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Research and Innovative Technology Administration

Implementation and Evaluation of RWIS ESS Siting Guide

Final Report

November 2008

Prepared for the Federal Highway Administration
Road Weather Management Program

The Federal Highway Administration provides high-quality information to serve Government, industry, and the public in a manner that promotes public understanding. Standards and policies are used to ensure and maximize the quality, objectivity, utility, and integrity of its information. FHWA periodically reviews quality issues and adjusts its programs and processes to ensure continuous quality improvement.

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16. Abstract

This report summarizes the effort initiated by FHWA in 2007 to update the "Road Weather Information System Environmental Sensor Station Siting Guide", originally published in 2004. A stakeholder process was conducted in order to document experience with implementation of the ESS Siting Guidelines. An initial phone outreach was conducted to nine DOTs. Most of these agencies have extensive RWIS, although most of the systems were implemented prior to issuance of the Guidelines. Three states; Michigan, New Hampshire and Idaho, were selected for site visits and in-depth interviews. The suggested revisions to the Guidelines are based on input from both phases of the stakeholder process.
Those familiar with the Guidelines generally provided positive feedback. The consensus was that the Guidelines covered most of the major issues in the siting of ESS and provided the necessary information in a concise manner. Knowing that there would be a number of recommended additions to the Guide, one important objective identified early in the process was to maintain the Guidelines as a concise and accessible document that stayed focused on the deployment of ESS.

The major change made to the Guide involved the metadata table that was included in the original report. Since the original Guidelines were developed a major effort was conducted as part of the Clarus project to define an standard set of metadata for ESS. An expanded metadata table was thus included in the Guidelines showing Clarus metadata in three categories; required, recommended and optional. The metadata requirements defined for Clarus were quite extensive and may not be realistic for all ESS installations. Some items in the recommended and optional categories were highlighted as not being critical for most DOT requirements.

Overall a very limited number of changes were recommended for the guidelines document. Other than the modification to the metadata table, most of the additions were limited, and designed to highlight areas of concern noted by DOT's with ESS experience. It is the case that many agencies are deploying other ITS technologies with ESS; however it was felt that this could greatly expand the document and result in a loss of focus on ESS technology. The feedback from most of the DOT's interviewed was positive and they expressed an interest in using the document for future deployments. Several noted that they would require their contractors to use it

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

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

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Revision History

Revision	**Issue Date**	**Status**	**Authority**	**Comments**
01.01	May 2, 2008	Draft	qrm	Initial draft
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1 EXECUTIVE SUMMARY

This document describes the implementation and evaluation of the existing *Road Weather Information System (RWIS) Environmental Sensor Station (ESS) Siting Guidelines* (Guide) and the recommended enhancements. The Guide was originally released in 2004 by the Federal Highway Administration (FHWA) in cooperation with the American Association of State Highway and Transportation Officials (AASHTO) Snow and Ice Cooperative Program (SICOP), and the Aurora Pooled Fund Program as a means of documenting best practices in RWIS ESS deployment. Potential changes in the Guide are driven by lessons learned from agencies using the Guide for ESS deployments and other road weather applications that seek to expand the availability and application of environmental information.

As part of the evaluation, State Departments of Transportation (DOTs) that have recently deployed ESSs were surveyed for their familiarity with, and experience using the Guide in those deployments. The Guide was reviewed in light of the DOT experience, other road weather management strategies, and systems engineering principles to identify potential areas for improvement. In addition, three State DOTs—Michigan, Idaho, and New Hampshire—provided more detailed insights on the impacts of the Guide on their ESS deployment experience. In the case of Michigan, evaluation of the Guide was provided as part of their deployment planning and design. Recommendations for revising and enhancing the Guide were derived from the review process.

Additional recommendations for the collection and management of RWIS ESS metadata are also included in this evaluation. This metadata is essential to ESS life cycle management and expands the usefulness of the ESS observations to the meteorological and transportation communities.

Recommendations accepted for inclusion in a subsequent revision of the Guide include

- Changing the title of the document itself to *Road Weather Information System (RWIS) Environmental Sensor Station (ESS) Siting Guide*
- Discussion of the use of the Guide and its systems engineering fit with the National ITS Architecture
- Use of examples to illustrate particular guidelines
- Enhanced discussion of siting ESS in conjunction with other ITS components
- Pointing to manufacturer recommendations for siting criteria specific to particular sensors
- Updating guidelines for ESS metadata

2 INTRODUCTION

This document describes the implementation and evaluation of the existing *Road Weather Information System Environmental Sensor Station Siting Guidelines* (Guide) based on State Department of Transportation (DOT) needs and practices in the field environment. Recommendations for revisions and enhancements to the Guide are then derived from the evaluation.

The Guide was an outcome of many years of research and development in response to traveler and transportation department needs for better road weather information. In 2004 the FHWA, AASHTO SICOP, and the Aurora Pooled Fund Program decided to jointly sponsor the development of the Guide as a means of documenting common transportation industry practices in placing road weather stations and sensors in the field. As stated in the Guide, RWIS generally refers to the hardware, software, and communications elements needed to collect, transmit, process, disseminate, and display field observations. The ESSs are the field collection components of RWISs. The Guide, issued early in 2005, focuses primarily on the ESS, and offers a set of recommendations, not standards, for agencies and vendors to follow.

While the Guide is based on current practices, there is a need to evaluate its applications in the field, ensuring that the recommendations are implementable, understandable and useful. There are currently about 2,400 ESSs deployed by State DOTs and the District of Columbia. The deployment of many of these systems predates the Guide, and there are no apparent uniform bases for their deployment. As such, the value of the ESS investments and their use by the greater weather community may be limited by the diversity of deployments.

