of the Quality and Attribute Importance computations were Likert scale values that ranged from 1 (very low) to 5 (very high). Appendix E contains the QAM results for Elements. The number of survey responses in the Element QAM is in the columns to the right of the attribute section rather than in the stacked format used in the Product Type QAM.

QUALITY ATTRIBUTE ANALYSIS - GENERAL FINDINGS AND CONCLUSIONS

An important conclusion from the quality attribute analyses and comparisons of the quality attribute average rankings across the three road weather management strategies is that each management strategy brings varying road weather expertise and focus by the personnel engaged in these activities. Whether this difference is accounted for by the road weather experience level of the respondent, or whether the result is dependent upon operational successes and/or challenges experienced in the past by the respondent relative to road weather situations involving the various road weather elements, the assessment of quality of road weather information is a human factors issue that is not completely measurable from the responses to a survey instrument. Follow-up interviews with several respondents provided little clarification of the above issue and this factor suggests a future area of investigation that should be considered.

Highlighting a number of the general findings in this study provides an important pathway for consideration of how to apply the baseline characteristics of road weather information for applications to improve the quality of road weather information and for future applications of the baseline data in follow-on evaluations. The results of quality assessment process should provide transportation agencies, environmental sensor manufacturers, and road weather service providers important information to support quality improvements in road weather information.

The results derived from this study provide valuable insights into the processes used by users in ascribing quality measures to the road weather information in the user's decision-making process. In general, the characterization of road weather quality attributes indicates that the road weather information received to support treatment, advisory, and control road weather management strategies is relevant and reasonably complete but the accuracy or precision of the information received could be improved. A summary of several significant findings extracted from the results in the QAM is listed in Table 2.

Table 2. Summary of General QAM Findings

Characterization of Road Weather Information General Findings
The higher quality averages for the Relevance attribute and lower quality averages for the Accuracy/Precision attribute indicate that users see many of the road weather elements as relevant to their operational decisions but not as accurate or precise as they would like.
The Ease of Use (EOU) attribute had the highest variance of all of the attributes indicating that users assess some elements as very easy to use and others as complex. The elements that received high EOU quality scores were primarily raw weather parameters and the elements that received low marks were predominantly derived road weather elements or "abstract" road weather parameters (chemical concentration, freeze point temperature, road conditions by segment). It was surprising to see elements such as severe thunderstorm watches/warnings and treatment recommendations at the bottom of the EOU list.
Often users perceive that some road weather product types do provide quality information; however, for their purposes these product types do not support their operational requirements and the attribute importance ranking is lower than the average. This results in a lower composite measure ranking for that product type.
Quality of road weather information appears to be biased by the worth of a particular road weather element resulting in a potential misrepresentation of the overall ranking of the quality of the road weather element.
For a number of road weather elements there is an inverse relationship between quality of an element and the importance of the element ranked within the product type section of the survey.
The quality attributes that tend to drive down the average quality values of several road weather elements are Accuracy/Precision and Ease of Use.
Differences between user expectations and quality performance may relate to issues associated with the specific element such as the measurement characteristics of instrumentation, the inadequacy of science to generate accurate forecasts, and the presentation of road weather elements in a format that are abstract or difficult to interpret.
Human factors have a significant influence on the manner by which users respond to the quality of road weather information. Techniques are needed to mitigate or at least minimize the effect of personal valuations of road weather information.
While the road weather characterization indicates a positive average quality for most road weather elements, the details of the individual quality attributes for each element provides guidance on aspects where the quality may be improved.

The results, within constraints identified earlier relative to human factors, are expected to be repeatable in the future. The information provided in this report represents a reasonable assessment of the current state-of-the-practice, and the details found in the individual quality attributes for each road weather element indicate opportunities for improvement in the observation, processing, and delivery of road weather elements and for improvements in the generation of derived road weather products. It is expected that while a variation in individual quality attributes is to be expected in future surveys, the aggregation of the quality

attributes are expected to provide a consistent comparative measure of road weather quality over time.

Current baseline characterization of road weather information

The two classes of road weather information, *Product Types* and *Road Weather Elements*, resulted in separate baseline characterizations for each class. A complete and detailed analysis of the resulting QAMs for each class is available in the accompanying full study report. Below is a summary of the findings for selected analyses.

Baseline Characterization of Road Weather Information Elements

The composite of all survey responses of the Road Weather Element attributes (Table 3) indicates the key variance parameters for each of the six quality attributes. These values were derived from the Element QAM shown in Appendix E. Within each quality attribute are sub-columns for Advisory strategies (A), Control strategies (C), and Treatment strategies (T). Quality attribute values for the individual Road Weather Elements clustered around the mean or median of 3.8 on a Likert scale, where the minimum value was 1 (very low quality) and the maximum value was 5 (very high quality). Most of the Road Weather Elements showed consistency in their average quality attributes.

Table 3. Aggregate quality attribute statistics for the Road Weather Elements as evaluated by road weather management strategy classification. The road weather management strategies are denoted by: Advisory (A), Control (C), and Treatment (T).

Quality Attributes		Maximum Value	Minimum Value	Mean	Median	Standard Deviation
Composite Measure	A	4.1	3.0	3.4	3.4	0.3
	C	4.4	2.3	3.8	3.8	0.3
	T	4.3	2.9	3.8	3.9	0.2
Accuracy / Precision	A	4.2	3.0	3.5	3.5	0.3
	C	4.5	2.0	3.9	4.0	0.4
	T	4.2	2.4	3.6	3.6	0.3
Completeness	A	4.1	2.4	3.3	3.3	0.4
	C	4.3	2.5	3.5	3.5	0.3
	T	4.3	2.9	4.0	4.1	0.3
Relevance	A	4.3	2.8	3.2	3.2	0.4
	C	4.8	1.7	3.9	4.0	0.6
	T	4.6	2.8	4.1	4.2	0.4
Currency /	A	4.0	3.2	3.5	3.5	0.2

Latency	C	4.3	2.5	3.3	3.3	0.5
	T	4.4	3.5	3.9	3.9	0.2
Timeliness / Reliability	A	4.0	2.9	3.4	3.4	0.3
	C	4.8	3.0	4.2	4.3	0.4
	T	4.3	3.1	3.8	3.8	0.2
Ease of Use	A	4.1	4.1	3.5	3.5	0.3
	C	4.8	2.3	4.0	4.0	0.5
	T	5.0	2.1	3.7	3.8	0.5

Relationships between Elements and quality attribute responses proved difficult using the raw quality attribute values, so the attribute average values were placed in descending order for each quality attribute category and the rankings were color coded into quartiles. The specific road weather elements from the Treatment category showed distinct patterns when ranked by these quartiles (Table 4). Pavement temperature, road closures, flood watches and warnings, and weather parameters were viewed as the highest quality elements (top quartile). Experience with treatment activities suggests these are trusted elements within a treatment strategy. Meanwhile, cloud cover, chemical concentration, and treatment recommendation received low quality marks (bottom quartile).

Elements in the top and bottom quartiles were consistent across almost all attributes, and will serve as good measures for benchmarking future assessments for the Treatment strategy.

Table 4. Treatment attribute rankings for Road Weather Elements listed in colors by quartiles; 1st quartile (green), 2nd quartile (blue), 3rd quartile (yellow), and 4th quartile (orange).

Road Weather Element	RANK							Average Composite Attribute Score
	Average Rank	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	
Pavement temperature	1	1	1	1	6	4	3	4.3
Air temperature	2	2	2	10	1	9	2	4.2
Road closures	3	3	25	18	3	31	1	4.2
Wind gust	4	13	5	2	7	5	7	4.1
Wind speed	5	14	6	3	8	6	8	4.1
Dew point temperature	6	5	14	26	2	10	14	4.1
Wind direction	7	6	15	22	13	12	9	4.0
Flood watches/warnings	8	11	4	37	17	2	5	4.0
Relative humidity	9	8	10	17	10	11	15	4.0
Precipitation type	10	10	7	6	18	30	12	4.0
Minimum Air Temperature	11	15	12	33	11	32	6	4.0

Snow accumulation	12	26	23	8	14	28	16	3.9
Maximum Air Temperature	13	16	13	36	12	33	13	3.9
Type of precipitation or Y/N precipitation indicator	14	18	36	14	9	13	19	3.9
Precipitation end time	15	38	9	16	22	15	17	3.9
Flood potential	16	29	31	38	4	1	22	3.9
Rain amount or liquid equivalent amount	17	24	18	21	32	17	23	3.9
Rain accumulation	18	25	20	23	33	14	21	3.9
Probability of precipitation	19	12	11	32	25	21	28	3.9
Snow rate	20	37	22	12	30	41	4	3.9
Type of weather & precipitation	21	18	27	4	20	34	31	3.9
Type of weather condition	22	9	26	24	23	35	32	3.9
Precipitation start time	23	32	21	7	28	27	25	3.8
Probability of precipitation types	24	19	8	35	26	22	29	3.8
Type of Weather	25	20	28	13	21	25	33	3.8
Estimated amount of precipitation in ranges	26	33	39	25	24	16	10	3.8
Snow Amount	27	30	32	9	29	38	18	3.8
Road conditions by highway segment	28	7	16	5	43	18	40	3.8
Winter advisories/watches/warnings	29	4	3	20	35	44	34	3.8
Visibility	30	40	19	19	31	19	26	3.8
Wind advisories/watches/warnings	31	17	17	30	34	39	30	3.8
Probability of deck and road frost	32	27	24	27	40	37	27	3.8
Pavement condition	33	35	35	34	16	29	20	3.8
Rain rate	34	43	33	31	27	26	24	3.8
Percent probability of deck and road frost	35	31	34	11	19	36	36	3.8
Freeze point temperature	36	42	37	15	15	7	39	3.7
Treatment recommendation	37	41	40	29	37	3	37	3.7
Severe thunderstorm watches/warnings	38	23	29	28	36	40	38	3.7
Flood stage	39	28	30	41	38	20	35	3.6
Dense fog advisories	40	36	41	39	44	23	11	3.6
River stage	41	34	42	42	5	24	43	3.5
Cloud cover	42	21	43	40	41	42	41	3.4
Flow rate	43	39	38	44	39	8	42	3.4
Chemical concentration	44	44	44	43	42	43	44	2.9

The inconsistency of second and third quartile rankings for each strategy indicates that each "average quality" element has its own unique rating characteristic. These quality "fingerprints" imply unique environmental factors influencing the users' perspective and represent markers for change in future baseline investigations.

Similar attribute rankings for the Control and Advisory strategies are shown in Tables 5 and 6. The elements selected for analyses within these strategies differed from the Treatment

strategy; however, key elements in the top and bottom quartiles of the two additional tables demonstrate a similar consistency across all attributes; whereas, elements falling in quartiles 2 and 3 were more inconsistent.

Table 5. Control attribute rankings for road weather elements listed in colors by quartiles; 1st quartile (green), 2nd quartile (blue), 3rd quartile (yellow), and 4th quartile (orange).

Road Weather Element	RANK							Average Composite Attribute Score
	Attribute Average	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	
View of the road	1	6	13	1	1	1	1	4.4
View of the weather	2	11	14	2	2	2	2	4.3
Severe thunderstorm watches/warnings	3	1	2	11	3	21	16	4.1
Road closures	4	3	1	12	9	22	4	4.1
Dense fog advisories	5	4	6	5	19	3	5	4.0
View of the traffic	6	23	24	3	7	4	11	4.0
Wind direction	7	7	15	13	8	5	12	4.0
Wind gust	8	8	16	14	9	6	13	4.0
Wind speed	9	9	17	15	10	7	14	4.0
Air temperature	10	10	5	21	20	8	3	4.0
Wind advisories/watches/warnings	11	5	18	16	4	23	27	3.9
Pavement condition	12	12	7	6	27	10	6	3.9
Road conditions by highway segment	13	13	3	17	21	11	17	3.9
Flood watches/warnings	14	30	4	25	5	24	18	3.9
Winter advisories/watches/warnings	15	2	19	7	6	29	28	3.9
Probability of precipitation types	16	24	8	8	12	25	19	3.9
Pavement temperature	17	14	25	10	22	18	15	3.8
Percent probability of deck and road frost	18	15	20	18	23	12	7	3.8
Probability of precipitation	19	16	21	9	13	26	20	3.8
Snow accumulation	20	28	9	19	24	13	21	3.8
Visibility	21	27	22	4	28	14	22	3.8
Type of weather	22	17	10	26	29	27	8	3.7
Type of weather & precipitation	23	18	11	27	30	28	9	3.7
Relative humidity	24	19	26	29	14	9	23	3.7
Rain accumulation	25	25	27	22	15	19	25	3.7
Snow rate	26	31	23	20	25	15	24	3.7

Dew point temperature	27	20	12	30	31	16	10	3.7
Rain rate	28	29	28	23	16	20	26	3.7
Minimum air temperature	29	21	30	28	17	17	29	3.6
Estimated amount of precipitation in ranges	30	26	29	24	18	30	31	3.5
Maximum air temperature	31	22	31	31	26	31	30	3.3
Cloud cover	32	32	32	32	32	32	32	2.3

Table 6. Advisory attribute rankings for Road Weather Elements listed in colors by quartiles; 1st quartile (green), 2nd quartile (blue), 3rd quartile (yellow), and 4th quartile (orange).

Road Weather Element	RANK							Average Composite Attribute Score
	Attribute Average	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	
Road closures	1	1	1	1	1	1	1	4.1
Road conditions by highway segment	2	2	2	2	3	4	2	3.7
Visibility	3	4	3	3	2	5	3	3.6
Minimum air temperature	4	3	7	4	5	6	6	3.5
Flood watches/warnings	5	6	8	9	6	2	7	3.5
Dense fog advisories	6	7	12	5	7	7	4	3.5
Maximum air temperature	7	8	10	7	4	3	9	3.4
Wind speed	8	11	5	6	8	9	5	3.4
Winter advisories/watches/warnings	9	9	9	10	9	8	8	3.4
Severe thunderstorm watches/warnings	10	10	6	11	12	11	13	3.3
Wind direction	11	14	11	8	10	12	11	3.3
Type of weather	12	5	4	12	15	14	12	3.2
Estimated amount of precipitation in ranges	13	13	14	13	14	10	10	3.2
Wind advisories/watches/warnings	14	12	13	15	13	15	14	3.1
Probability of precipitation	15	15	15	14	11	13	15	3.0

A side-by-side comparison of the rankings from the three strategies (Table 7) shows some consistency across strategies, but the differences between the results from the different strategies are more noticeable. This is likely related to the differences in responsibilities associated with the implementation of the different road weather management strategies.

Table 7. Comparison of average quality attribute rankings of individual Road Weather Elements between treatment, control, and advisory road weather management strategies; 1st quartile (green), 2nd quartile (blue), 3rd quartile (yellow), and 4th quartile (orange).

ROAD WEATHER ELEMENT	Treatment		Control		Advisory	
	Rank	Score	Rank	Score	Rank	Score
Pavement temperature	1	4.3	17	3.8		
Air temperature	2	4.2	10	4.0		
Road closures	3	4.2	4	4.1	1	4.1
Wind gust	4	4.1	8	4.0		
Wind speed	5	4.1	9	4.0	8	3.4
Dew point temperature	6	4.1	27	3.7		
Wind direction	7	4.0	7	4.0	11	3.3
Flood watches/warnings	8	4.0	14	3.9	5	3.5
Relative humidity	9	4.0	24	3.7		
Precipitation type	10	4.0				
Minimum Air Temperature	11	4.0	29	3.6	4	3.5
Snow accumulation	12	3.9	20	3.8		
Maximum Air Temperature	13	3.9	31	3.3	7	3.4
Type of precipitation or Y/N precipitation indicator	14	3.9				
Precipitation end time	15	3.9				
Flood potential	16	3.9				
Rain amount or liquid equivalent amount	17	3.9				
Rain accumulation	18	3.9	25	3.7		
Probability of precipitation	19	3.9	19	3.8	15	3.0
Snow rate	20	3.9	26	3.7		
Type of weather & precipitation	21	3.9	23	3.7		
Type of weather condition	22	3.9				
Precipitation start time	23	3.8				
Probability of precipitation types	24	3.8	16	3.9		
Type of Weather	25	3.8	22	3.7	12	3.2
Estimated amount of precipitation in ranges	26	3.8	30	3.5	13	3.2
Snow Amount	27	3.8				
Road conditions by highway segment	28	3.8	13	3.9	2	3.7
Winter advisories/watches/warnings	29	3.8	15	3.9	9	3.4
Visibility	30	3.8	21	3.8	3	3.6
Wind advisories/watches/warnings	31	3.8	11	3.9	14	3.1
Probability of deck and road frost	32	3.8				
Pavement condition	33	3.8	12	3.9		
Rain rate	34	3.8	28	3.7		
Percent probability of deck and road frost	35	3.8	18	3.8		
Freeze point temperature	36	3.7				

Treatment recommendation	37	3.7				
Severe thunderstorm watches/warnings	38	3.7	3	4.1	10	3.3
Flood stage	39	3.6				
Dense fog advisories	40	3.6	5	4.0	6	3.5
River stage	41	3.5				
Cloud cover	42	3.4	32	2.3		
Flow rate	43	3.4				
Chemical concentration	44	2.9				

BASELINE CHARACTERIZATION OF ROAD WEATHER INFORMATION PRODUCTS

The Product Type QAM quality attribute averages (Table 8) are slightly higher than those from the Element survey. These values were derived from the Product Type QAM shown in Appendix D. The averages indicate a "high" quality rating for all management strategies and suggest a general acceptance for the quality of the information products. The incorporation of road weather elements within the product type packages seems to create a higher quality or more acceptable resource.