In addition, recent initiatives have created incentives to revisit and potentially enhance the Guide. For example, FHWA's Road Weather Management Program has sponsored a variety of development efforts and task forces under the aegis of the *Clarus* Initiative. The *Clarus* System gathers, quality checks, and disseminates observations from RWISs, and will itself be enhanced by increased standardization among those systems. Numerous agencies are investing in maintenance decision support systems (MDSSs) that use observations from ESSs to monitor current roadway conditions and to initialize forecast models which predict future road conditions.

3 REVIEW OF ESS SITING GUIDE AND METADATA CHECKLISTS

The initial review of the Guide consisted of a survey of State DOTs with active RWIS programs and subsequent analysis of the survey results. Preliminary recommendations for enhancements were distilled from the analysis. Inclusion of a recommendation in this analysis, however, does not necessarily predict a corresponding change in the Guide. Recommendations that would increase the scope of the Guide, for example, are included for completeness in this report, but will not result in any changes to the Guide.

3.1 Results from Survey of DOT ESS Implementers

Fifteen DOTs were contacted to discuss their familiarity and experience with the Guide. Of the nine respondents, eight were familiar enough to discuss the Guide, and one referred to its consultant, who had used the Guide to design a major ESS deployment. Overall impressions of the Guide were positive. Most respondents felt it was useful, some as a guide, others as a check against their own procedures. Coordination of ESS with other intelligent transportation system (ITS) technologies such as dynamic message signs (DMSs), closed-circuit television (CCTV) cameras, and bridge anti-icing spray systems was mentioned as an emerging area that needed more attention. Flooding was another concern raised. Water level gauges, possibly deployed with roadway warning signs, could be deployed along with standard ESSs in these situations. Deployment of mobile sensors on agency maintenance vehicles was another. Most of the DOTs interviewed have significant RWISs but most said they are only planning limited expansion, with funding as the primary concern.

Survey Respondents

- Iowa DOT – Tina Greenfield
- Idaho Transportation Department (ITD) – Bryon Breen
- Iteris (consultant to ITD) – Todd Hoffman
- Utah DOT – James Dziatlik
- Colorado DOT – Philip Anderle
- Wisconsin DOT – Michael Adams
- Kansas DOT – Peter Carttar
- Alaska DOT & Public Facilities– Jack Stickel
- Nevada DOT – Denise Inda

3.1.1 Familiarity with Guide

All of the respondents were familiar with the Guide, although one or two respondents said they only had passing familiarity. Several had been involved in the development and review of the Guide, had read through it and were familiar with the siting recommendations in detail. Other respondents had either skimmed through the document or read specific sections that were relevant to their concerns. One respondent had used it in a siting project while several others used them as a check against their own procedures and guidelines.

Most respondents felt that the Guide was useful in siting decisions and was relatively easy to follow. The checklist in Appendix D of the Guide, which provides a synopsis of siting criteria contained in the main document, was noted by a number of respondents as a very useful tool. They said that it provided a sound, structured approach, and helped confirm that they considered all the important factors in siting an ESS. Most respondents felt that the document effectively covered the key factors in siting, without being too long or overly technical. Some consider it more of a reference document than a set of guidelines, something to use to find specific pieces of information or address specific concerns.

One respondent noted that the Guide leans heavily toward meteorological considerations and could benefit from more consideration of transportation concerns. Another had a similar comment that the Guide is stronger on representative sites than location-specific sites, even though both are covered and the difference is explained. Another respondent, who is a meteorologist, felt the emphasis on meteorological concerns is beneficial, since most of the DOT personnel responsible for ESS installation do not have a meteorological background. Most respondents understood that siting almost always requires a compromise between meteorological concerns and roadway maintenance concerns.

One respondent noted that knowledge of available technology helps to achieve an optimal balance between operational (for example, power) and meteorological concerns. In this case, the respondent's agency uses a portable, modular generator for remote sites where power is not available. The unit operates on propane and only needs to be accessed every six months. Another tradeoff issue mentioned was the desire to locate ESSs on State property rather than on adjacent private land. In some cases, private property may be advantageous from a meteorological perspective, but this advantage must be very significant in order to justify the additional time and expense needed to lease or appropriate property.

There was an interest in providing more information in the Guide on ESS siting in conjunction with ITS components such as cameras and DMSs. Cameras were mentioned as being very helpful in areas of heavy snow depth, to give winter maintenance personnel a better idea of conditions that they will face in the field. One respondent noted that bridge anti-icing spray systems are becoming more popular and that ESS siting issues related to these systems should be covered. One respondent noted that DOT personnel would like a better understanding of what makes weather observations acceptable to the meteorological community. The document gives a partial explanation in that regard, but more information would be helpful. Compatibility with *Clarus* was another issue that was raised by several respondents. Two respondents also mentioned that MDSS data requirements were an important consideration in their ESS deployment strategies. One respondent mentioned the importance of metadata, which is covered in the Guide. It was noted that the reasons for providing metadata should be highlighted since their importance is recognized within the meteorological community but not to the same degree within the State DOT community.

Another respondent felt that the Guide should state the importance of ongoing maintenance on ESS accuracy. Information should be included on how the location of the station impacts the ability to effectively maintain the sensing devices.