The QAM composite measure attribute rankings for the Treatment strategy (Table 9) show the same consistency in the highest and lowest quartiles as seen in the element analysis. One noticeable inconsistency occurs in the Currency/Latency and Ease of Use rankings between Product Types, which suggests further assessment and monitoring are needed over time. The low ranking of Currency/Latency for the Road Condition Report product type may indicate users see an issue with the methodology of transferring road condition reports from the field to the users. Also, the low ranking of Ease of Use for the Weather History product type indicates the site-specific data presentation mode causes users problems and may be an area for improvement.

Table 8. Aggregate quality attribute statistics for the Road Weather Product Types as evaluated by road weather management strategy classification. The road weather management strategies are denoted by: Advisory (A), Control (C), and Treatment (T).

Quality Attributes		Maximum Value	Minimum Value	Mean	Median	Standard Deviation
Composite Measure	A	4.6	3.9	4.2	4.1	0.3
	C	4.3	3.2	3.8	3.8	0.5
	T	4.5	3.4	3.9	3.9	0.4
Accuracy / Precision	A	4.5	3.9	4.2	4.1	0.3
	C	4.5	3.0	4.0	4.0	0.6
	T	4.3	3.0	3.8	4.0	0.4
Completeness	A	4.5	3.9	4.1	3.9	0.3
	C	4.8	3.0	3.6	3.3	0.7
	T	4.5	3.0	3.8	3.8	0.4
Relevance	A	4.5	3.9	4.1	4.1	0.3
	C	4.3	3.0	3.7	3.8	0.5
	T	4.5	3.0	3.9	3.9	0.4
Currency / Latency	A	4.8	3.6	4.1	4.1	0.5
	C	4.5	3.0	3.6	3.7	0.7
	T	4.7	3.0	3.8	3.8	0.5
Timeliness / Reliability	A	4.8	3.9	4.2	4.0	0.4
	C	4.0	3.0	3.5	3.7	0.5
	T	4.8	3.3	4.0	4.1	0.4
Ease of Use	A	4.8	3.8	4.2	4.2	0.4
	C	4.3	3.3	4.0	4.0	0.4
	T	4.4	3.6	4.0	4.1	0.3

Table 9. Treatment attribute rankings for Road Weather Products listed in colors by quartiles; 1st quartile (green), 2nd quartile (blue), 3rd quartile (yellow), and 4th quartile (orange). Red denotes lowest rank determined.

Road Weather Product Type	RANK							Average Composite Attribute Score
	Composite Measure	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	
MDSS	1	6	1	1	1	1	5	4.3
Pavement Forecast	2	5	4	2	5	4	1	4.2
History Listing	3	3	2	4	4	6	4	4.2

Regional Map of Road Weather Parameter	4	1	3	5	3	3	2	4.1
Current Conditions	5	2	5	3	2	2	3	4.1
Weather Summary	6	8	8	7	8	7	7	4.1
Road Condition Report	7	7	7	6	10	9	6	4.0
Weather History (Site Specific)	8	4	6	9	6	5	13	4.0
Watches and Warnings	9	9	10	8	7	10	9	4.0
Flood Warning	10	10	9	10	9	11	12	4.0
Local / Regional Forecast	11	11	11	12	11	12	11	4.0
Road Weather Alert	12	12	12	11	12	13	8	3.9
Verbal Forecast	13	13	13	13	13	8	10	3.9

The attribute rankings for the Control and Advisory strategies (Tables 10 and 11) show similar relationships as those for the Treatment strategy.

Table 10. Control attribute rankings for Road Weather Products listed in colors by quartiles; 1st quartile (green), 2nd quartile (blue), 3rd quartile (yellow), and 4th quartile (orange). Red shading denotes lowest ranking.

Road Weather Product Type	RANK							Average Composite Attribute Score
	Composite Measure	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	
Camera Images	1	1	1	3	1	1	2	4.3
Road Condition Report	2	2	2	1	3	3	1	4.3
Watches and Warnings	3	3	4	2	2	2	3	3.8
Zone Forecasts	4	4	3	4	4	4	5	3.3
Pavement Forecast	5	5	5	5	5	5	4	3.2

Table 11. Advisory attribute rankings for Road Weather Products listed in colors by quartiles; 1st quartile (green), 2nd quartile (blue), 3rd quartile (yellow), and 4th quartile (orange).

	RANK							
Road Weather Product Type	Composite Measure	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	Average Composite Attribute Score
Route Specific Forecast	1	1	1	1	1	1	1	4.6
Road Condition Report	2	2	2	2	2	3	3	4.2
Watches and Warnings	3	3	3	3	3	2	2	4.1
Zone Forecast	4	4	4	4	4	4	4	3.9

Task 3 Quality Analysis Tracking and Comparison Recommendations

The results of Task 3 provide a recommendation for future pathway toward the application of the baseline characteristics, and recommends strategies to monitor change. A key element of this study is the determination of how changes in users' perception of road weather information may be reflected through the valuation of its quality attributes. Future applications of road weather information performance measures will need to be accomplished in a manner that provides a clear understanding of the state of practice and best practices. Fundamental to this is defining what constitutes an improvement in quality over time. Parameters for each of the quality measures must be such that their change is measurable and the introduction of *Clarus* or other advances in technology do not alter their character or require new metrics.

For information users, the best assessment of quality will come from transportation agencies who use the data for their decision-making and provide the data to the traveling public. Present limitations in quality of certain road weather elements, as noted in this baseline study, have resulted in reservation and likely reduction in the use of these road weather information types among transportation agencies. A prime example of this is the low assessment of quality of chemical concentration information and the reduced emphasis being placed by some transportation maintenance agencies in using this data to make decisions, or in some situations the continued collection of the chemical concentration sensor data.

Developing confidence in road weather information of all types requires assurance of the quality of the basic data. Present observational data programs such as the NOAA MADIS (Meteorological Assimilation and Data Ingest System) project and the Federal Highway Administration (FHWA) Road Weather Management Program's *Clarus* Initiative are

working to establish mechanisms to support improved quality checking of weather and road weather data. Where members of the road weather service provider community do not have a quality assurance program in place, it will be important that such programs be implemented to provide confidence that the products and services they provide are meeting expected industry levels of performance. Further, the availability of quality check flags to transportation agencies maintaining their own road weather observation systems will require that these agencies incorporate methods to apply these quality check flags to their calibration and maintenance programs supporting their road weather observation systems.

How well these activities are adopted and implemented will largely determine the change that will occur in the quality characteristics of road weather information. The ongoing monitoring of road weather information quality will provide a road weather community "report card" on the state of the quality of road weather information and where improvements can yet be made. Performing ongoing quality monitoring of road weather information will not be a simple process and will require a commitment within the community and leadership by the federal government.

Various issues will need to be addressed to determine the most appropriate strategy for implementing an ongoing quality monitoring process. First, given the level of work required to complete the analysis and the need to appropriately identify real change that is taking place, it will be important to establish an appropriate time interval required to compare the present baseline characteristics of road weather information to future quality states. Next, it will be important to establish appropriate protocols to follow such that the methodologies are repeatable and provide real comparisons that are not diluted or distorted by changing technologies. Finally, it is necessary to understand the risks and caveats associated with performing such monitoring and setting appropriate expectations for monitoring the change in road weather information quality character. Each of these issues is discussed further in the following sections.

PERFORMANCE ANALYSIS TIME INTERVAL REQUIREMENTS

The perception of road weather quality is dependent upon technological advances that:

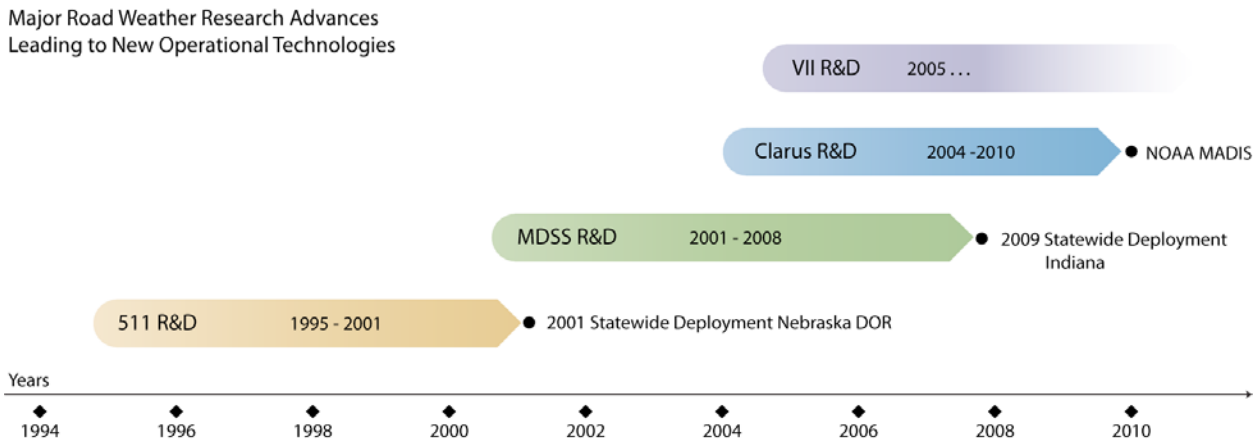
- Modify/enhance the measurement of the raw road weather elements;
- Create new road weather measurement or display tools;
- Improve the methods employed to transfer the data from source to the end user; or,
- Create unique solutions to present road weather data to the end user.

The improvement in the quality of road weather information over the past century has generally been derived from both gradual technological advances and rapid transitions in one or more of the technological support mechanisms. Gradual changes may be attributed to the ongoing improvements in instrumentation and the continual steady improvement in weather and road weather forecast accuracy. However, road weather has also benefited from the introduction of significant changes in the road weather information support structure. Some examples include the advent of numerical weather prediction in the 1950s, weather radar imagery following World War II, the development of Road Weather Information Systems

(RWIS) (especially with the introduction of pavement temperature) in the mid-70s, the explosion of personal computing and cellular communications in the 1990s, and Advanced Traveler Information Systems (511) around 2000. The influence of each of these significant infrastructure modifications occurred over a period of years and the transition from introduction through growth to maturation went through a characteristic sigmoid curve integration into our societal infrastructure similar to the common model of business development. Government programs (such as the expansion of the weather radar network) took place relatively quickly whereas systems that were integrated through a procurement process extended over a longer period of time. The RWIS program within state DOTs, for example, started its growth cycle in the early 1980s and moved into its maturity phase around 2000. Thus, the user's perception of road weather information is influenced by a broad spectrum of factors and the rate at which each influence modifies the assessment of quality tends to vary over time.

The road weather community has been in one of these significant technological growth periods during the past decade and a half (Figure 3). Much of this growth is attributable to a greater level of detail in road weather information products resulting from improved collection of weather and road weather data. The growth also came as a result of greater awareness within the surface transportation community of the benefits of road weather information to support road weather management strategies. However, the growth is not uniform across the nation nor is it linear in time. Rather, the advances have occurred in a somewhat stepwise progression with the benefits realized from these advances diffusing to DOTs and the traveling public in a similar stepwise manner. Thus, the specification of appropriate timing to capture quality variability in road weather information must be carefully considered. An interval that is too short could potentially show little to no growth from one characterization period to the next. This could lead to a perception of insufficient progress and have negative consequences on enthusiasm for continued development of new advancements in road weather information. An interval that is too great between performance analyses, while ensuring that the piecewise growth would be captured in the characterization relative to the baseline, could fail to demonstrate to DOT and federal funding sources that adequate progress is being made.

Figure 3. Growth of road weather technology over time



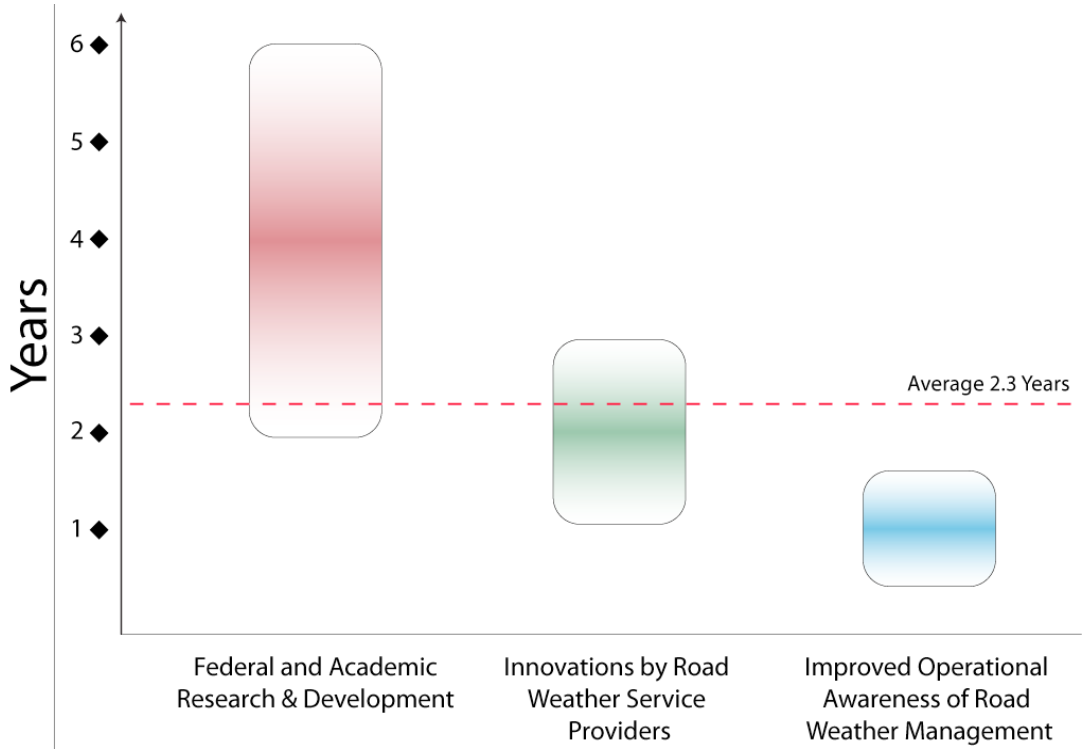
Using the frequency of major technological road weather initiatives as one measure for the frequency of advancement (Figure 3); these initiatives typically extend for a period of time ranging from two to six years with an average completion of a new initiative approximately every four years. With an added assumption that at the end of these initiatives the technology will be assimilated into operational decision-making and procedures in the road weather community, an appropriate performance analysis time interval based upon these initiatives would be between every two to six years.

Improvements in road weather information are also largely dependent upon the improvements within the road weather service provider community. These improvements are induced from various factors including, but not limited to, market competitiveness resulting in quality improvement in road weather products, more stringent quality requirements within DOT contract language with road weather service providers, and improved technology utilization by the road weather service providers and the DOTs in applying quality monitoring to raw and derived road weather information. While the latter may be strongly influenced by the aforementioned research and development road weather initiatives, they may also come from local DOT operational and private sector initiatives. The time scale for these benefits are likely realized at the time scale of the procurement of road weather services from one to three years.