3.1.2 ESS Deployment Activities

Most of the respondents did not have major ESS deployments underway during the survey. The one exception was Idaho, which was in the process of deploying 50 ESSs around the state at the time of the survey. The Idaho Transportation Department (ITD) asked its design consultant to use the Guide in its design effort. The consultant used the Guide and found it easy to implement and very helpful in identifying the full range of concerns that need to be addressed in ESS siting. They noted that the Guide added technical rigor to their process and led to location changes for a number of sites.

One agency that used the Guide as a check against their own process said that in retrospect they would have used the Guide more formally to avoid some problems that have been experienced with specific sites in a recent major deployment. Some decisions that have caused both maintenance problems and data quality problems probably would have been made differently. Several respondents said that the Guide would have been helpful in recent deployments. Some basic siting mistakes were noted, such as locating a solar-powered sensor in an area that was shaded a large percentage of the time, or locating a camera in a spot subject to high winds and low visibility.

Most of the responding agencies said they were either adding small numbers of ESSs or upgrading existing stations. Several noted that their systems were relatively mature and they did not anticipate significant new deployments in the near future. Most noted they are adding ESSs in small numbers or relocating some of them as part of larger roadway projects. Others are interested in expanding their RWISs but are having difficulty obtaining the funding. Several noted they are adding ITS technology to existing ESSs, including DMSs that will warn of high winds or wet/icy conditions on downstream roadway sections. Several respondents also noted they are concentrating on improving their communications infrastructure for existing ESSs. Improved wireless systems are being implemented at some locations where communications problems have been experienced in the past. As improved systems come on the market, greater flexibility in siting ESSs may result.

One respondent mentioned that his department is in the process of outfitting most of their vehicle fleet with weather sensors. They felt that mobile sensors will be a growing area of importance and that the Guide should be expanded to address these.

3.1.3 Use of Guide

None of the other respondents had used the Guide in the same way as Idaho, as the primary source for siting decisions. Several agencies, however, noted that they have used them as general guidance or have checked their own guidelines to see how well they matched. Those who did the latter felt that their own guidelines were generally in line with those of FHWA. Most of the respondents said that they expected to use the Guide going forward in some fashion. Some plan to use them as a primary source of information while others will use them as a check on their own guidelines or procedures.

3.1.4 Current Siting Standards

About half the respondents had existing guidelines but in most cases they were informal and oriented toward location-based deployments. For example, those guidelines may have noted items like height, acceptable distance from the road, structural and power requirements. For location-based ESSs, most DOTs rely on information from their District maintenance personnel. Areas that freeze quickly or roadway segments that are more susceptible to accidents are given higher priority. Utility access is a primary concern of most agencies as well. Some of the respondents have a checklist similar to that in Appendix D of the Guide, but include fewer specific items. Some of the respondents indicated that the guidelines they have are not meteorologically-oriented and that they could use additional help from the Guide.

3.2 Analysis

Respondent comments on the Guide were oriented along operational lines, and did not necessarily relate to a particular section of the Guide. There was a consistent interest among respondents in better documentation of how the Guide can be used by transportation agencies. The survey revealed, for example, that whereas it is the exception today to have used the Guide as the basis for ESS deployments, virtually all DOT personnel with knowledge of the Guide have used them as reference material and to support or supplement their own guide. This suggests that there may be value in adding text to the document describing "How to Use this Guide". Both new and previous users would benefit from insights provided by the growing base of DOT experience with the Guide.

One approach to documenting the utility of the Guide would be to recognize and emphasize its fit within the systems engineering principles of ESS deployments. While the Guide recognizes ESSs as components of an ITS, the guidance therein is not explicitly structured around a systems engineering approach. The National ITS Architecture and systems deployed within the context of a Regional Architecture are conditioned to a systems engineering model, and it would benefit the Guide to conform to that model as well. To that end:

- Section 1, "Introduction", contains many of the elements of a Concept of Operations for DOT RWIS and ESS deployments. A more focused discussion of user needs and description of usage scenarios would identify more specific requirements for particular applications.
- Section 1 also contains descriptions of RWISs and ESSs, and categorization of sensors. This discussion could be expanded and integrated with a description of the system's relationship to the ITS

architectures to provide a more comprehensive basis for the system design.

- Section 2, "Assessing Road Weather Informational Requirements", provides extensive discussion of potential system requirements. It does not, however, provide traceability to user needs or application scenarios. The same requirements could be more explicit in the Appendix D "ESS Checklist".
- Sections 3 ("Site Selection") and 4 ("Recommended Siting Criteria") generally describe considerations to be included in designing an ESS deployment. The guidance is extensive, but would benefit from being traceable to specific requirements and user needs.
- The contents of Section 5, "Additional Considerations," could be redistributed among the other sections without any loss of information and with value added by restoring context to each consideration. For example, "Siting Considerations", "Power", and "Communications" could be included with the requirements as constraints on the design. The "Siting Metadata" discussion could be incorporated into an architectural discussion.
- Section 5 also describes "Siting Reevaluation". This description could be one piece of a larger discussion of deployment and maintenance of the ESS as it relates to the system life cycle.

This more explicit alignment of sections in the Guide with steps in a systems engineering process allows the operational issues highlighted in the survey responses to flow consistently through ESS design and deployment.

3.2.1 Introduction to RWIS ESS Concepts

The current "1.0 Introduction" section of the Guide provides excellent background information on ESS operations and equipment. It discusses the scope and purposes of the Guide itself, with a brief description of ESSs and the benefits of ESS data. As noted earlier, the Introduction serves the systems engineering purpose of a Concept of Operations.