The final factor to be considered in establishing a time interval for conducting performance analyses is associated with the human factor aspect of road weather information utilization. Although no definitive study has been conducted to date to document the growth in knowledge and user sophistication regarding road weather information utilization, the dramatic upswing in road weather emphasis at both the federal and state level has no doubt resulted in a greater awareness of road weather management within the road weather user community. This has resulted in a non-linear increase in sophistication of the user base, particularly within winter maintenance. Thus, this represents an opportunity for a more frequent characterization of road weather performance on approximately an annual schedule due to the growth in user recognition of quality attributes within road weather information and a proactive emphasis to support improved quality within the road weather information.

Figure 4 provides a synthesis of the aforementioned features associated with the uptake of technology and the growth of road weather information utilization where the vertical structure depicts the variability in the timing associated with each feature. As shown in this figure, a reasonable period for performing a re-characterization of road information quality is approximately once every two years (denoted as the red dashed line in Figure 4). This is not significantly different from present efforts to capture the utilization of intelligent transportation system (ITS) technologies, presently being done every other year as part of the ITS Deployment Statistics assessment.

Figure 4. Frequency of road weather technology initiatives and growth showing also the recommended frequency for re-characterization of road weather information quality



METHOD FOR ONGOING ROAD WEATHER INFORMATION QUALITY CHARACTERIZATION

Measuring future variations in the quality characteristics of road weather information will require establishing evaluation methods that are acceptable to the road weather stakeholder community. This will involve the commitment and participation by transportation agencies

and the awareness and support by the road weather service providers. Acceptable methods will share various fundamental protocol and data gathering requirements:

- Protocols that are open and documented;
- Protocols that are repeatable;
- Protocols that provide objective statistical measures;
- Data that are representative of the current road weather state of the practice;
- Data that have minimal human bias; and,
- Data that are appropriate to a long-term longitudinal study of quality characteristics.

Open protocols provide for scrutiny of the methods by the entire community and do not restrict their accessibility as a result of proprietary licenses or regulations. This openness is crucial to provide fairness in the quality characterization process and permits an opportunity for all stakeholders of the quality monitoring process to understand and comment on the methods being used. The protocols should be documented and discussed in a public forum that encourages feedback on the processes being used. The publishing of the protocol provides a formal means of enhancing the likelihood that the protocol will be applied in a similar manner in the future. This repeatability of the measurement process is central to the meaningfulness of the monitoring results by providing comparative process that relates similar aspects at different times in a consistent and equal manner. Finally, an open and repeatable protocol must also have an unbiased method of managing and reducing the study data such that it provides a measure of change in the quality characterization. The use of statistical measures provides an effective means of aggregating similar data for comparison with previous and future data. Optimally, the protocol would be applied to a sufficiently large sample size to permit robust statistical significance testing. However, the limited size of the road weather community likely precludes anything but the use of bulk statistics for the foreseeable future.

The single most likely challenging issue in implementing a method for ongoing characterization of road weather information is ensuring that human factors are a minimal factor in the assessment of quality. Methods to perform a totally objective measure of quality would require either a significant limitation to the types of road weather elements and product types in the ongoing monitoring or they would present tremendous institutional issues in implementing the methods across a sufficient number of transportation agencies to provide meaningful measures. Thus, the method to perform ongoing monitoring of road weather information will inherently require the participation of a transportation agency individual knowledgeable of that agency's road weather information quality attributes. The presence of an individual within the ongoing monitoring program injects a further requirement that the method associated with a measurement not be too cumbersome to apply. Results and feedback from the current baseline activities indicate that responsiveness to questions on road weather information quality is a function of the amount of time required to respond and the detail involved in providing the quality attribute data.

The resulting recommendation of a method to perform ongoing monitoring of the quality characteristics of road weather information is the use of a well-defined questionnaire. The

method explicitly used to characterize a baseline of road weather information quality proved fundamentally sound but some adjustments may be warranted.

Using lessons learned from the present study, it is recommended that the existing method, with appropriate modifications, become a formalized FHWA data collection procedure. This should become similar in design and application to the USDOT Research and Innovative Technology Administration's (RITA) ITS Deployment Statistics database currently in place. A surface transportation weather section already exists within the ITS Deployment Statistics database; however, none of the present questions in the surface transportation weather survey deals explicitly with the quality of the road weather information in use by the transportation agency. The presence of a long-lived relational database should be established from the resulting road weather information quality surveys.

The present baseline information should serve as the foundation for the database. Subsequent entries into the database at a frequency of every two years will permit the desired longitudinal development of a road weather information quality attribute database for use in defining change vectors either individually by road weather element and/or product type or in an aggregation across all road information types. This database should be openly accessible to the road weather community for use in local quality monitoring evaluations and to support research studies into the promulgation of quality awareness within the community. The initial implementation should initially contain all or part of the road weather elements and product types used in the present baseline activities (Table 12 and Table 13) with the possibility of further expansion of the database as required in time.

Table 12. Road weather elements recommended for future longitudinal quality attribute monitoring

ROAD WEATHER ELEMENT
WEATHER CONDITIONS
Air temperature
Relative humidity
Dew point temperature
Wind direction
Wind speed
Wind gust
Visibility
Type of weather
Precipitation type
Rain rate
Snow rate
Cloud cover
Precipitation start time
Precipitation end time
Probability of precipitation
Probability of precipitation by types
Rain accumulation or liquid equivalent
Snow accumulation
Maximum air temperature
Minimum air temperature
PAVEMENT CONDITIONS
Pavement temperature
Pavement condition
Chemical concentration
Freeze point temperature
Road conditions
Probability of road or deck frost
Treatment recommendation
HYDROLOGY
River stage
Flood stage
Flow rate
Flood potential
ADVISORY MESSAGES
Flood watches and warnings
Winter advisories/watches/warnings
Wind advisories/watches/warnings
Severe thunderstorm watches/warnings
Dense fog advisories
Road closures
TRAFFIC
View of the road
View of the traffic
View of the weather

Table 13. Road weather product types recommended for future longitudinal quality attribute monitoring

ROAD WEATHER PRODUCT TYPE
WEATHER
Weather summary
Weather history
Local/regional forecast
Zone forecast
Watches and warnings
ROAD WEATHER
Current conditions
History listing
Regional map of road weather conditions
Pavement forecast
MDSS
Route specific forecast
Road condition report
Road weather alert
Camera images
HYDROLOGY
Flood warning

INCREASED OPERATIONAL ACTIVITIES INCUMBENT TO ONGOING MONITORING

In using road weather information, including the generation of derived road weather information products, assumptions are often made regarding the existence of reasonable quality in the observed weather and road weather data and the resulting quality of road weather derived products using these observed data. The fallacy of assuming data to be meeting an acceptable quality level is that too often it results in frustration within the road weather information user community when less than ideal information is subsequently available to support road weather management decision-making. Often these assumptions include the following:

- Site-specific data are representative of an area extending beyond the location of its observation or predicted location;
- ESS sensors are operating within manufacturer's specifications;
- ESS sensors are routinely and properly maintained;
- ESS data are a significant portion of the data used to generate derived and/or forecast products;
- Road weather data users assign quality in an objective manner based upon operational experiences by the user; and,
- The more experience users have using road weather information in applications, the more reliable will be the characterization of quality and value of road weather.

An important effort with potential to improve the overall assessment of the quality of road weather information is the rigorous use of quality check flags and a more robust quality

assurance program that provides conditional integration of the existing individual quality check tests. A thorough quality assurance program will more accurately discriminate between anomalous road weather conditions induced by unusual conditions and those caused by sub-standard sensor performance. Quality assurance programs will also benefit from an active "blacklist" program that temporarily eliminates known defective sensors from their use in operational activities.

An active metadata program is also necessary to assure the appropriate use of field data for different objectives. Data from ESS sites chosen to provide guidance on specific maintenance problem areas must be available to support maintenance operations; however, these data may not be representative of conditions in the general area and may need to be suppressed or treated in special ways to eliminate or minimize its influence on the quality assurance and use in regional displays and weather forecasting programs. Ongoing updates to the metadata files are essential to address ESS sites that met meteorological standards at the time of installation but are subsequently affected by surrounding vegetation or impacted by new structures in the area.

The metadata files must also reflect sites where the instrumentation does not meet WMO siting guidelines. Situations exist wherein sensors are not installed at the specified WMO heights or at proper distances away from obstructions. A concerted program needs to be developed to assist procuring agencies to understand the importance of site selection and the impact of properly siting RWIS instrumentation. This includes the continued encouragement for DOTs to review and utilize the FHWA Road Weather Management Program ESS siting guidelines developed to address the special situation associated with ESS while emphasizing the importance of the WMO guidelines.

Sensor technology continues to change and new observation techniques are introduced routinely. Replacement of instrumentation at an ESS site has the potential to significantly modify the performance of certain measurements and change the value of given data elements at those sites. It would be advantageous for agencies owning ESS equipment or contemplating the expansion of their networks to have access to an information clearinghouse on the advantages/benefits that would accrue from the introduction of new technology. As new sensors are integrated, the metadata needs to reflect such changes and a mechanism needs to be in place to apprise weather service providers of the changes.

The instrumentation that measures and transfers field information is an essential tool in the generation of raw road weather information and secondary types of information. As with any other tool used by DOT personnel it is imperative to keep this tool working properly. Those responsible to assure the proper performance of their ESS tool need to understand the importance of the resource and what has to be done to keep the instruments working within specifications and assuring that the support metadata are routinely updated. Effective management of the RWIS resource for the benefit of all stakeholders will require a solid training program and a community-wide commitment to an effective resource management program.

STRATEGIES FOR IMPLEMENTATION OF A MONITORING PROCESS

The implementation of an ongoing monitoring process should be led by an appropriate federal agency with strong relationships with transportation agencies nationwide. The recommended agency for this oversight of the ongoing quality monitoring process should the FHWA Road Weather Management Program. While the RITA ITS Deployment Statistics database already has an organized process to collect information associated with surface transportation weather, this effort is primarily associated with Intelligent Transportation Systems activities. Although it could be argued that road weather information quality monitoring could be considered an aspect of ITS, situations would likely occur where this could become an institutional barrier that would limit the participation by some transportation agencies.

Therefore, it is recommended that the FHWA Road Weather Management Program, in addition to oversight for the monitoring process, also assume the responsibility for establishing a road weather information quality attribute database and to implement an electronic questionnaire process to acquire current quality attributes of road weather information every two years. The initial data within the database should be comprised of those data collected as part of the present baseline study where the quality attributes contained in the database are based on the same quality attributes contained in the present baseline study. After review and revision of the questionnaires previously used, a set of questionnaires should be developed for utilization during the first occurrence of database update to occur during the federal fiscal year 2010. Subsequent questionnaires and database updates should occur every two years for a period of no less than ten years.

The protocol used in the implementation of the monitoring process should be presented for open discussion at appropriate road weather stakeholder community meetings. Examples of these meetings would be the annual *Clarus* ICC meeting, the meeting of the ITS and Surface Transportation Weather Committee meeting at the annual American Meteorological Society meeting, the annual ITS America (ITSA) meeting of the ITSA Weather Special Interest Group, and at the annual Transportation Research Board Surface Transportation Weather Committee meeting. Further, a state of the quality of road weather information findings summary report should be prepared and distributed at the aforementioned meetings as well as through an electronic distribution to the road weather community as a whole.

ANTICIPATED OUTCOMES FROM ONGOING MONITORING

Heightened awareness and greater responsiveness to road weather information quality issues affords the road weather community the opportunity to expand the effective use of road weather support for advisory, control, and treatment management strategies. Establishing a proactive program to stimulate a heightened awareness of where quality issues exist will create an atmosphere of collaboration to improve the state of the quality between users and providers of road weather information. Recognition and acknowledgement of the current state of the quality of road weather information (Figures 5 and 6) should be a catalyst to achieve better quality levels. The vertical bars in Figures 5 and 6 represent the quality attributes used to assess the characterization of the Road Weather Elements and Product

Type state of quality. Although the present quality levels are considered within the road weather community to be towards the high end of the quality value scale (the red dashed "mean" line in Figures 5 and 6), there exists considerable room for improvement. This is particularly true for the quality assessments in the Control and Treatment road weather management areas.

Figure 5. State of the Practice – Quality Characterization of Road Weather Product Types for each Road Weather Management Strategy.

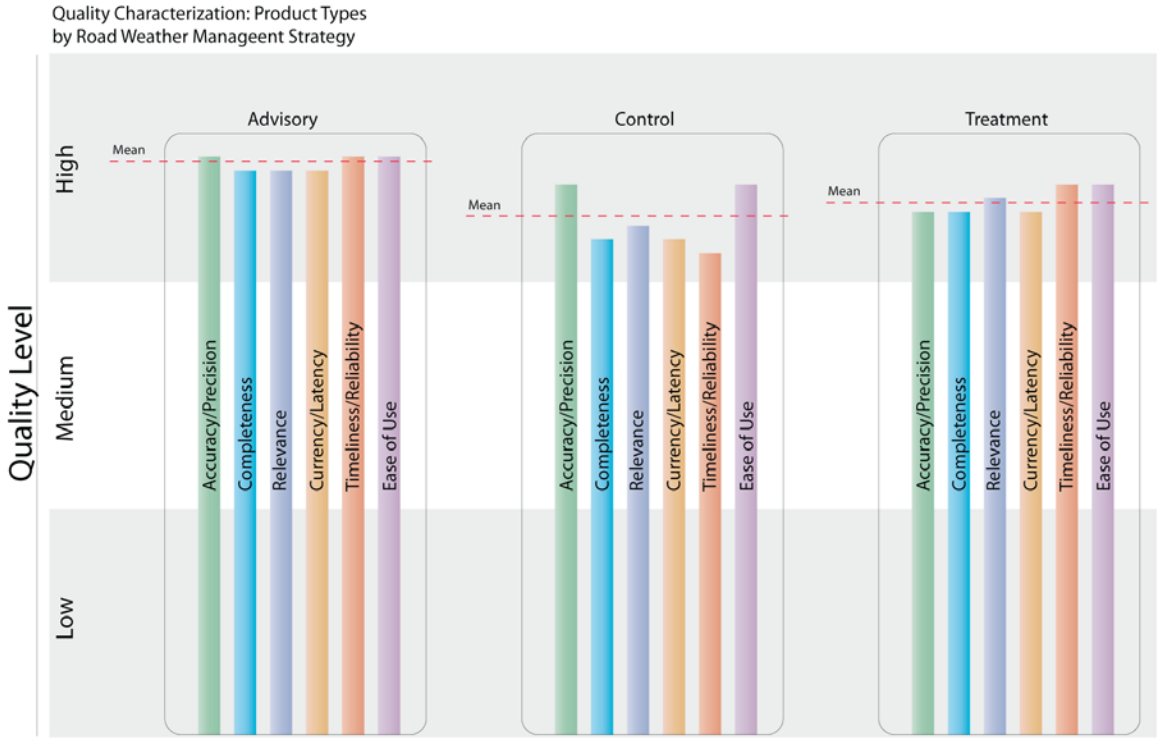
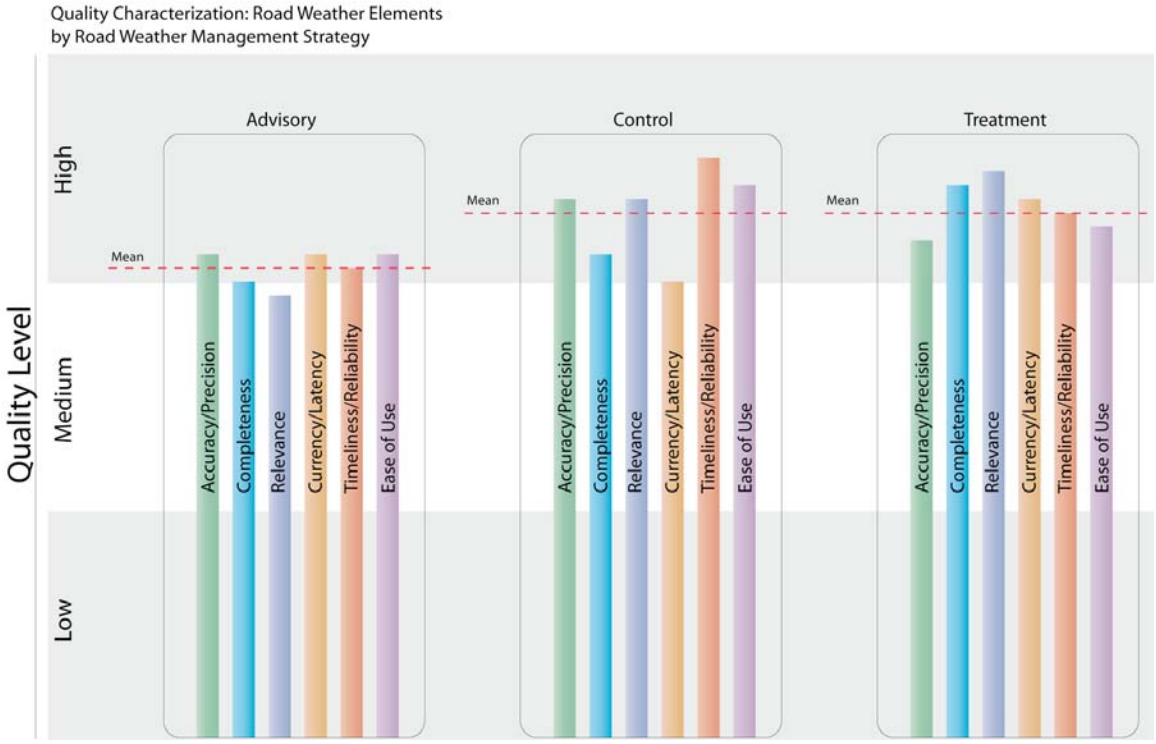


Figure 6. State of the Practice – Quality Characterization of Road Weather Elements for each Road Weather Management Strategy.