With this purpose, the Introduction should provide a perspective that encompasses a broader view of road weather information applications and the RWIS ESS as a means of fulfilling the data needs of those applications. The current Guide text provides an overview of the flow and use of the data, but does not link the data to specific applications. Data applications are listed as benefits of deploying ESS, but the relationships between applications and the data needed to support them are not explicitly stated. For example, transportation agencies might be interested in incorporating weather information into traffic management decisions in a variety of modes and methods. Signal timing plans for adverse weather conditions could be developed for major corridors. Agencies might mandate or recommend a lower speed on limited access highways rather than simply warning of adverse conditions ahead. In order to implement these types of strategies, transportation agencies must have a clear understanding of the availability and accuracy of ESS data.

ESS siting decisions will have an impact on both the development and the implementation of weather-responsive traffic management strategies. While this document is not intended to discuss weather-responsive traffic management strategies in detail, a brief narrative and table with the implications of weather-responsive traffic management strategies on ESS siting would be helpful. It should include roadway monitoring, winter maintenance, signal timing strategies, traveler information, and management strategies for major incidents or construction. The information may be general at first with greater detail added over time as more agencies gain experience with these strategies.

In this context, the Introduction section of the document should describe the user needs *and constraints* to be considered in development of the RWIS program plan. This is particularly true in the case where the needs are many, but resources are constrained. Agencies implementing RWIS ESSs want to know how to characterize and assess the trade-offs among competing needs for road weather information. While the Guide provides a list of significant benefits, there is a need for corresponding guidance on the relative costs of implementation to meet particular operational needs. The cost data would enable agencies to make more informed deployment plans. Prioritization within the plan is an essential step in establishing the agency needs for data, which then become the basis for assessing the informational requirements in the next section of the Guide.

For example, agencies surveyed on their ESS deployment experience consistently indicated that maintainability of the ESS was, in hindsight, a major deployment constraint. The Guide should provide greater prominence to the need to maintain ESSs, as well as some indications of best maintenance practices, and how these practices impact siting decisions. Technological advances in areas such as remote diagnostics could be discussed, along with the impact that these changes may have on siting decisions. Communications technology and power generation could also constrain maintenance needs. The impact of maintainability needs could then be revisited in the requirements and siting criteria sections of the Guide.

The broad view of RWIS ESS deployments is also incomplete without some discussion of the *Clarus* Initiative. FHWA's *Clarus* Initiative is an example of the tremendous opportunities for making ESS observations available across larger regions and jurisdictional boundaries. Observations fed to *Clarus* from DOT ESSs are quality checked and disseminated throughout the transportation and meteorological communities for developing value-added products and services. The DOTs providing their observations to *Clarus* then have access to the quality checks performed on their environmental data, to similar data from other jurisdictions, and to the value-added products.

Agencies participating in the *Clarus* Initiative would benefit from a discussion of these opportunities in the Guide. It is recommended that *Clarus* background information be included in the revised Guide, and that the impacts of *Clarus* on siting, if any, and on collection of ESS metadata (as described below) be integrated elsewhere in the document as appropriate.

3.2.2 RWIS and ESS Requirements

The Guide section on "Assessing Road Weather Information Requirements" provides a bridge from the road weather concepts in the Introduction to the siting details in subsequent sections. The text discusses the planning for ESS acquisition and installation, describes the kinds of sensors generally available for ESSs, distinguishes between regional and local installations, and describes opportunities for road weather information partnerships. The core of the requirements discussion relates to the distinction between regional and local implementations, and should be expanded.

For example, there is a growing recognition among DOTs deploying ESSs that there may be operational benefits to coordinating the deployment of ESSs with other ITS components.

- Dedicated bridge anti-icing spray systems could be coordinated or integrated with traditional ESSs to provide more detailed road and bridge weather information to winter maintenance and meteorological staff;
- Precipitation sensors could be deployed with CCTV cameras to provide mutual confirmation of precipitation observations;
- A DMS coordinated with an ESS could provide real-time "on-the-ground" warnings of adverse weather conditions to travelers; and
- Water level sensors in flood-prone areas and snow depth sensors in areas prone to drifting are two weather-related technologies that can be integrated with ITS.

ESSs currently installed across the United States are providing valuable road weather data to the DOTs, but most of them are not coordinated or integrated with existing ITS technologies. Operational and safety benefits could accrue from coordination in both localized deployments (like bridges subject to high winds) and regional integrations (perhaps in support of MDSS and winter maintenance operations). In other words, the requirements for ESS siting need to be traceable to the intended applications and user needs.

3.2.3 Site Selection Guidelines

The "Site Selection" section of the Guide describes the rationale by which DOT planners may make ESS deployment decisions and the circumstances associated with particular types of sites. The guidance covers the cases for regional and local sites, and provides a brief discussion of siting tools that may be helpful in the site selection process. The bulk of the text is focused on guidelines for siting ESSs in response to local road weather data requirements. The text is very informative and focused. In the context of the systems engineering process, this section fulfills the intent of a system architecture or high-level design.

As part of the discussion of siting tools, this section includes a discussion of portable sensor systems. The text notes that such systems are useful for temporary monitoring of certain locations and for "scouting" of locations for permanent ESS sites. This section would benefit from extending this discussion from portable versions of existing ESS platforms to truly mobile systems. Road weather sensors have been successfully used on DOT maintenance vehicles for many years, and technology is making the sensors more accurate and thus more useful in identifying specific problems and contributing to more general weather data collection. Higher quality data from vehicle "black boxes" are likely to become more available, especially from agency-owned vehicles, and this data source will provide useful information on surface conditions. Telematics solutions could dramatically change the way road weather information is collected and processed. It is important that the Guide discuss these developments, even if the Guide is otherwise intended specifically for fixed ESS installations.

3.2.4 Recommended Siting Criteria

The "Siting Criteria" section of the Guide provides specific guidance on the design of the ESS observation tower and placement of sensors. The guidance reflects an extensive body of experience from transportation agencies and the broader weather community. This section fulfills its intent with no apparent need for improvement.

3.2.5 Additional Considerations

The "Additional Considerations" section of the Guide generally addresses siting considerations not directly associated with weather-related aspects of the ESS. Topics covered in this section include power supply to the ESS, communications, site access (aesthetics, safety, and security), periodic site reevaluation, and siting metadata. Any ESS deployment will have to deal with these considerations as part of the planning and design of the sites.

Among these considerations, the increasing extent and sophistication of ESS deployments have brought increased attention to the need for better data about the ESS (metadata) with which to manage their deployment. To that end, several State DOTs have put significant effort into improving the collection, quality assurance, and maintenance of this metadata. In addition, the *Clarus* Initiative needs high-quality metadata to reliably gather and check the quality of observations provided by the contributing DOTs. A Metadata Task Force was convened by the FHWA as part of the *Clarus* Initiative to prepare recommendations for prioritization and standardization of meteorological metadata for transportation applications.

Tables 2 and 3 of the Guide provide classification, structuring, and specifications for ESS metadata. Supporting text generally describes the need for metadata and standardization efforts underway within the National Oceanic and Atmospheric Administration (NOAA). The tables themselves describe metadata components and distinguish between those that are recommended and those that are supplemental. Many of the metadata descriptions correspond closely to data described in the *National Transportation Communications for ITS Protocol Environmental Sensor Station Interface Standard*, NTCIP 1204, for object definitions.

Metadata treatment within the Guide could be significantly enhanced by:

- Incorporation of the *Clarus* Metadata Task Force recommendations;[1]
- A more robust and complete comparison of metadata recommendations from *Clarus*, NTCIP 1204, and any NOAA standards; and
- Provision of metadata checklists or tools implementing those recommendations.

Section 6 of this report explicitly addresses these factors in the treatment of metadata in the Guide.

3.2.6 ESS Checklist

Appendix D of the Guide provides a checklist summarizing the key points from the body of the document. The checklist is in the form of an outline that roughly follows a typical planning and deployment process. Specific siting and sensor configuration criteria are included in appropriate contexts within the checklist.

The checklist should be updated for any changes or extensions to material in the body of the Guide. In particular, as discussed earlier in this evaluation, the checklist should be updated to include discussion of constraints and prioritization among sites being considered (Section 3.2.1) and discussion of integration with other ITS considerations (Section 3.2.2).

[1] These recommendations, in the form of the *Clarus* Metadata Dictionary, are available online at http://www.clarusinitiative.org/documents.htm.

4 STATE DOT IMPLEMENTATION EXPERIENCE AND EVALUATION

This section discusses State DOT experiences in implementing and evaluating the Guide as part of recent or new ESS deployments.

4.1 Michigan Department of Transportation Implementation and Evaluation

4.1.1 Background

In 2006, the Michigan DOT (MDOT) began to plan the deployment of RWISs and ESSs across all regions of the state. While the Department has previously supported aeronautical weather stations across the state, this plan is the first effort focused on road weather information collection by MDOT. The plan is a significant component of MDOT's ITS Strategic Plan, and is coordinated with the ITS regional architecture and statewide ITS deployment plans.

MDOT decided that its initial RWIS program deployments would be in its Superior Region. The effort was segmented into several projects, the first of which was to study road weather information needs and opportunities, to be documented in a Concept of Operations (COO). That project was followed by the detailed design studies, which resulted in a set of design and procurement documents. Construction of the first set of ESS sites and RWIS implementation is planned for completion in 2008.

The MDOT development timeline has coincided with this review of the ESS Guide and has allowed participation in many of the MDOT RWIS program milestone meetings. While it is not the intent of this report to reproduce or redistribute the MDOT project documentation, it was helpful to the analysis to have direct access to MDOT and its contractor personnel. Meetings attended in conjunction with the MDOT project included:

- RWIS Project Deliverables Review, April 10, 2007 – Reviewed analysis of user needs and draft Concept of Operations for RWIS/ESS in Michigan's Superior District (Upper Peninsula)
- Design Project Kickoff Meeting, Sept. 10, 2007 – Kickoff meeting for final site selection and site design pursuant to developing bid packages for build-out
- Design Project Progress Meeting, Nov. 6, 2007 – Update on progress of site surveys, plans, and geotechnical analysis in preparation for preliminary design submittal
- Design Project Preliminary Design Review Meeting, Dec. 13, 2007 – Preliminary design review of ESS site design, RWIS, and associated DMS
- Design Review Meeting, March 5, 2008 – Final design review for all components of the project; distribution of bid package documents for review

4.1.2 Experience Relative to the Guide

4.1.2.1 Requirements Assessment

The requirements assessment for MDOT's Superior Region RWIS deployment was performed in the first study project and documented in the COO as described in Section 4.1.1. Requirements in the COO addressed user needs, ESS siting, sensors and devices, and communications/power/processing. These categories broadly match the content of the requirements Section 2.0 of the Guide.