The development of the *Clarus* System has as one of its central objectives the improvement of environmental sensor station (ESS) data quality monitoring. Monitoring of data quality and element quality attributes are two themes in the successful application of a road weather information quality improvement process.

The *Clarus* data quality checking flags provide valuable information for ESS system managers to monitor the health and use of their sensors while also providing important quality flags to road weather service providers for appropriate incorporation of the ESS data in their provision of road weather elements and products. A similar quality checking capability is provided with the NOAA MADIS data provision.

A forward looking premise is that changes in quality will result in improved data quality and measurable variation, and over time element and product attributes of road weather information utilization will improve. The following are anticipated outcomes of the ongoing monitoring of quality characteristics.

Improved Road Weather Observations:

The process of using road weather information begins with the collection and processing of the observed road weather data. These data are crucial to the monitoring of current roadway environment conditions and serve as an important part of the preparation of predictions of the future conditions of the pavement and the weather conditions along the

roadway. Ongoing monitoring of the quality will provide an important indicator of the reliability of these data for use in supporting agency and service provider activities leading to a greater awareness of sensor issues at the critical point of the observation.

Improved Traveler Advisory Content with Road Weather Information:

Road weather information provided to travelers has long been limited due to concerns of the quality of the information and the risks of providing untimely and less than accurate information. Ongoing monitoring will provide an important measure of the reliability and accuracy of road weather information. Where the quality meets sufficient levels to permit greater use in traveler advisory content, the result will be a broader level of traveler information system content on the road weather conditions present and expected along a travel corridor.

Improved Winter Maintenance Tactical Response to Snow and Ice Conditions:

Confidence in ESS data is currently less than desirable due to a lack of information on the quality of the data. Snow and ice control operations depend upon having timely and accurate knowledge from the ESS and ESS-derived road weather information of the present and future pavement conditions. Ongoing monitoring of quality characteristics of road weather information will promote a strengthening of the road weather information content (i.e., both the observed and predicted road weather conditions) and permit the evolution of new winter maintenance tools.

Improved Responsiveness by Traffic Managers on Placing Weather-Related Traffic Controls:

Much of the road weather information utilized today within traffic management centers and traffic operations centers support reactive responses to changing road weather conditions. Through ongoing monitoring of the quality of road weather information, it will be possible to develop a level of trust in the ease of use and reliability of road weather information. This increased trust will promote greater use of road weather information sources to provide planning decisions given the current and near-term future conditions of the road and the resulting impacts to traffic flows.

Higher Quality Road Weather Products Provided by the Road Weather Service Provider Community:

The highest level of knowledge regarding the quality of road weather information exists largely within the road weather service provider community. Existing monitoring practices and the presence of new capabilities afforded by *Clarus* and MADIS will provide for better understanding of limitations within the road weather data sources that are used by the road weather provider community. Further, knowing that the quality attributes of the road weather products of the road weather service provider community are being regularly monitored will provide a stimulus to effect improvements in their product and service provisions. As monitoring of ESS data quality provide transportation agency's insight into quality issues of their ESS data, this will result in an improved source of input data to road weather service providers and assist in the improvement of the products and services they provide back to these agencies.

Greater Confidence by Transportation Personnel in Road Weather Products and Services:

Transportation personnel expect high quality road weather information to support their decision-making activities. When the quality of the road weather information fluctuates, it diminishes their ability to make appropriate decision and reduces their confidence in the road weather information sources. Ongoing monitoring of quality attributes of road weather data permits transportation agencies to understand the present limitations of the information capabilities, while seeking ways to improve the quality. The awareness of the quality will allow transportation personnel to set appropriate expectations and, with indications of improved quality through the monitoring process, to adjust their expectations accordingly

Incentives for Improvement of Instrumentation or Processing to Address Elements Perceived as Low Quality Resources:

All members of the road weather stakeholder community have expectations about the performance level of sensors or post processing techniques employed to provide resource information to address the stakeholders' needs. When road weather information resources perform below their levels of expectation, providers who can profit from resolving the deficiency are motivated to look for innovative solutions. This often requires viewing the measurement or data processing technique from a different perspective and being willing to invest resources to facilitate a new solution. A demonstrated quality deficiency and the associated opportunity to profitably gain from resolving the less than desirable state offers the incentive to those vendors who can design and market a more effective resource

Continuing System Improvement for Road Weather Information Products:

Fundamentally, the evaluated quality attributes (Accuracy/Precision, Completeness, Relevance, Currency/Latency, Timeliness/Reliability, and Ease of Use) relate to customer satisfaction with a product. Surveying and interpreting the level of quality for each of these attributes form a true baseline for which improvement of the customer's (DOT personnel) perspective based on product or data quality changes, familiarity, skill improvement, or interest can be charted over time. It is anticipated that the key items where quality improvement would make the greatest difference will experience a decline in attribute values as familiarity and skill of using road weather information increase. Changes in these will highlight opportunities for improvement of the products and the development of trust in the data.

The assessment of these parameters serves the desired objective of establishing an overall performance level of the road weather information and yielding information that should lead to targeted improvement methods.

Initial tasks in this study focused on establishing a current baseline of road weather information through a characterization of the sources of information, and an assessment of quality attributes associated with road weather information used by state departments of

transportation (DOT). The assessment was determined through feedback provided by DOT personnel actively engaged in advisory, control, and treatment management strategies. The results of this study serve as a baseline for future comparisons of enhanced road weather information enabled by the *Clarus* system and other advanced road weather management technologies.

In the design of the characterization process, an objective was to provide clear and useful measures of quality for existing road weather information sources in a method that is efficient, economical, and effective for continued use. This baseline provides the metric to capture future changes in user perceived quality of road weather information. The study also provides a catalog and characterization of the pre-*Clarus* road weather information quality "state of practice."

This report presents a recommendation for a future pathway toward the application of the aforementioned baseline characteristics and recommends strategies for the implementation of monitoring longitudinal change. A key aspect considered in this study has been to determine how change in the user's perception of road weather information may be reflected through the valuation of the intrinsic characteristics of road weather information. Future applications of road weather information performance measures will need to be accomplished in a manner that provides a clear understanding of the state of practice and best practices. Since users may view a specific road weather element from different perspectives related to their subsequent use of the information, several individual quality metrics will need to be utilized in order to assess the overall quality of the various forms of road weather information. Fundamental to this is defining what constitutes an improvement in quality over time. Parameters for each of the quality measures must be such that their change is measurable and the introduction of *Clarus* or other advances in technology do not alter their character or require new metrics. This report provides recommendations for tracking and comparing changes in available road weather information occurring as a result of *Clarus* or other technological advancements.

Stakeholder Review

Eighty-six (86) individuals in the state departments of transportation (DOT) were asked on March 3, 2009 to review the Baselining Road Weather Information Summary Report (hereafter noted as Summary) of research done on the Baselining Current Weather Information project. These individuals were DOT employees who have been involved in road weather activities within their respective states and are considered the key resources relating to road weather as it affects advisory, control, and treatment strategies in daily operations.

Eleven (11) recipients of the request-to-participate in the evaluation of the Summary provided input to a short online survey designed to capture respondent feedback. The results, discussion, and comments are presented in Appendix F. Question 12 in this survey requested users to select in which management strategy areas the respondents were most involved. The expectation had been that the respondents would select one of the three, or at least allocate their efforts primarily to one and partially to the others. The responses seemed to indicate, rather, the respondent's allocation of time to the different areas, and may indicate they do not spend all of their time on functions dedicated to the three strategies. The total number of

responses in each of the three strategy categories was essentially equal; however, the predominant response of "Most Involvement" from the Advisory strategy suggests the survey has an advisory strategy bias. Two interesting points result from this question. First, the answers tend to indicate respondents to this post-report survey see themselves as participants in multiple strategies rather than explicitly classified within one area. The respondents came from the same sample set used in the original quality attribute survey that forced respondents to classify themselves into one of the three strategies. More evaluation is needed to determine whether the separation of responses into strict strategy categories creates a viable statistical partition. Second, the advisory bias of this review survey does not match with the dominant response from individuals in the treatment strategy in the quality attribute survey.

In general, the survey indicate that the results presented in the Summary Report were well received by the reviewers, and that the findings in the Baseline Study provide a baseline assessment reflecting the perception of the stakeholders and practitioners. However, the survey also provided the perspective of at least one individual who did not see the value of the baseline assessment and the presentation of the results.

APPENDICES

APPENDIX A

SCAN RESULTS - WEATHER SERVICE PROVIDERS ROAD WEATHER SERVICE PROVIDERS.

Tabulation of weather service providers and road weather service providers

Company	Location	Road Weather Provider (Y/N)	Services
3SI	Marlton, NJ	N	Weather support system, aviation support system
Aanderaa Instruments	Attleboro, MA	N	Weather and RWIS equipment
About.com Weather	NY Times Company	N	Weather education
Accuweather	State College, PA	Y	Commercial forecasting to large community base; high resolution forecasting of weather and precipitation propagation
Advanced Designs Corporation	Bloomington, IN	N	Doppler radar equipment and services
Advanced Forecasting Corporation	Wilmington, DE and Miami, FL	Y	Risk management services where weather is one component along with terror, bio, geological, network, etc.; risk for transportation services is one component
Aerocomp Inc.	Santa Ana, CA	N	Environmental assessments; Siting and installation of met equipment; hydrology services; climatology for transmission lines
Aerology		N	Weather map forecasts
Aerospace & Marine International	San Jose, CA	N	Weather routing sea; Offshore weather; Tropical weather & storms; SST & ice conditions
Agricultural Weather Information Information Service (AWIS), Inc.	Auburn, AL	N	Ag & energy wx
Air Science Consultants, Inc.	Bridgeville, PA	N	Ag, aviation, media, construction, forensics, trucking, recreation weather support services
Air Weather & Sea Conditions Inc.	Pacific Palisades, CA	N	Consulting and forensics; CCM
Alert Weather Serivces, Inc.	Lafayette, LA	N	Marine weather service solely
Allivan Marketing	Tyngsboro, MA	N	Barometers
AmbientWeather	Tempe, AZ	N	Amateur weather station equipment
America's Weather		N	Repackage of NWS weather information
AnythingWeather.com	Palm Desert, CA	N	Amateur weather station equipment
Applied Modeling, Inc.	Henderson, NV	N	Air quality assessment consulting
Applied Weather Technology	Sunnyvale, CA	N	Marine forecasting
ASAI/Weather 2000	New York, NY	N	Weather derivatives
Associated Science Experts	Green Valley, CA	N	Forensics
AtmosForecast	Portland, ME	N	Forensics, general wx forecasting
Atmospheric and Enviromental Research Inc	Lexington, MA and other US locations	N	Provide meteorological suite of svcs; primary emphasis is consulting about impact of wx on various industries

Company	Location	Road Weather Provider (Y/N)	Services
Atmospheric Information Services	Delmar, NY	N	Forensics, consulting
AWS Convergence Technologies (WeatherBug)	Germantown, MD	N	School net wx equipment, forecasting
Aviation Weather, Inc.	New York, NY?	N	Aviation weather
Avtec Systems, Inc.	Chantilly, VA	N	Satellite receivers and support eqpt
Baron Services	Hunstville, AL	Y	Weather information & data display systems; wx info content distributor for satellite radio
Big Country Weather	Abilene, TX	N	Web interface to Abilene, Tx area weather & general wx condtions
Biral	Portishead, Bristol, UK	N	Weather, partical detection, & biodetection instruments
Boschung America	New Castle, PA	Y	Weather and pavement monitoring eqpt, weather and pavement forecasting, MDSS
Bruce F. Watson	White Bear Lake, MN	N	Consulting meteorologists, forensics, and general wx info provider in upper Midwest
Burk Weather Center	Burkburnett, TX	N	Packages NWS wx info content for west central OK
Cable News Network (CNN)	Atlanta, GA	N	Wx info dissemination; uses content provided by AccuWeather
1 California Weather & Earth Sciences, Inc.	Phelan, CA	N	Consulting; Forensics; Some operational info; associated with American Weather & Earth Sciences, Inc.
Campbell Scientific, Inc.	Logan, UT	N	Data logger manufacturer & weather equipment integrator
Cape Ann Mass.com	Cape Ann, MA	N	Community integration of wx info from NWS and local sources to support local wx info needs
Clear Weather Solutions	Thompson's Station, TN	N	Information unavailable via website query
Clearwest	Wenatchee, WA	N	Ag wx forecasts primarily for Washington growers
Climadata Corporation	Miami, FL	N	Media, film, forensics
Climate Logic	Superior, CO	N	Seasonal to inter-annual climate forecasts
Climate-Charts.com	Joe Casey, individual web page	N	Climate maps of the world; not a business
Climatological Consulting Corporation	Palm Beach Gardens, FL	N	Forensics and applied climatology
Climatronics Corporation	Bohemia, NY	N	Weather and environmental monitoring eqpt
Climet Systems	Newmarket, Ontario	N	Forensic and applied climatology
Coastal Environmental Systems	Seattle, WA	N	Manufactures professional weather instrumentation
Columbia Weather Systems, Inc.	Hillsboro, OR	N	Manufactures weather instrumentation for industrial applications
Commanders' Weather Corporation	Nashua, NH	N	Marine forecasting for yacht racing
Comptus,Inc.	New Boston, NH	N	Weather and environmental monitoring eqpt
Compu-Weather, Inc.	Hopewell Junction, NY	N	Forensic consulting, historical analyses, and forecasting
Connecticut Weather Center, Inc.	Danbury, CT	N	Weather information & forecasts for Connecticut
Consumer Lightning Products, Inc.	Asheville, NC	N	Lightning retardant cable
Continental Weather Corporation	Lutz, FL	N	Fcsts for media, agriculture, marine, aviation; forensics
Convective Development	Blaine, MN	N	Software packages to support ind interested in weather; wx alerts, hurricane tracking
Cox Weather Services		N	Wx info portal to a variety of wx info resources
Crown Weather Services		N	Wx info portal to a variety of wx info resources covering northern Maine and New England

Company	Location	Road Weather Provider (Y/N)	Services
Custom Weather	San Francisco, CA	N	Meteorological information packaged for a variety of industries
Davis Instruments	Hayward, CA	N	Manufactures weather instrumentation for general use
DayWeather Inc.	Cheyenne, WY	N	Media forecasting, general forecasting for WY and vicinity, forensics
DBS Weather Impact Corporation	Delray Beach, FL	N	Climate impact assessments, forensics
Demico Inc.	Atlanta, GA	N	Wind sensors and signal transducers
Digital RF Technology, Inc.	Corsicana, TX	N	Radar (WSR doppler image) enhancement program for broadcast
Disaster Warning Network, Inc.	Oceanside, CA	N	Disaster collection and dissemination for wx and other natural or biological events
doityourselfWEATHER		N	Portal to weather, astronomical, and related info from NWS and other weather service providers
E-Alert USA		N	Link to weather alerts for mobile devices
Early Alert, Inc.	Tampa, FL	N	Alerts to potential disasters and NWS watches and warnings
East Coast Weather	Scituate, MA	N	Portal to weather information primarily from NOAA and EC sources
East End Weather	Long Island, NY	N	Portal for coastal erosion project; contains weather info from NWS and private vendor
Ed Roy, Ltd	Lafayette, LA	N	Forensic meteorologist
EJS Weather	Newton, IL	N	Forecasting for a variety of weather sensitive industries both domestically and worldwide
ENSCO, Inc.	Springfield, VA	N	Weather support systems for meteorologists
Enterprise Electronics Corporation	Enterprise, AL	N	Manufacturer of radar systems
EnviroTech Sensors, Inc.	Columbia, MD	N	Manufacturer of visibility and fog assessment systems
Expert Weather Investigations (EWI)	New York, NY	N	Forensics, consulting
F5WeatherAlert.com		N	Portal for passthrough of NWS products
FleetWeather, Inc.	Hopewell Junction, NY	N	Marine weather
Foreca	Helsinki, Finland	N	Weather information for media and websites; forecasting for broad community of industrial users in Europe
Forensic Meteorology Associates Inc.	Fort Collins, CO	N	Walt Lyons; consulting and forensics
Forensic Meteorology Associates, Inc.	Fort Collins, CO	N	Forensics
Forensic Weather Consultants	Albany, NY	N	Forensics
Fox Weather, LLC	Fortuna, CA	N	Ag weather services
Franklin Time and Weather	Franklin, MA	N	Manufacturer of weather instruments
Freese-Notis Weather	Des Moines, IA	N	Weather support svcs for ag, energy, construction, media plus forecsics
Geonor, Inc.	Milford, PA	N	Manufacturer of precipitation gauges
Global Weather Dynamics, Inc.	Monterey, CA	N	Aviation weather message switching
Golden Gate Weather Services	Saratoga, CA	N	Climatological consulting; Special event forecasts; forensics; Training
Great Lakes Weather Service	Stetsonville, WI	N	General forecasting for various industries in upper Midwest
Guaranteed Weather	Overland Park, KS	N	Risk assessment of wx on ag and precipitation related situations
Hawaii Weather Today	Kahului, Hawaii	N	Portal to Hawaiian weather information
Hometown Forecast Services	Nashua, NH	Y	Media forecasting, commercial forecasting, forecasts for winter maintenance operations in New England
HOTWEATHER	South Bay Area, CA	N	Portal to weather sites provided by NOAA and DOD
How the Weather Works	Naples, FL	N	Weather education services

Company	Location	Road Weather Provider (Y/N)	Services
Hurricane Consulting, Inc.	Friendswood, TX	N	Portal to hurricane info, hurricane consulting and advisories
Hurricanecity	Delray Beach, FL	N	Portal to hurricane info, hurricane consulting and advisories
Hurricaneville		N	Portal to hurricane info
I*ON Weather, Inc.	Morristown, NJ	N	Media, storm alerts, and forensics
Intellicast		N	Weather support services to broad set of industries
IntelliWeather, subsidiary of ItWorks	Chico, CA	N	Broadcast weather support systems
InterMet Systems	Grand Rapids, MI	N	Rawindsonde collection systems
IPS MeteoStar	Aurora, CO	N	Weather support system for meteorologists
Jeppesen	Englewood, CO	N	Aviation
Jersey Weather Service	New Jersey	N	Portal to forecasts for agriculture, marine, and general content.
Katy Weather	Katy, Tx	N	Portal to conditions around Katy TX
Locus Weather	Camden, ME	N	General forecasting for various industries with emphasis on Northeast
Marta Systems	Santa Paula, CA	N	Weather support system for meteorologists
MDA Federal Inc. (EarthSat)	Rockville, MD	N	Agriculture, energy, and historical weather services
Meridian Environmental Technology Inc.	Grand Forks, ND	Y	Surface transportation weather services and 511 systems
Met One Instruments Inc.	Grants Pass, OR	N	Manufacturer of weather instruments
MeteoGroup	London, UK	Y	General forecasting for various industries in western Europe; surface transportation weather services are one component
Meteorlogix	Minneapolis, MN and Omaha, NE	Y	Commercial wx svcs including transportation; consulting; RoadCast maintenance decision support
Meteorological Solutions Inc.	Salt Lake City, UT	N	Air quality and general weather forecasts for construction, recreation, special events
Metro Weather, Inc.	Valley Stream, NY	N	Media, film, general forecasts, forensics
Mission Instruments	Tucson, AZ	N	Lightning detection equipment
Mobile Weather Team, Inc.	Washington, IL	N	Lightning detection equipment
Morcom International, Inc.	Chantilly, VA	N	Satellite receivers and support eqpt and weather services
Mountain States Weather Services	Fort Collins, CO	N	Portal to NWS and other private sector weather services and forensics
MountainWeather	Jackson, WY	N	Portal to Jackson weather information
Murray & Trettel, Inc.	Palantine, IL	Y	Environmental monitoring integration, weather and pavement forecasting, forensics
My-Cast	Minnetonka, MN	N	Garmin based hand-held access to NWS data
New England Weather Associates	North Adams, MA	N	Personalized forecasting for a number of different industries
New England Weather Science	Hull, MA	N	Archived weather data and personalized forecasting
NewsWX	San Diego, CA	N	Portal to NWS data and presentation of customized displays of NWS data.
NEXRAIN Corporation	Longmont, CO	N	Rainfall analysis based upon gauge-adjusted radar estimates.
Northwest Weathernet	Issaquah, WA	Y	Surface transportation weather services
NovaLynx Corporation	Grass Valley, CA	N	Manufacturer/distributer of weather instruments
NY NJ PA Weather	Freehold, NJ	N	General forecast for New York and Philadelphia
Ocean-Pro.com	Naples, FL	N	Marine forecasting
Oceanweather, Inc.	Cos cob, CT	N	Marine research and forecasting
Pace Scientific, Inc.	Mooresville, NC	N	Data logger manufacturer & weather equipment integrator
Pacific Coast Forecasting	Salinas, CA	N	Personalized forecasting, consulting, forensics

Company	Location	Road Weather Provider (Y/N)	Services
PC Weather Products, Inc.	Marietta, GA	N	Hurricane tracking and risk analysis
Peet Bros. Company, Inc.	St. Cloud, Fl	N	Amateur weather station equipment
Planalytics, Inc.	Wayne, PA	N	Risk analysis of weather impact for energy, retail, manufacturing
Planetary Data, Inc.	Prague, NE	N	NOAA Port and client-based display system
Praxis Software	Orlando, FL	N	Software packages to monitor assets and weather impacted services
Premiere Products	Columbus, NE	N	Distributor for amateur weather systems
Qwikcast	Northern CA	N	Portal to general weather information
RainWise Inc.	Bar Harbor, ME	N	Manufacturer of weather instruments
Rapid Weather	Rapid City, SD	N	Personalized forecasts for Rapid City area, links to weather data, and consulting services
Remote Systems Integration	Millington, TN	N	Aviation and environmental monitoring systems (AWOS)
REMTECH Inc.	St. James, NY	N	Atmospheric remote sensing equipment
Scientific Sales, Inc.	Lawrenceville, NJ	N	Distributor for amateur weather systems
Scintec	Tubingen, Germany	N	Manufacturer of remote sensing, turbulence, and radiation sensors
Shade Tree Meteorology, LLC	Niskayuna, NY	N	Forensics and personalized forecasts
Skyview Weather	Castle Rock, CO	N	Forecasting for a variety of weather sensitive industries in the CO region
Sonalysts, Inc.	Waterford, CT	N	Weather suppport system for meteorologists
Sonoma Technology, Inc.	Petaluma, CA	N	Air quality and emissions monitoring
Speranza's Weather Service	Hendersonville, NC	N	Distributor for amateur weather systems
Surface Systems, Inc. (SSI)	St. Louis, MO	Y	RWIS vendor
Susan Genett's Real Weather	Newport, RI	N	Forecasting for special events
Sutron Corporation	Sterling, VA	N	Manufacturer and integrator of weather and oceanic monitoring equipment
Tactical Weather	Wyoming, MN	N	Forecasts for adventure events
Texas Electronics, Inc.	Dallas, TX	N	Manufacturer of weather instruments
The Disaster Center	Federal System	N	Portal to disaster information from wx and other federal sources
The National Weather Station, Inc.	Lodi, NJ	N	General forecasting for various industries
The Weather Channel	Atlanta, GA	N	Weather information for public and users in all business sectors.
The Weather Underground, Inc.	San Francisco, CA	N	Weather information portal
THOR GUARD, Inc.	Sunrise, FL	N	Lightning detection equipment
Travelforecast.com, Inc.	Madison, WI	N	Portal to NWS forecasts and products associated with travel requirements
Unisys Weather	Blue Bell, PA	N	Weather information for meteorologists
Universal Weather & Aviation, Inc.	Houston, TX	N	Aviation weather services
Vaisala	Boulder, CO	Y	Weather and pavement monitoring eqpt, automated weather and pavement temperature forecasts
Vieux & Associates, Inc.	Norman, OK	N	Hydrological software, flood projections, & water resource analysis.
Weather 2000	New York, NY	N	Weather derivatives
Weather Bank Inc.	Edmond, OK	N	Commercial wx svcs including transportation; consulting; Historical wx data
Weather Central, Inc.	Madison, WI	N	Weather content for media
Weather Decision Technologies	Norman, OK and Arlington, VA	N	Modeling tools; Precipitation Tools; Lightning; Weather models; DSS in hydrology, lightning, radar; forensics, display systems; Provision of

Company	Location	Road Weather Provider (Y/N)	Services
			sophisticated weather support tools to other weather resource facilities
Weather for You	Grants Pass, OR	N	Weather information portal to NWS and other service providers
Weather History Research	Central Indiana	N	Weather history research for insurance and legal community
Weather One Corp.	Knoxville, TN	N	Weather observers
Weather or Not	Shawnee, KS	Y	Web site wx svcs, consulting, paging svcs
Weather Research Associates	Westbrook, ME	N	Meteorological hazard mitigation research
Weather Research Center	Houston, TX	N	Weather education
Weather Risk Management, LLC	Norman, OK	N	Energy, construction, insurance, recreation, retail
Weather Routing Inc.	Glen Falls, NY	N	Marine weather service solely
Weather Ventures	Boalsburg, PA	N	Probabilistic forecasting to assist risk analysis of high value ventures
Weather Works	Hackettstown, NJ	N	Forensics
WeatherData, Incorporated	Wichita, KS	N	Forecasts and warning service for a broad spectrum of users from various industry sectors.
WeatherExperts.com	Chantilly, VA	N	Sale of satellite weather equipment a subsidiary of Morcom, International
WeatherExtreme Ltd.	Zephyr Cove, NV	N	Forensics and personalized forecasts
Weatherguy.com	Kailua, HI	N	Worldwide marine forecasting
WeatherMarkets.com	Wayne, PA	N	Energy and agriculture forecast service
Weathernews	San Francisco, CA and Norman, OK	Y	Broad spectrum of wx svcs including maintenance; maintenance guidance advisories
weatherTAP	Crossville, TN	N	Weather information display mechanisms for weather info at meteorologist's level
Western Weather Group	Chico, CA	N	Forecasting for agriculture, industrial, and commercial interests.
Wilkens Weather Technologies Inc.	Houston, Texas	N	Web site graphics, hurricane animation software, customized web pages.
WorldWinds, Inc.	Slidell, LA	N	Weather, marine, and aviation forecasting; research & development in meteorology and oceanography
WSI Corporation	Andover, MA	N	Weather support tools and forecasting for media, aviation, energy, and insurance interests.
Wxforecast Services	Bradenton, FL	N	General weather forecasting for a broad spectrum of clients
WxPortal - SSESCO, Inc.	St. Paul, MN	N	Wx Portal is part of WindLogics
WxUSA		N	NWS general weather forecasts for cities
Zephyrus Electronics, Ltd.	Tulsa, OK	N	Hardware and weather alert messaging software

APPENDIX B

SCAN INFORMATION

ATIS Telephone-Based Services

Informer	Delivery Format	Road Content Provider	Weather Content Provider	Road Specific Content	Weather Specific Content	Comments
Alabama DOT	None	None	None			
Alaska DOT	511	NWS	NWS	Pavement state	Forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility	
Arizona DOT	511	NWS	NWS	Pavement state	Forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility	NWS NDFD
Arkansas DOT	Toll-free call	DOT	None	Pavement state	None	Only when conditions warrant
Sacramento/Northern California DOT	511	DOT	None	Pavement state	None	
San Francisco DOT	511	DOT	None	None	None	
San Diego DOT	511	DOT	None	None	None	
Colorado DOT	Toll call	DOT	DOT	Pavement state	Forecast cloud cover, precipitation type, minimum temperature, maximum temperature	Manually recorded
Connecticut DOT	None	None	None			
Delaware DOT	None	None	None			
Florida Statewide DOT	511	DOT	None	None	None	A manual as conditions warrant system
Central Florida DOT	511	None	None	None	None	
Jacksonville DOT	511	None	None	None	None	
Southeast Florida DOT	511	None	None			
Tampa Bay DOT	511	None	None			
Georgia DOT	511	DOT	Private Sector	Pavement state	Current and forecast cloud cover, wind speed, wind direction, wind gusts, air temperature, visibility, precipitation type, and precipitation intensity	
Hawaii DOT	None					
Idaho DOT	Toll-free call	DOT	NWS	Pavement state	Forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air	

Informer	Delivery Format	Road Content Provider	Weather Content Provider	Road Specific Content	Weather Specific Content	Comments
					temperature, wind speed, wind direction, visibility	
Illinois DOT	Toll-free call	DOT	None	Pavement state	None	Interstates only
Indiana DOT	Toll-free call	State Patrol	None	Pavement state	None	
Iowa DOT	511	DOT	None	Pavement state	None	
Kansas DOT	511	DOT	Private Sector	Pavement state	Current and forecast cloud cover, wind speed, wind direction, wind gusts, air temperature, precipitation type, and precipitation intensity	
Kentucky DOT	511	None	None			
Louisiana DOT	511	DOT	NWS	Pavement state	Forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility	
Maine DOT	511	DOT	NWS	Pavement state	Forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility	Weather not provided relative to specific roads
Maryland DOT	None					
Massachusetts DOT	511	DOT	Private Sector	Pavement state	Forecast precipitation type, precipitation amount, precipitation probability, wind speed and direction, cloud cover, air temperature	Recorded manually by private sector
Michigan DOT	Toll-free call	DOT	None	Pavement state		
Minnesota DOT	511	DOT	NWS	Pavement state	Forecast precipitation type, precipitation amount, precipitation probability, wind speed and direction, cloud cover, air temperature	Not provided relative to specific roads
Mississippi DOT	None					
Missouri DOT (St. Louis)	511	None				
Montana DOT	511	DOT	Private Sector	Pavement state	Current and forecast cloud cover, wind speed, wind direction, wind gusts, air temperature, visibility, precipitation type, and precipitation intensity	
Nebraska DOR	511	DOT	Private Sector	Pavement state	Current and forecast cloud cover, wind speed, wind direction, wind gusts, air temperature, visibility, precipitation type, and precipitation intensity	
Nevada DOT	511	DOT	Private Sector	Pavement state	Current and forecast cloud cover, wind speed, wind direction, wind gusts, air temperature, visibility, precipitation type, and precipitation intensity	DOT road condition reports
New Hampshire DOT	511	DOT	NWS	Pavement state	Forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air	Weather not provided relative to specific roads

Informer	Delivery Format	Road Content Provider	Weather Content Provider	Road Specific Content	Weather Specific Content	Comments
					temperature, wind speed, wind direction, visibility	
New Jersey DOT	511	None				
New Mexico DOT	Toll-free call	None				
New York DOT	None					
North Carolina DOT	511	None	NWS	None	Forecast maximum temperature, minimum temperature, precipitation type, precipitation probability, cloud cover	Weather not provided relative to specific roads. NWS NDFD used.
North Dakota DOT	511	DOT	Private Sector	Pavement state	Current and forecast cloud cover, wind speed, wind direction, wind gusts, air temperature, visibility, precipitation type, and precipitation intensity	DOT road condition reports
Cincinnati/Northern Kentucky	511	None	NWS	None	NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility	Weather not provided relative to specific roads
Ohio DOT	Toll-free call	None	None			
Oklahoma DOT	Toll-free call	DOT	None	Pavement state		
Oregon DOT	511	DOT	NWS	Pavement state	Current cloud cover, precipitation type	Weather not provided relative to specific roads
Pennsylvania DOT	Toll-free call	DOT	None	Pavement state		Available only from Nov. 1 – Apr. 30
Rhode Island DOT	511	DOT	NWS	Pavement state	Forecast precipitation type, precipitation amount, precipitation probability, wind speed and direction, cloud cover, air temperature	Weather not provided relative to specific roads. NWS zone forecast.
South Carolina DOT	None					
South Dakota DOT	511	DOT	Private Sector	Pavement state	Current and forecast cloud cover, wind speed, wind direction, wind gusts, air temperature, visibility, precipitation type, and precipitation intensity	DOT road condition reports
Tennessee DOT	511	DOT	NWS	Pavement state	Current and forecast cloud cover, wind speed, wind direction, wind gusts, wind chill, air temperature, visibility, precipitation type, and precipitation intensity.	
Texas DOT	Toll-free call	DOT	DOT	Pavement state	Precipitation types, maximum temperature, minimum temperature, watches, warnings, advisories.	Manual DOT synthesis of NWS regional forecasts
Utah DOT	511	DOT	DOT	Pavement state	Current and forecast precipitation type, sky	