Section 4 of the COO documents the RWIS User Requirements from the perspective of each of several stakeholder groups, including operators, system administrators, maintenance technicians, trainees, DOT management, media, public/private partners, and road maintenance services. This is similar in concept to the discussion of functional applications in the introductory text of the Guide Section 2.0. These user perspectives provide detailed interface requirements for each stakeholder group, but provide relatively few functional requirements.

Section 5 of the COO begins with a reference to the FHWA Guide Section 2.2 and the discussion of "local" and "regional" siting issues. It also notes that "the approach selected during the stakeholder process is a combination of these," driven by the need to get data for particular "trouble spots" while retaining the flexibility to apply the data regionally. This is to be accomplished by deploying a full complement of sensors at each station and by locating and designing each site to serve both types of applications. This section also discusses MDOT's interest in locating the ESS sites near other state facilities so as to reduce the cost of utility connections. The section concludes with a list of proposed locations.

Section 6 of the COO corresponds to Section 2.1 of the Guide and discusses environmental sensors and devices. The applications of road weather information are discussed as an introduction to the sensors that provide the underlying data. Station sensor configurations are then presented for "basic" and "reduced power" installations, and for optional sensors applicable to those configurations. Special case configurations for seasonal flooding and portable ESSs are also discussed.

4.1.2.2 Site Selection

Site selection for the Superior Region has been ongoing throughout the project. Sites were initially nominated by stakeholders and consolidated into a list of thirty-three candidate sites. These sites were, for the most part, initially selected based on attributes that would categorize them as "local" ESS sites—historically heavy local snow, or high winds and blowing sand, or severe icing. Some sites, however, were suggested specifically because weather monitoring in the area was particularly limited and there was a need for a "regional site."

Based on the studies documented in the COO and MDOT's program budgeting, the list of sites was reduced to six high-priority locations to be deployed in conjunction with five dynamic message signs (DMSs). MDOT's desire to integrate RWIS and ESS deployment was a significant consideration in all site selection discussions and provides an immediate and public demonstration of the value of RWISs and ESSs.

Site selection was further refined in the RWIS design phase. Discussion in the design project kick-off meeting led to a relocation within the general vicinity of two of the six sites. It was further noted in the meeting that sites along the M-28 corridor had not been fully evaluated with respect to the Guide in prior phases and should be further evaluated to provide optimal siting. Site selection was finalized in the Preliminary Design Report, specifically noting that criteria in the Guide provided the basis for siting.

4.1.2.3 Recommended Siting Criteria

The Preliminary Design Report describes the siting and sensor requirements specific to each of the six selected ESS locations and explicitly references the Guide as a basis for the design of each site.

> "In general each specific sensor has its very own unique set of requirements which must be met, such as mounting placement height on tower, to enable optimal ESS site operation. However each RWIS ESS site location as a whole also has some very high-level requirements and guidelines, as defined by the FHWA. Generally the major guidelines applicable to this deployment phase are:
>
> - Distance from edge of pavement (maintaining minimum distance/clearance of 30 feet from the edge of pavement).
> - Openness of site location (eliminating site locations near a hill, trees, body of water, bridges, etc.). Typically ESS sites must be about 10 times (the size of the nearest obstruction) farther than obstructions.
>
> All RWIS ESS sites in this Bid package were selected and further defined following the FHWA Guide, and are located in open areas for better representation of the local weather elements while minimizing weather data measurement bias."

Site locations and ESS design specifications are assembled into procurement packages for bidding. Consistent with MDOT's standard practices, the relevant ESS specifications have been compiled into a *Special Provision for Environmental Sensor Station* (Special Provision).

Table 1 - Guide Siting Criteria and MDOT Implementation

Guideline Topic	Relevant Text from Guide	Discussion	Exception to Guidelines?
Tower Design	"The tower should be sturdy (e.g., open matrix type) using instrument booms to reduce contamination of sensor data by turbulence and wind flow around the tower structure. \ For water level and road flooding applications, standpipes (i.e., vertical pipes ranging from 3 to 12 inches in diameter and up to 10 feet tall such as shown in Figure 5) are typically used. Masts can be placed above the top of the standpipe to mount wind, air temperature/dewpoint, or other weather sensors. In this situation, the weather sensors may not be consistent with the siting guidelines below; however, the sensors should be installed high enough above the top of the standpipe to eliminate the environmental effect caused by the standpipe."	Tower design is specified in the Special Provision and is consistent with this description. Water level and road flooding applications are not applicable to any of the sites.	N

Guideline Topic	Relevant Text from Guide	Discussion	Exception to Guidelines?
Distance of Tower from Roadway	"At this time, there are no studies that determine the minimum distance the tower should be placed from the roadway to avoid the effects of traffic on the accuracy of the sensors (e.g., heat, wind, splash) or how close it must be to adequately represent the environment over the roadway. Towers are most frequently installed within a range of 30-50 feet (9-15 meters) from the edge of the paved surface."	Distance from pavement ranges from 34 to 51 feet.	N
Pad and Barrier	"The tower base should be attached to a concrete pad to provide a sturdy platform. The size of the pad should take into consideration the soil conditions, frost activity, and wind loading. If the tower is within the clear zone, a barrier or guard rail should be used."	Concrete pad is specified in the Special Provision and is consistent with this description. None of these sites are within the clear zone.	N
Tower Base Elevation	"The tower base should be at the same elevation as the surface of the road, if possible."	Elevation offsets are not noted in the Special Provision or plans. All sites are located on level ground near roadways.	N
Tower Height	"The tower height should depend on the planned sensors. If a wind sensor is planned, the tower should be tall enough to install it at a height of 33 feet (10 meters)."	Per the Special Provision, the tower height will be according to the manufacturer's requirements, but not less than 30 feet. This is not necessarily a deviation from the Guide, since the wind sensor could be on a three-foot boom.	N