Informer	Delivery Format	Road Content Provider	Weather Content Provider	Road Specific Content	Weather Specific Content	Comments
					conditions.	
Vermont DOT	511	DOT	NWS	Pavement state	Forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility	Weather not provided relative to specific roads; DOT road conditions
Virginia DOT	511	DOT	NWS	Pavement state	Forecast precipitation type, precipitation amount, precipitation probability, wind speed and direction, cloud cover, air temperature	Weather not provided relative to specific roads; NWS NDFD data.
Washington DOT	511	DOT	NWS	Pavement state, current and forecast	Current air temperature, precipitation, cloud cover. Forecast cloud cover, wind speed, wind direction, air temperature, freezing level, precipitation type, precipitation intensity	
West Virginia DOT	Toll-free call	DOT	None	Pavement state		
Wisconsin DOT	Toll-free call	State Patrol	None	Pavement state	None	
Wyoming DOT	511	Private Sector/DOT		Pavement state	Current and forecast cloud cover, wind speed, wind direction, wind gusts, air temperature, visibility, precipitation type, and precipitation intensity	DOT road condition reports

Public Web-Based Road Weather Content Delivery

Informer	Web Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Comments
Alabama DOT	Traveler Information	DOT	None	Pavement state	None	Link to NWS website and DOT hurricane evacuation routes
Alaska DOT	Traveler Information	DOT		Pavement state	Current and forecast precipitation type, precipitation amount, precipitation probability, wind speed and direction, cloud cover, air temperature	
Arizona DOT	Traveler Information	DOT	DOT, NWS	Pavement state	Current ESS includes air temperature, dew point, pressure, air temperature, visibility, wind speed, wind direction, wind gust, precipitation type, and precipitation rate. Forecast precipitation type, precipitation probability, cloud cover, air temperature	NWS state tabular forecast
Arkansas DOT	Traveler Information	DOT	None	Pavement state	None	
CalTrans (Sacramento/Northern California)	Traveler Information	DOT	None	Pavement state	None	Link to general NWS web site
CalTrans (San Diego)	Traveler Information	None	None	None	None	
CalTrans (San Francisco)	Traveler Information	None	None	None	None	
Colorado DOT	Traveler Information	DOT	DOT	Pavement state	Current ESS includes air temperature, dew point, pressure, air temperature, visibility, wind speed, wind direction, wind gust, precipitation type, and precipitation rate. Forecast cloud cover, precipitation type, minimum temperature, maximum temperature	Provide links to NWS
Connecticut DOT	Traveler Information	None	None	None	None	

Informer	Web Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Comments
Delaware DOT	Traveler Information	DOT	DOT	Current pavement state, pavement temperature, sub-pavement temperature	Current ESS includes air temperature, dew point, pressure, air temperature, visibility, wind speed, wind direction, wind gust, precipitation type, and precipitation rate.	Google Map-based. Incident-based reporting of weather.
Central Florida	Traveler Information	None	None			
Jacksonville	Traveler Information	None	None			
Southeast Florida	Traveler Information	None	None			
Tampa Bay	Traveler Information	None	None			
Georgia DOT	Traveler Information	DOT	None	Pavement state	None	
Hawaii DOT	Traveler Information	DOT		None	None	
Idaho DOT	Traveler Information	DOT	NWS	Pavement state	Current air temperature, sky cover, precipitation type, wind speed, wind direction, visibility, pressure, dew point temperature, and humidity. Forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility	
Illinois DOT	Traveler Information	DOT		Pavement state	Current ESS includes observations air temperature, dew point, pressure, air temperature, visibility, wind speed, wind direction, wind gust, precipitation type, and precipitation rate.	Difficulty with web access
Indiana DOT	Traveler Information	State Patrol, DOT	DOT	Current and forecasted pavement state. ESS pavement temperature, sub-pavement	Current ESS observations includes air temperature, dew point, air temperature, wind speed, wind direction, wind gust	Traffic speeds. Link to NWS

Informer	Web Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Comments
				temperature		
Iowa DOT	Traveler Information	DOT	DOT, NWS, Private Sector.	Pavement temperature, sub-pavement temperature	Current ESS air temperature, precipitation type, wind speed, wind direction, dew point temperature, and humidity wind gust, precipitation type, and precipitation rate. NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility. NWS watches / warnings / advisories.	
Kansas DOT	Traveler Information	DOT	Private Sector	Road conditions, current and forecast precipitation type, precipitation intensity	Current and forecast cloud cover, wind speed, wind direction, air temperature	DOT road condition reports
Kentucky DOT	Traveler Information	DOT	DOT, NWS	Pavement wetness, pavement temperature, sub-pavement temperature	Current ESS air temperature, dew point temperature, solar radiation, precipitation rate, wind direction, wind speed, wind gust, relative humidity, precipitation accumulation. NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility.	
Louisiana DOT	Traveler Information	DOT	NWS	Pavement state	NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility.	
Maine DOT	Traveler Information	DOT	NWS	Pavement state	Current air temperature, sky cover. NWS forecast precipitation type, precipitation	

Informer	Web Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Comments
					intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility.	
Maryland DOT	Traveler Information	DOT	DOT	Pavement temperature, pavement state.	Current ESS air temperature, precipitation type, wind speed, wind direction, visibility, dew point temperature, and relative humidity, precipitation type, and precipitation intensity.	Link to NWS forecasts
Massachusetts DOT	Traveler Information	DOT	NWS	Pavement state	Current air temperature, dew point temperature, sky cover, wind speed, wind direction, pressure, precipitation type, precipitation amount.	Weather is from airport METARS
Michigan DOT	Traveler Information	DOT	None	Pavement state		
Minnesota DOT	Traveler Information	DOT	NWS	Pavement state	NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility.	
Mississippi DOT	Traveler Information	None	None			
Missouri DOT	Traveler Information	DOT	None	Pavement state		
Montana DOT	Traveler Information	DOT	DOT	Pavement temperature, sub-pavement temperature, pavement state, chemical factor, freezing point temperature, chemical percent, depth of water, ice	Current ESS air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity.	Link to NWS forecasts

Informer	Web Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Comments
				percent, conductivity, salinity		
Nebraska DOR	Traveler Information	DOT	None	Pavement state	None	Link to various private sector and NWS web sites
Nevada DOT	Traveler Information	None	Private Sector	None	Current and forecast cloud cover, wind speed, wind direction, wind gusts, air temperature, visibility, precipitation type, and precipitation intensity	
New Hampshire DOT	Traveler Information	DOT	DOT	Pavement state, pavement temperature.	Current ESS air temperature, dew point temperature, relative humidity, wind speed, wind direction, wind gust, precipitation intensity, precipitation type, visibility.	
New Jersey DOT	Traveler Information	None	None			
New Mexico DOT	Traveler Information	DOT	DOT	Pavement state	Reported wind speed, precipitation, and visibility.	Link to NWS web site
New York DOT	Traveler Information	DOT	NWS	Pavement state	Forecast maximum temperature, minimum temperature, precipitation type, precipitation probability, cloud cover, watches, warnings, and advisories.	NWS NDFD data
North Carolina DOT	Traveler Information	None	None	None	None	Link to NWS web site
North Dakota DOT	Traveler Information	DOT	Private Sector	Pavement temperature, sub-pavement temperature, pavement state, chemical factor, freezing point temperature, chemical percent, depth of water, ice percent,	Current ESS air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Current and forecast cloud cover, wind speed, wind direction, wind gusts, air temperature, visibility, precipitation type, and precipitation intensity.	

Informer	Web Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Comments
				conductivity, salinity		
Cincinnati/Northern Kentucky						
Ohio DOT	Traveler Information	DOT	DOT	Pavement state (ESS), pavement state (reports), pavement temperature, sub-pavement temperature	Current ESS air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation type.	
Oklahoma DOT	Traveler Information	DOT	None	Pavement state		Links to NWS and private sector weather web sites
Oregon DOT	Traveler Information	DOT	DOT, NWS	Pavement state	Current ESS air temperature, dew point temperature, relative humidity, wind speed, wind direction, wind gust, precipitation, snow indicator. Sky cover, precipitation type reported by observer. NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility	
Pennsylvania DOT	Traveler Information	DOT	DOT, Private Sector	Pavement state, pavement temperature, chemical percent, freeze point temperature, sub-pavement temperature	Current ESS air temperature, dew point temperature, relative humidity, wind speed, wind direction, wind gust, precipitation. Private sector provision of NWS radar and satellite.	Links to NWS weather web sites across the state.
Rhode Island DOT	Traveler Information	DOT	NWS	Pavement state	NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air	

Informer	Web Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Comments
					temperature, wind speed, wind direction, visibility	
South Carolina DOT	Traveler Information	DOT	None	Pavement state		Links to various private sector and the NWS weather web sites.
South Dakota DOT	Traveler Information	DOT	Private Sector	Pavement state	Current and forecast cloud cover, wind speed, wind direction, wind gusts, air temperature, visibility, precipitation type, and precipitation intensity	
Tennessee DOT	Traveler Information	DOT	None	Pavement state		
Texas DOT	Traveler Information	DOT	None	Pavement state		Link to 'hurricane' goes to NWS and Private Sector web sites
Utah DOT	Traveler Information	DOT	DOT	Pavement state	Current and forecast precipitation type, sky conditions.	Link to NWS web sites
Vermont DOT	Traveler Information	DOT	NWS	Pavement state	Current air temperature, sky cover. NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility.	
Virginia DOT	Traveler Information	DOT	Private Sector	Pavement state	Forecast maximum temperature, minimum temperature, precipitation type, cloud cover, radar and satellite images.	Weather not provided relative to specific roads.
Washington DOT	Traveler Information	DOT	DOT, NWS	Pavement temperature	Current ESS air temperature, dew point temperature, relative humidity, wind speed wind direction, visibility, pressure, 24-hr maximum air temperature, 24-hr minimum air temperature. NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility, weather satellite.	
West Virginia DOT	Traveler	DOT	NWS	Pavement state	NWS forecast precipitation type,	NWS NDFD clickable

Informer	Web Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Comments
	Information				precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility	maps
Wisconsin DOT	Traveler Information	DOT	None	Pavement state	None	Links to various private sector, academic, and NWS web sites
Wyoming DOT	Traveler Information	DOT	DOT	Pavement state, pavement temperature, sub-pavement temperature	ESS air temperature, relative humidity, dew point temperature, wind speed, wind direction, wind gust.	

DOT Operation Support (Excludes the ESS data)

Informer	Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Delivery Format	Comments
Alabama DOT	Maintenance	None	NWS	Flooding	NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility, weather radar.		
Alaska DOT	Winter Maintenance	None	DOT, NWS	None	Snow depth. NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, air temperature, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility.	Graphics, Text	
Arizona DOT	Winter Maintenance	None	NWS	None	NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, air	Graphics, Text	

Informer	Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Delivery Format	Comments
					temperature, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility		
Arkansas DOT	Maintenance	None	NWS	None	NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility, weather radar.	Graphics	
California District 2	Winter Maintenance	DOT	DOT, Academia		METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity.	Graphics	
California District 3	Winter Maintenance	DOT, Private Sector	DOT, Private Sector	Forecasts pavement temperature, pavement condition, treatment recommendations, mobility	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, solar radiation, cloud cover.	Graphics	MDSS
Colorado DOT	Winter Maintenance	DOT, Private Sector	DOT, Private Sector	Treatment reports. Forecasts pavement temperature, pavement condition,	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature,	Graphics, In-vehicle	

Informer	Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Delivery Format	Comments
				treatment recommendations, mobility	precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, solar radiation, cloud cover.		
Colorado DOT	Traffic Mgmt	DOT	DOT	Treatment reports. Traffic cameras. Analyzed pavement conditions.	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity.	Graphics	
Colorado E-470	Winter Maintenance	Private Sector, DOT, Federal Lab	Private Sector, DOT, Federal Lab	Forecasts pavement temperature, pavement condition, treatment recommendations, mobility	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, cloud cover	Graphics	
Colorado - Denver	Winter Maintenance	City, DOT, Federal Lab	City, DOT, Federal Lab	Forecasts pavement temperature, pavement condition, treatment recommendations, mobility	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, cloud	Graphics	

Informer	Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Delivery Format	Comments
					cover		
Connecticut DOT	Winter Maintenance	DOT	DOT				
Delaware DOT	Winter Maintenance	Unknown	Unknown				ESS usage only
Florida DOT	Maintenance	DOT	NWS, Private Sector	Flooding	Weather radar, NWS watches, warnings, advisories	Graphics, Text	ESS usage only
Georgia DOT	None						ESS usage only
Hawaii DOT	Maintenance	Unknown	Unknown				ESS usage only
Idaho DOT	Winter Maintenance	Private Sector	Private Sector, NWS	Forecasts pavement temperature, pavement condition	Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, dew point temperature, cloud cover	Graphics, Text	
Illinois DOT	Winter Maintenance	Private Sector	Private Sector	Forecast pavement temperature, pavement condition	Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, dew point temperature, percent of sunshine, cloud cover	Graphics, Text	
Indiana DOT	Maintenance	Private Sector	Private Sector	Treatment reports. Forecast pavement temperature, pavement condition, treatment recommendations, mobility, frost probability	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, solar radiation, cloud cover. Thunderstorm outlook, flooding hazard assessment	Graphics, Text, Electronic alerts, In-vehicle	
Indiana Toll Road	Winter Maintenance	Private Sector	Private Sector	Forecast pavement	Forecast for air temperature, precipitation type, precipitation amount,	Graphics, Electronic	Seasonal

Informer	Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Delivery Format	Comments
Concession				temperature, pavement condition, frost probability	precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, solar radiation, cloud cover.	Alerts	
Iowa DOT	Winter Maintenance	Private Sector	Private Sector	Treatment reports. Forecasts pavement temperature, pavement condition, treatment recommendations, mobility, frost	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, solar radiation, cloud cover.	Graphics, Electronic Alerts, Text	
Kansas DOT	Winter Maintenance	Private Sector	Private Sector	Treatment reports. Forecasts pavement temperature, pavement condition, treatment recommendations, mobility	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, solar radiation, cloud cover.	Graphics, In-vehicle	
Kentucky DOT	Winter Maintenance	Private Sector	Private Sector	Forecast pavement temperature, pavement condition, frost, treatment recommendations	Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, dew point temperature, cloud cover	Graphics, Text	

Informer	Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Delivery Format	Comments
Louisiana DOT	Maintenance	Unknown	Unknown				
Maine DOT	Winter Maintenance	Private Sector	Private Sector	Forecast pavement temperature, pavement condition, frost, treatment recommendations	Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, dew point temperature, cloud cover	Graphics, Text	
Maryland DOT	Winter Maintenance	Unknown	NWS		Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, dew point temperature, cloud cover		
Massachusetts DOT	Winter Maintenance	Unknown	Unknown				
Michigan DOT	Winter Maintenance	Unknown	Unknown				
Minnesota DOT	Winter Maintenance	Private Sector	Private Sector	Treatment reports. Forecast pavement temperature, pavement condition, treatment recommendations, mobility	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, solar radiation, cloud cover.	Graphics, In-vehicle	
Minnesota DOT (Minneapolis)	Traffic Mgmt	DOT	Private Sector, NWS	Traffic cameras, pavement condition forecasts	Weather radar. Forecast of precipitation type, precipitation probability, precipitation rate	Graphics	
Mississippi DOT	Maintenance	Unknown	Unknown				