Guideline Topic	**Relevant Text from Guide**	**Discussion**	**Exception to Guidelines?**
Site Terrain	"Towers should be sited on relatively flat terrain. If possible, avoid steep slopes within 300 feet (approximately 90 meters) that could impact wind measurements. Sites near steep road cuts, swampy areas, and bedrock (a detriment to cable trenching) should be avoided."	All sites are on relatively flat terrain. Sites near open water are intentionally so located for monitoring local conditions.	N
Tower Wind Shadow	"If possible, towers should be placed upwind of the roadway based on the predominant wind direction for the season of most interest.	Predominant wind directions are not explicitly noted in the design documentation, but all sites are described as being representative of local conditions.	N
Surrounding Terrain Coverage	"The surrounding terrain coverage out to at least 50 feet (15 meters) should be low vegetation or native soil."	The exact nature of coverage and distance to tree lines are not indicated on plan sheets.	N
Standing Water	"Avoid standing water. Many ESSs are installed on the opposite side of a depression adjacent to the road. This depression is a natural collection point for rain and/or water draining off the road. Given the choice of two potential sites, both of which would satisfy other siting requirements, the ESS should be installed in the one less likely to be affected by ponding water."	Several sites are indeed near drainage ditches, but there are no indications of extended periods of ponding.	N

Guideline Topic	**Relevant Text from Guide**	**Discussion**	**Exception to Guidelines?**
Site Fence	"A fence should cordon off the tower from its surroundings if the threat of vandalism is present. If possible, the distance between the fence and the tower should be at least 15 feet (5 meters). This distance is recommended to minimize the effect of the fence on the sensors readings especially when weeds and/or debris on the fence act as a horizontal obstruction. Limited space in the right of way may require the distance between the fence and tower to be reduced. The positioning of the fence and its gate should not restrict access to the equipment or the tower. Careful planning is necessary to assure that fold-over towers with their attached instrumentation may be lowered with sufficient room for a technician to work on the sensors. The fence should not obstruct any sensors on the tower."	The Special Provision specifies the design of the fence and gate. Sites are specified to be as small as ten feet by ten feet. The gate is to be designed so as to allow access to both sides of the tower when it is lowered through the open gate.	Y
Unauthorized Access	"Anti-climb panels can be installed to restrict persons from climbing up the open lattice of towers."	Anti-climb panels are not specified in the Special Provision, but access is limited by the site fence. The top of the fence is specified to include materials intended to prevent unauthorized entry, meeting the intent of the guideline.	N

Guideline Topic	Relevant Text from Guide	Discussion	Exception to Guidelines?
Maintenance Access	"Ease of maintenance tasks should be considered in the siting, such as the use of folding towers and the availability of maintenance vehicle pull offs. In some situations, sensor heights may need to be adjusted to accommodate maintenance activities."	Folding towers are specified in the Special Provision. Vehicle access was evaluated and noted for all sites.	N
Alternatives to an ESS Tower	"Insufficient space in the right-of-way outside the clear zone may preclude installation of a tower. If requirements for road weather information preclude selecting another site, DOTs may find other options for installing some atmospheric sensors."	The guideline is not applicable. All sites are designed with the tower described in the Special Provision.	N
Site Metadata	"The positioning of the tower and the height of the sensors on the tower should be included in the metadata file available for the data customers."	Metadata meeting this guideline are required in the Special Provision.	N
Sensor Locations	Sensor location guidelines are detailed throughout Section 4.2 of the Guide.	The Special Provision specifies that all ESS instruments and devices shall be installed in accordance with manufacturer guidelines. It furthermore specifies that the contractor shall comply with the latest edition of the Guide.	N

4.1.2.4 Additional Considerations

Significant attention was given throughout the planning process to the non-meteorological aspects of the Superior Region ESS deployment. Power and communications issues are addressed with their own Special Provisions within the bid package. Aesthetics were explicitly considered in Section 5.0 of the Preliminary Design Report and are being addressed in a manner consistent with the Guide. Security and access are addressed by sites designed specifically to conserve the site footprint, fencing, and access constraints by using a “folding” tower design that lowers the tower and instruments through the gate opening in the site fence.

Siting metadata is not yet available for the Superior Region deployment, but requirements for the provision of metadata by contractors have been included in the Special Provisions. Metadata is to be provided and, at a minimum, include all items listed in the most recent version of the Guide.

4.1.3 Conclusions and Recommendations

The MDOT Superior Region RWIS/ESS program has made extensive and profitable use of the Guide. The Guide was consulted at key milestones throughout the program thus far and has provided a base body of knowledge for much of the system documentation.

Integration with other ITS components—in this case, message signs—is an important aspect of the Superior Region deployment that is not, however, detailed in the current Guide. The inclusion and evaluation of these components as part of the road weather information requirements can impact, for example, site location and the specification of particular sensors to support the desired messaging.

The only significant deviation from the guidelines in the MDOT design was the size of the fenced enclosure for the ESS. The Guide recommends fifteen feet between the ESS tower and the fence, whereas the MDOT Special Provision for ESS specifies a ten feet square enclosure for the commercially-powered site—five feet between the tower and the fence. The Guide bases its recommendation on the need to preclude the enclosure from affecting sensor measurements, but MDOT has placed other specifications on sensor accuracy that will force the contractor, ESS manufacturer, and maintenance provider to make allowances for the smaller enclosure.