Informer	Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Delivery Format	Comments
Missouri DOT	Winter Maintenance	Private Sector	Private Sector	Forecast pavement temperature, frost probability	Forecast of cloud cover, precipitation type, precipitation probability, precipitation accumulation, maximum air temperature, minimum air temperature, wind speed, wind direction, wind gust, dew point temperature, drifting snow.	Text	
Montana DOT	Winter Maintenance	Private Sector	Private Sector, NWS	Forecast pavement temperature, pavement condition	Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, dew point temperature, cloud cover.	Graphics, Text	
Nebraska DOR	Winter Maintenance	Private Sector	Private Sector	Treatment reports. Forecast pavement temperature, pavement condition, treatment recommendations, mobility	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, solar radiation, cloud cover.	Graphics	
Nevada DOT	Winter Maintenance	Private Sector	Private Sector, NWS	Forecast pavement temperature, pavement condition	Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, dew point temperature, cloud cover.	Graphics, Text	
New Hampshire DOT	Winter Maintenance	Private Sector, Academia	Private Sector, Academia	Treatment reports. Forecast pavement temperature, pavement	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity.	Graphics	

Informer	Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Delivery Format	Comments
				condition, treatment recommendations, mobility	Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, solar radiation, cloud cover.		
New Jersey DOT	Winter Maintenance	Private Sector	Private Sector	Forecast pavement temperature, pavement condition, frost, treatment recommendations	Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, dew point temperature, cloud cover	Graphics, Text	
New Jersey (Cherry Hill)	Traffic Mgmt	DOT	Private Sector, NWS	Forecast pavement condition	Weather radar. Forecast of precipitation type, precipitation probability, precipitation rate,	Graphics	
New Mexico DOT	Winter Maintenance	None	NWS	None	NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility	Graphics	
New York DOT	Winter Maintenance	Private Sector	Private Sector	Treatment reports. Forecasts pavement temperature, pavement condition, treatment recommendations, mobility	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, solar radiation, cloud cover.	Graphics, Electronic Alerts	
North	Winter	None	NWS		NWS forecast precipitation type,	Graphics	Major concern

Informer	Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Delivery Format	Comments
Carolina DOT	Maintenance				precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility		for forecasting of ice storms
North Dakota DOT	Winter Maintenance	Private Sector	Private Sector	Treatment reports. Forecast pavement temperature, pavement condition, treatment recommendations, mobility, frost probability	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, solar radiation, cloud cover.	Graphics, In-vehicle, Electronic Alerts	
Ohio DOT	Winter Maintenance	Private Sector	Private Sector	Forecast pavement temperature, pavement condition, frost probability	Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, dew point temperature, cloud cover.	Graphics, Electronic Alerts	
Oklahoma DOT	Winter Maintenance	None	NWS, Academia	None	Oklahoma Mesonet for air temperature, precipitation rate, precipitation accumulation, wind speed, wind direction, wind gust, dew point temperature. NWS weather radar. NWS forecast precipitation type, precipitation intensity, precipitation amount, precipitation probability, maximum air temperature, minimum air temperature, wind speed, wind direction, visibility	Graphics	
Oregon DOT	Winter Maintenance	Unknown	Unknown				

Informer	Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Delivery Format	Comments
Pennsylvania DOT	Winter Maintenance	None	Private Sector	None	Forecast for air temperature, precipitation type, precipitation amount, wind speed, wind direction, dew point temperature, cloud cover, severe weather potential	Text	
Rhode Island DOT	Winter Maintenance	Unknown	Unknown				
South Carolina DOT	Maintenance	Unknown	Unknown				
South Dakota DOT	Winter Maintenance	Private Sector	Private Sector	Treatment reports. Forecast pavement temperature, pavement condition, treatment recommendations, mobility	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, solar radiation, cloud cover.	Graphics, In-vehicle	
Tennessee DOT	Winter Maintenance	None	Private Sector		Forecast for precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation	Electronic Alerts	
Texas DOT	Maintenance	None	NWS	Flash flooding	Current precipitation, air temperatures, wind speed. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, dew point temperature, cloud cover, flooding, severe convection, fire hazard.	Graphics, Text	
Texas DOT (Houston)	Traffic Mgmt	DOT	NWS	Flood monitors, pavement condition	Weather radar. Forecast of precipitation type, precipitation probability, precipitation	Graphics	

Informer	Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Delivery Format	Comments
					rate,		
Utah DOT	Winter Maintenance	DOT	DOT	Forecasts pavement temperature, pavement condition	MesoWest and METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, dew point temperature, cloud cover.	Verbal, Text	
Utah DOT	Traffic Mgmt	DOT	DOT	Forecasts pavement temperature, pavement condition	MesoWest and METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, dew point temperature, cloud cover.	Verbal	
Vermont DOT	Winter Maintenance	Unknown					
Virginia DOT	Winter Maintenance	Private Sector	Private Sector	Treatment reports. Forecasts pavement temperature, pavement condition, treatment recommendations, mobility, frost probability.	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing	Graphics	

Informer	Resource Type	Road Specific Content Provider	Weather Specific Content Provider	Road Specific Content	Weather Specific Content	Delivery Format	Comments
					snow, dew point temperature, solar radiation, cloud cover.		
Washington DOT	Winter Maintenance	Academia, Private Sector	Academia, Private Sector	Forecast pavement temperature, pavement conditions	Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, cloud cover.	Graphics, Text	
Washington, D.C. DOT	Winter Maintenance	Private Sector	Private Sector	Forecast pavement temperature, pavement conditions	Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, wind speed, wind direction, dew point temperature, cloud cover.	Text	
West Virginia DOT	Winter Maintenance	Unknown	Unknown				
Wisconsin DOT	Winter Maintenance	Private Sector	Private Sector	Forecast pavement temperature, pavement condition, frost probability	Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, dew point temperature, cloud cover.	Graphics, Electronic Alerts	
Wyoming DOT				Treatment reports. Forecast pavement temperature, pavement condition, treatment recommendations, mobility	METAR air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity. Forecast for air temperature, precipitation type, precipitation amount, precipitation rate, precipitation probability, precipitation accumulation, wind speed, wind direction, blowing snow, dew point temperature, solar radiation, cloud cover.	Graphics, In-vehicle	

APPENDIX C

SCAN RESULTS - UNIFORM ESS CONTENT

Environmental Sensor Station Data Typical to State DOTs

Pavement temperature, sub-pavement temperature, pavement state, chemical factor, freezing point temperature, chemical percent, depth of water, ice percent, conductivity, salinity, camera imagery.	ESS air temperature, dew point temperature, precipitation rate, wind direction, wind speed, wind gust, relative humidity, visibility, precipitation accumulation, precipitation type, precipitation intensity.

APPENDIX D

QAM RESULTS FOR ROAD WEATHER PRODUCT TYPES

Road Weather Information		Description	Components					Quality Attibutes						Quality Measures		Value Measures	
Class	Type		Provider	Informer	Delivery Format	Consumer	Road Weather Elements	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	Composite Measure	Scan Reference	Cost	Perceived Benefit-to-Cost
RESOURCES USED BY DOT AGENCIES WITH TREATMENT RESPONSIBILITIES																	
W	Weather Summary	Composite summary of current conditions at multiple reporting sites	NWS	DOT	Web	DOT	T, DP, WD, WS, Wx, Pamt, Samt	3.86	3.71	3.86	3.71	4.14	4.14	3.93	Survey	1.00	0.83
								4.71	4.71	4.57	4.57	4.43	4.71				
								7	7	7	7	7	7	7		7	6
W	Weather History (site specific)	A 24 hour sequence of observations at a single site usually in 1 hour time steps	NWS	DOT	Web	DOT	T, DP, WD, WS, Wx, Pamt, Samt	4.00	3.86	3.71	4.00	4.17	3.57	3.90	Survey	0.43	0.75
								4.71	4.57	4.83	4.67	4.50	4.29				
								7	7	7	6	6	7	7		7	8
RW	Current Conditions	Current weather and pavement conditions for a single ESS site	DOT	DOT	Web	DOT	T, DP, WD, WS, (Wx), P or P(Y/N), PavT, C%, FP	4.20	4.10	4.20	4.30	4.60	4.22	4.23	Survey	0.60	0.83
								4.60	4.40	4.30	4.30	4.60	4.40				
								10	10	10	10	10	9	10		10	9
RW	History listing	A sequential listing of RWIS observations for a single ESS for a 24 hour or longer period with time step based upon ESS update cycle	DOT	DOT	Web	DOT	T, DP, WD, WS, (Wx), P or P(Y/N), PavT, C%, FP	4.17	4.17	4.17	4.17	4.17	4.17	4.27	Survey	0.83	0.75
								4.67	4.67	4.50	4.60	4.40	4.33				
								6	6	6	6	6	6	6		6	6
RW	Regional Map of RW Parameter	A regional map that displays the user-selected parameter for all ESS and NWS sites in a geospatial reference	STWSP/DOT	DOT	Web	DOT	T, DP, WD, WS, (Wx), P or P(Y/N), PavT, C%, FP	4.29	4.14	4.14	4.29	4.29	4.29	4.24	Survey	0.71	0.71
								4.71	4.71	4.71	4.57	4.43	4.43				
								7	7	7	7	7	7	7		7	7

Road Weather Information		Description	Components					Quality Attibutes						Quality Measures		Value Measures	
Class	Type		Provider	Informer	Delivery Format	Consumer	Road Weather Elements	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	Composite Measure	Scan Reference	Cost	Perceived Benefit-to-Cost
RESOURCES USED BY DOT AGENCIES WITH TREATMENT RESPONSIBILITIES																	
W	Local / Regional Forecast	Text discussion of the forecasted weather conditions	NWS	DOT	Web	DOT	Tmax, Tmin, Winds, Wx, POP	3.44	3.33	3.44	3.33	3.44	3.67	3.48	Survey	0.56	0.56
								4.11	4.00	4.00	4.11	4.00	4.11				
								9	9	9	9	9	9	9		9	8
RW	Pavement Forecast	Table or meteogram portrayal of forecasted weather in hourly time steps	STWSP	DOT	Web	DOT	T, DP, WD, WS, Wgust, Wx, POP, Prate, Pamt, Srate, Samt, PavT, Cond, %Frost, CC	4.00	4.14	4.29	4.14	4.29	4.43	4.27	Survey	1.00	0.94
								4.57	4.57	4.57	4.43	4.57	4.29				
								7	7	7	7	7	7	7		8	8
RW	Road Weather Alert	An automated alert system to apprise user of impending weather or pavement conditions that may affect maintenance decisions	STWSP	DOT	Pager, text message on cell phone, e-mail	DOT	Various wx or pavement parameters, usually precipitation	3.25	3.25	3.50	3.25	3.25	4.00	3.42	Survey	0.75	0.80
								5.00	4.25	4.50	4.75	5.00	4.75				
								4	4	4	4	4	4	4		4	5
W	Watches and Warnings	Speacial weather alerts that may include NWS watches, warnings, and special weather statements	NWS	DOT	Web	DOT	Severe wx watches, warnings, & special wx statements	3.75	3.50	3.75	3.75	3.75	4.00	3.79	Survey	0.20	1.00
								4.75	4.25	4.75	4.75	4.50	4.25				
								4	4	4	4	4	4	4		5	4
RW	MDSS	Combination of pavement forecast and the associated maintenance recommendations	STWSP	DOT	Web/Client Ap	DOT	T, DP, WD, WS, Wgust, Wx, POP, Prate, Pamt, Srate, Samt, PavT, Cond, %Frost, CC, TR	4.00	4.50	4.50	4.67	4.83	4.17	4.46	Survey	1.00	0.86
								4.83	4.83	4.83	4.83	4.67	4.50				
								6	6	6	6	6	6	6		7	7
RW	Road Condition Report	A report of road conditions made by a government entity	DOT	DOT	Web	DOT	RC	4.00	3.83	4.00	3.50	3.83	4.17	3.90	Survey	0.50	0.75
								4.33	4.33	4.33	4.33	4.50	4.33				
								6	6	6	6	6	6	6		6	6

Road Weather Information		Description	Components					Quality Attibutes						Quality Measures		Value Measures	
Class	Type		Provider	Informer	Delivery Format	Consumer	Road Weather Elements	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	Composite Measure	Scan Reference	Cost	Perceived Benefit-to-Cost
RESOURCES USED BY DOT AGENCIES WITH TREATMENT RESPONSIBILITIES																	
RW	Verbal Forecast	A synopsis of the pavement forecast provided in verbal format	STWSP	DOT	Phone	DOT	T, DP, WD, WS, Wgust, Wx, POP, Prate, Pamt, Srate, Samt, PavT, Cond, %Frost, CC	3.00	3.00	3.00	3.00	4.00	4.00	3.35	Survey	1.00	1.00
								5.00	4.00	4.00	4.00	5.00	4.00				
								1	1	1	1	1	1	1		1	1
H	Flood warning	An advisory of potential flooding conditions	NWS	DOT	Web	DOT	Flood stage	3.67	3.67	3.67	3.67	3.67	3.67	3.62	Survey	0.25	0.63
								4.33	4.33	4.33	4.33	4.33	4.33				
								3	3	3	3	3	3	3		4	4

Road Weather Information		Description	Components					Quality Attibutes						Quality Measures		Value Measures	
Class	Type		Provider	Informer	Delivery Format	Consumer	Road Weather Elements	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	Composite Measure	Scan Reference	Cost	Perceived Benefit-to-Cost
RESOURCES USED BY DOT AGENCIES WITH ADVISORY RESPONSIBILITIES																	
W	Zone Forecast	Text discussion of the forecasted weather conditions	NWS	DOT	Phone, Cell Phone, Web	DOT	Tmax, Tmin, Winds, Wx, POP	3.88	3.88	3.88	3.63	3.88	3.75	3.85	Survey	1.43	2.71
								4.50	4.13	4.25	4.38	4.38	4.00				
RW	Route Specific Forecast	Text discussion of the forecasted weather conditions along specific route segments	STWSP	DOT	Phone, Cell Phone, Web	DOT	T, WD, WS, Wx, P	4.50	4.50	4.50	4.75	4.75	4.75	4.61	Survey	1.00	2.75
								4.75	4.50	4.50	4.50	4.75	4.75				
RW	Watches and Warnings	Speacial weather alerts that may include NWS watches, warnings, and special weather statements	NWS	DOT	Phone, Cell Phone, Web	DOT	Severe wx watches, warnings, & special wx statements	3.88	3.88	3.88	4.00	4.13	4.25	4.08	Survey	1.43	2.57
								4.38	4.25	4.38	4.50	4.50	4.50				
RW	Road Condition Report	A report of road conditions made by a government entity	DOT	DOT	Phone, Cell Phone, Web	DOT	RC	4.33	4.00	4.22	4.11	3.89	4.11	4.17	Survey	1.67	2.75
								4.56	4.67	4.78	4.78	4.78	4.67				

Road Weather Information		Description	Components					Quality Attibutes						Quality Measures		Value Measures	
Class	Type		Provider	Informer	Delivery Format	Consumer	Road Weather Elements	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	Composite Measure	Scan Reference	Cost	Perceived Benefit-to-Cost
RESOURCES USED BY DOT AGENCIES WITH CONTROL RESPONSIBILITIES																	
RW	Camera Images	Both single frame images and streaming video of traffic and weather conditions	DOT	DOT	Web, direct link to cameras	DOT	Images, video	4.50	4.75	3.75	4.50	4.00	4.25	4.31	Survey	1.25	3
								4.75	4.75	4.50	4.75	4.75	4.25				
W	Zone Forecast	Text discussion of the forecasted weather conditions	NWS	DOT	Web	DOT	Tmax, Tmin, Winds, Wx, POP	4.00	3.33	3.33	3.00	3.00	3.33	3.33	Survey	1.25	3
								5.00	5.00	4.67	5.00	5.00	4.33				
RW	Pavement Forecast	Table or meteogram portrayal of forecasted weather in hourly time steps	STWSP	DOT	Web	DOT	T, DP, WD, WS, Wgust, Wx, POP, Prate, Pamt, Srate, Samt, PavT, Cond, %Frost, CC	3.00	3.00	3.00	3.00	3.00	4.00	3.16	Survey	1	2.5
								5.00	4.50	4.50	5.00	5.00	4.50				
RW	Road Condition Report	A report of road conditions made by a government entity	DOT	DOT	Web	DOT	RC	4.00	3.00	4.00	4.00	4.00	4.00	3.16	Survey	2	3
								5.00	5.00	4.50	4.50	5.00	4.50				
RW	Watches and Warnings	Speacial weather alerts that may include NWS watches, warnings, and special weather statements	NWS	DOT	Phone, Cell Phone, Web	DOT	Severe wx watches, warnings, & special wx statements	4.33	3.67	4.33	3.67	3.67	4.33	4.25	Survey	1.5	2.5
								5.00	5.00	5.00	5.00	5.00	4.50				

APPENDIX E

QAM RESULTS FOR ROAD WEATHER ELEMENTS.

TREATMENT STRATEGY (1 of 4)

Road Weather	Quality Attibutes						Quality Measure	NUMBER OF RESPONSES						RANK
Element	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	Attribute Average	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	
Pavement temperature	4.2	4.3	4.6	4.2	4.0	4.3	4.3	13	12	12	11	10	10	1
Air temperature	4.1	4.3	4.3	4.4	3.9	4.4	4.2	13	12	12	11	10	10	2
Road closures	4.0	4.0	4.3	4.3	3.7	5.0	4.2	4	2	4	4	3	2	3
Wind gust	3.7	4.3	4.4	4.2	4.0	4.0	4.1	13	12	10	11	10	10	4
Wind speed	3.7	4.3	4.4	4.2	4.0	4.0	4.1	12	12	10	11	10	10	5
Dew point temperature	3.9	4.2	4.2	4.3	3.9	3.9	4.1	13	12	12	11	10	10	6
Wind direction	3.9	4.2	4.2	4.1	3.9	4.0	4.0	13	12	11	11	10	10	7
Flood watches/warnings	3.8	4.3	3.7	4.0	4.2	4.2	4.0	8	6	7	5	5	5	8
Relative humidity	3.8	4.2	4.3	4.1	3.9	3.9	4.0	12	11	11	10	10	10	9
Precipitation type	3.8	4.2	4.4	3.9	3.7	4.0	4.0	13	10	11	11	10	8	10
Minimum Air Temperature	3.7	4.2	4.0	4.1	3.7	4.1	4.0	12	11	11	10	9	8	11

TREATMENT STRATEGY (2 of 4)

Road Weather	Quality Attibutes						Quality Measure	NUMBER OF RESPONSES						RANK
Element	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	Attribute Average	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	
Snow accumulation	3.5	4.1	4.4	4.0	3.7	3.9	3.9	12	11	11	11	10	9	12
Maximum Air Temperature	3.7	4.2	3.9	4.1	3.7	4.0	3.9	12	11	11	10	9	8	13
Type of precipitation or Y/N precipitation indicator	3.6	3.8	4.3	4.1	3.9	3.8	3.9	12	11	10	10	9	10	14
Precipitation end time	3.3	4.2	4.3	3.9	3.9	3.9	3.9	12	10	11	10	8	8	15
Flood potential	3.4	4.0	3.7	4.2	4.3	3.8	3.9	7	4	7	5	4	4	16
Rain amount or liquid equivalent amount	3.5	4.1	4.2	3.8	3.9	3.8	3.9	11	8	10	10	8	8	17
Rain accumulation	3.5	4.1	4.2	3.8	3.9	3.8	3.9	11	10	11	10	9	9	18
Probability of precipitation	3.7	4.2	4.0	3.9	3.8	3.6	3.9	10	11	12	10	9	8	19
Snow rate	3.3	4.1	4.3	3.8	3.4	4.3	3.9	11	10	10	10	9	8	20
Type of weather & precipitation	3.6	4.0	4.4	3.9	3.7	3.6	3.9	11	10	10	10	9	9	21
Type of weather condition	3.8	4.0	4.2	3.9	3.7	3.6	3.9	11	10	11	10	9	9	22

TREATMENT STRATEGY (3 of 4)

Road Weather	Quality Attibutes						Quality Measure	NUMBER OF RESPONSES						RANK
Element	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	Attribute Average	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	
Precipitation start time	3.3	4.1	4.4	3.8	3.8	3.8	3.8	12	10	11	10	8	8	23
Probability of precipitation types	3.6	4.2	3.9	3.9	3.8	3.6	3.8	11	10	11	10	9	8	24
Type of Weather	3.6	4.0	4.3	3.9	3.8	3.4	3.8	11	10	10	10	8	9	25
Estimated amount of precipitation in ranges	3.3	3.7	4.2	3.9	3.9	4.0	3.8	12	11	11	10	8	8	26
Snow Amount	3.4	4.0	4.4	3.8	3.6	3.9	3.8	12	10	11	10	9	8	27
Road conditions by highway segment	3.9	4.1	4.4	3.6	3.8	3.1	3.8	7	8	8	7	6	7	28
Winter advisories/watches/warnings	4.0	4.3	4.2	3.8	3.1	3.4	3.8	9	9	10	9	8	9	29
Visibility	3.2	4.1	4.2	3.8	3.8	3.7	3.8	11	9	9	10	10	10	30
Wind advisories/watches/warnings	3.7	4.1	4.1	3.8	3.5	3.6	3.8	12	8	10	10	10	10	31
Probability of deck and road frost	3.5	4.1	4.2	3.7	3.6	3.7	3.8	12	11	12	11	10	9	32
Pavement condition	3.3	3.9	4.0	4.0	3.7	3.8	3.8	13	10	11	9	10	10	33

TREATMENT STRATEGY (4 of 4)

Road Weather	Quality Attibutes						Quality Measure	NUMBER OF RESPONSES						RANK
Element	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	Attribute Average	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	
Rain rate	3.1	4.0	4.1	3.9	3.8	3.8	3.8	11	10	10	9	8	8	34
Percent probability of deck and road frost	3.4	3.9	4.3	3.9	3.6	3.4	3.8	13	11	12	11	10	10	35
Freeze point temperature	3.1	3.8	4.3	4.0	4.0	3.2	3.7	10	9	10	10	9	10	36
Treatment recommendation	3.2	3.7	4.1	3.8	4.1	3.3	3.7	6	7	9	8	7	7	37
Severe thunderstorm watches/warnings	3.6	4.0	4.1	3.8	3.5	3.2	3.7	9	8	9	8	8	9	38
Flood stage	3.5	4.0	3.3	3.8	3.8	3.4	3.6	6	5	6	4	5	5	39
Dense fog advisories	3.3	3.6	3.6	3.5	3.8	4.0	3.6	10	8	9	10	9	9	40
River stage	3.3	3.6	3.3	4.2	3.8	3.0	3.5	6	5	6	5	4	4	41
Cloud cover	3.6	3.4	3.5	3.7	3.4	3.1	3.4	8	10	11	9	8	7	42
Flow rate	3.3	3.8	2.8	3.8	4.0	3.0	3.4	4	4	5	4	4	4	43
Chemical concentration	2.4	2.9	3.2	3.6	3.2	2.1	2.9	11	10	10	8	9	8	44

ADVISORY STRATEGY (1 of 1)

Road Weather	Quality Attibutes						Quality Measure	NUMBER OF RESPONSES					
Element	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	Attribute Average	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use
Road closures	4.2	4.1	4.3	4.0	4.0	4.1	4.1	6	7	7	7	7	7
Road conditions by highway segment	3.7	3.8	3.6	3.8	3.6	4.0	3.7	7	8	8	8	8	8
Visibility	3.6	3.6	3.3	3.8	3.6	4.0	3.6	8	9	8	9	8	9
Minimum air temperature	3.7	3.4	3.3	3.5	3.5	3.5	3.5	9	11	12	12	12	12
Flood watches/warnings	3.6	3.3	3.2	3.5	3.7	3.5	3.5	5	6	6	6	6	6
Dense fog advisories	3.6	3.1	3.3	3.5	3.5	3.8	3.5	7	7	8	8	8	8
Maximum air temperature	3.5	3.2	3.2	3.5	3.6	3.5	3.4	8	10	11	11	11	11
Wind speed	3.4	3.5	3.3	3.5	3.3	3.6	3.4	8	11	12	12	12	12
Winter advisories/watches/warnings	3.5	3.3	3.1	3.5	3.4	3.5	3.4	8	8	8	8	8	8
Severe thunderstorm watches/warnings	3.5	3.4	3.1	3.3	3.3	3.1	3.3	6	8	8	8	8	8
Wind direction	3.1	3.2	3.2	3.5	3.3	3.4	3.3	8	11	11	11	12	12
Type of weather	3.6	3.5	3.0	3.2	2.9	3.2	3.2	8	10	10	10	10	10
Estimated amount of precipitation in ranges	3.2	2.9	3.0	3.2	3.3	3.4	3.2	6	9	9	9	9	9
Wind advisories/watches/warnings	3.4	3.1	2.8	3.3	2.9	3.1	3.1	8	9	8	8	9	8
Probability of precipitation	3.0	2.4	3.0	3.3	3.2	3.1	3.0	7	7	9	9	9	9

CONTROL STRATEGY (1 of 2)

Road Weather	Quality Attibutes						Quality Measure	NUMBER OF RESPONSES					
Element	Accuracy / Precision	Complete ness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	Attribute Average	Accuracy / Precision	Complete ness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use
View of the road	4.2	3.5	4.8	4.3	4.8	4.8	4.4	5	4	4	4	4	4
View of the weather	4.0	3.5	4.8	4.3	4.8	4.8	4.3	4	4	4	4	4	4
Severe thunderstorm watches/warnings	4.5	4.0	4.0	4.0	4.0	4.0	4.1	2	2	3	3	3	3
Road closures	4.3	4.3	4.0	3.3	4.0	4.3	4.1	3	3	3	3	2	3
Dense fog advisories	4.3	3.7	4.3	3.0	4.7	4.3	4.0	4	3	3	3	3	3
View of the traffic	3.8	3.3	4.5	3.5	4.7	4.3	4.0	5	4	4	4	3	4
Wind direction	4.2	3.5	4.0	3.5	4.5	4.3	4.0	5	4	4	4	4	4
Wind gust	4.2	3.5	4.0	3.5	4.5	4.3	4.0	5	4	4	4	4	4
Wind speed	4.2	3.5	4.0	3.5	4.5	4.3	4.0	5	4	4	4	4	4
Air temperature	4.2	3.8	3.8	3.0	4.5	4.5	4.0	5	4	4	4	4	4
Wind advisories/watches/warnings	4.3	3.5	4.0	4.0	4.0	3.7	3.9	4	2	3	3	3	3
Pavement condition	4.0	3.7	4.3	2.7	4.3	4.3	3.9	4	3	3	3	3	3
Road conditions by highway segment	4.0	4.0	4.0	3.0	4.3	4.0	3.9	4	3	3	3	3	3
Flood watches/warnings	3.5	4.0	3.7	4.0	4.0	4.0	3.9	2	2	3	3	3	3
Winter advisories/watches/warnings	4.5	3.5	4.3	3.7	3.7	3.5	3.9	2	2	3	3	3	2

CONTROL STRATEGY (2 of 2)

Road Weather	Quality Attibutes						Quality Measure	NUMBER OF RESPONSES					
Element	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use	Attribute Average	Accuracy / Precision	Completeness	Relevance	Currency / Latency	Timeliness / Reliability	Ease of Use
Probability of precipitation types	3.8	3.7	4.3	3.3	4.0	4.0	3.9	5	3	3	3	3	3
Pavement temperature	4.0	3.3	4.3	3.0	4.3	4.3	3.8	5	4	4	4	4	4
Percent probability of deck and road frost	4.0	3.3	4.0	3.0	4.3	4.3	3.8	5	3	3	3	3	3
Probability of precipitation	4.0	3.3	4.3	3.3	4.0	4.0	3.8	5	3	3	3	3	3
Snow accumulation	3.7	3.7	4.0	3.0	4.3	4.0	3.8	3	3	3	3	3	3
Visibility	3.8	3.3	4.5	2.7	4.3	4.0	3.8	4	3	4	3	3	3
Type of weather	4.0	3.7	3.7	2.7	4.0	4.3	3.7	4	3	3	3	3	3
Type of weather & precipitation	4.0	3.7	3.7	2.7	4.0	4.3	3.7	3	3	3	3	3	3
Relative humidity	4.0	3.3	3.3	3.3	4.5	4.0	3.7	5	4	4	4	4	4
Rain accumulation	3.8	3.3	3.8	3.3	4.3	3.8	3.7	5	4	4	4	4	4
Snow rate	3.3	3.3	4.0	3.0	4.3	4.0	3.7	3	3	3	3	3	3
Dew point temperature	4.0	3.7	3.0	2.7	4.3	4.3	3.7	4	3	3	3	3	3
Rain rate	3.7	3.3	3.8	3.3	4.3	3.8	3.7	3	4	4	4	4	4
Minimum air temperature	4.0	3.0	3.5	3.3	4.3	3.5	3.6	3	3	4	4	3	4
Estimated amount of precipitation in ranges	3.8	3.3	3.8	3.3	3.7	3.0	3.5	5	4	4	4	3	3
Maximum air temperature	4.0	3.0	3.0	2.8	3.7	3.5	3.3	3	3	4	4	3	4
Cloud cover	2.0	2.5	1.7	2.5	3.0	2.3	2.3	1	2	3	2	3	3

APPENDIX F

STAKEHOLDER REVIEW RESULTS, DISCUSSION, AND COMMENTS

Survey Responses

The survey was composed of twelve questions, nine of which were multiple-choice. Three questions requested free form text input, but the online survey permitted comments after each of the multiple-choice questions. This section presents the questions, the associated answers, and comments that were added after the multiple-choice questions. An assessment and evaluation of the responses is provided in a subsequent section.

Q1) How well did the quality attributes used in the study provide the desired characterization of **road weather elements**?

	Very Well	Well	Neutral	Poorly	Very Poorly	No Opinion
Advisory	2	5	1	0	0	1
Control	1	5	2	0	0	1
Treatment	1	6	1	0	0	1

Q1 Comments:

"*Charts and graphs are very diffucult (sic) to understand. I can answer the questions but diffucult (sic) for the field folks on the front line.*"

"*There needs to be more discussion of what is meant by Advisory, Control and Treatment Strategies, with some examples. On page 2 Figure 1 there needs to be an explanation of the abbreviations used under Road Weather Elements. On page 3 there is "Table Definitions", but I couldn't find Class or Scan Reference. Where are these used? Why was CLARUS not listed as a provider of information?*"

Q2) How well did the quality attributes used in the study provide the desired characterization of **road weather products**?

	Very Well	Well	Neutral	Poorly	Very Poorly	No Opinion
Advisory	2	4	2	0	0	1
Control	2	4	2	0	0	1
Treatment	1	5	2	0	0	1

Q2 Comments:
"What is the purpose? What are we trying to say here?"

Q3) Please provide comments on what you believe was overlooked in the characterization of current road weather information.

"Very good document that really doesn't say anything of value!"

Q4) Provide comments on the alternate methods that you believe would have provided better methods of quality attribute characterization of road weather information.

"Direct contact with highway maintenance workers."

"Phone surveys might have been used to make sure that answers to the survey were understood by the respondent and the questioner for quality assurance."

Q5) How well do the summary tables communicate the findings of the quality attribute characterization?

	Very Well	Acceptable	Poorly
Road Weather Elements	4	4	1
Road Weather Products	2	6	1

Q5 Comments:
"Make clear conclusions, state what is really meant!"

Q6) Recommendation: A survey instrument (similar to that used in the present study) should be developed and applied during the Federal fiscal year 2010.

	Yes	No	No Comment
Is this recommendation appropriate?	6	1	3

Q6 Comments:
"NOOOOOOOOOO , needs to be simple and easy to understand!"

"I think there are too many parameters being surveyed. I would suggest condensing it down to the highest priority ones."

Q7) Recommendation: Subsequent stakeholder surveys and database updates should occur every two years for a period of no less than ten years.

	Yes	No	No Comment
Is this recommendation appropriate?	6	0	4

Q8) Recommendation: The monitoring process should be presented for open discussion at appropriate road weather community stakeholder meetings.

	Yes	No	No Comment
Is this recommendation appropriate?	8	0	1

Q8 Comments:
"The more discussion about the meanings of the terms the more representative the results will be."

Q9) Recommendation: A *state of the quality* of road weather information findings summary report should be prepared and distributed at the appropriate road weather community stakeholder meetings, as well as an electronic distribution to the road weather community as a whole.

	Yes	No	No Comment
Is this recommendation appropriate?	7	1	1

Q10) Would you be willing to participate in future road weather information characterization surveys?

Yes	No	No Opinion
7	1	2

Q11) Please provide additional recommendations for future road weather information characterization studies.

"This is a poor document written for an administrative level."

Q12) Please indicate the management strategy area(s) in which you are involved, ranking them from most to least involved.

	Most Involvement	Moderate Involvement	Least Involvement
Advisory	5	2	1
Control	0	6	1
Treatment	1	3	3