It has also come to light in the Superior Region ESS deployment that the siting criteria within the Guide need to be updated to reflect advances in sensor design. Many of the recommendations in the Guide (for example, the sensor locations in Section 4.2) were developed for older-model sensors and may be inappropriate for the newer equipment. In practice, MDOT specified sensor performance criteria in its Special Provision for ESS and required the deploying contractor to both comply with the Guide and to install and calibrate the ESS according to the manufacturer’s guidance. It is recommended that the Guide suggest in Section 4.2 that agencies and their contractors follow the manufacturer’s guidance for installation and calibration of all sensors, relying on the subsequent guidance only in the absence of more specific instructions from manufacturers.

4.2 Idaho Transportation Department (ITD) Evaluation

4.2.1 Background

ITD has operated RWISs throughout the state of Idaho since the late 1980s. Data provided by the system has been useful to both ITD maintenance staff and travelers throughout the state. Information in the form of observation data and camera images is available to the staff through the Road-Weather Integrated Data System (RWIDS) and to the travelers on the ITD website.

ITD contracted with Iteris in 2005 to assist with the planning, site development, site assessment, and procurement for its Statewide RWIS Build Out project. As described in the Site Assessment Report, the project developed an implementation approach for deployment of a significant number of RWIS ESSs over several years, developed the basis for subsequent plans and specifications, and provided an assessment of build out priorities from among the potential ESS sites. FHWA's Guide was used by both ITD and Iteris in this project. The report concluded with recommendations for deployment over a multi-year period.

ITD's prime contractor, Vaisala, is providing the ESS packages and calibration services during the construction phase, with site installation being provided by an Idaho-based civil engineering contractor. The first of these new sites was deployed in 2007.

Most of the original ESS sites need upgrades to make the ESS messages comply with NTCIP 1204. ITD has contracted to make these upgrades.

ITD has considered creating an algorithm that would automatically present a message recommendation to an operator for DMSs. The DMSs in Idaho are operated by other state and local agencies, however, and not by ITD.

ITD is currently not considering using ESS information for their 511® system. ITD believes that the trend for 511 is going away from presenting weather information except for alerts and warnings received from the National Weather Service.

4.2.2 Experience Relative to the Guide

4.2.2.1 Requirements Assessment

The Site Assessment Report describes in detail the ITD stakeholders involved during the planning phase. Two decision points for site placement were money and number of sites in each district. Based on the number of sites, stakeholders looked for trouble spots and areas that would represent a large segment of roadway suitable for an ESS site. Factors that were found to be important in site assessment and prioritization include the following:

- Maintenance Support Characteristics
- Weather Characteristics

- Road Characteristics
- Logistical Characteristics
- Other Functional Characteristics

4.2.2.1.1 Maintenance Support Characteristics

Because of their knowledge of local weather and their experience with maintenance, the input received from ITD District personnel, maintenance foremen, and lead workers was the primary input used in the prioritization of the ESS sites. These stakeholders are often called on to drive out into their areas of responsibility to assess road weather conditions. This practice provides first-hand knowledge of the situation, but may incur increased risk, time, and expenses in labor and fuel. RWIS deployments that address the need for timely and operations-critical information can mitigate these costs and risks.

These advantages can be further leveraged by considering the use of a single site to provide observations that may be characteristic of more than one roadway or maintenance area. Sites that could be used for multiple roadways or maintenance needs should receive higher priority in deployment decisions.

4.2.2.1.2 Weather Characteristics

While the Guide draws a distinction between regional and local sites, the variation in Idaho’s topography, like that of other mountainous states, calls for ESS sites with widely varying areas of application. A site may be typical of a long highway segment along the base of a range, but have very different conditions than within an adjacent canyon. ITD chose to give higher priority to sites that are representative of conditions over larger areas or longer roadway segments.

Some ITD maintenance personnel indicated that they may use data from the existing RWIS ESS as a forecasting tool for conditions downstream of the weather event. In the absence of better forecasting tools, sites where personnel suggested that this might be helpful were given higher priorities.

4.2.2.1.3 Road Characteristics

ESS sites along roadways with higher functional and winter maintenance classifications were given higher priority by ITD than those with lower classifications. This prioritization reflects the usefulness of RWISs in providing information that improves winter maintenance and traveler information on more heavily traveled routes.

4.2.2.1.4 Logistical Characteristics

Provision of services for successful RWIS ESS operations was a consideration for ITD in siting. Siting decisions balanced optimal ESS placement with cost increases, and did not take exception to guidelines or affect siting priorities. Logistical factors considered by ITD included access for construction and maintenance, right-of-way ownership, power, and communications. Alternative locations or services were evaluated for cases where the preferred or standard configuration was not viable. For example, a site without commercial power access was evaluated with solar power.

4.2.2.1.5 Other Functional Characteristics

ITD site assessments included consideration of existing and planned ESSs not associated with ITD or road weather systems. Proposed ITD sites that were near existing ESSs were evaluated to determine whether maintenance information needs could be fulfilled by the existing sites. If those needs could be fulfilled by enhancing the existing site, the proposed new ESS was given a lower priority.

Site assessments also considered proximity of other ITS field elements with which ESSs could share power and communications, or with which there might be additional information advantages. ESS sites downstream of DMSs, for example, provide notification of weather conditions to allow travelers to find alternative routes.

4.2.2.2 Site Selection

A comprehensive RWIS Location Data Collection Checklist was developed by ITD from the Guide. The checklist was used at each location to document the characteristics of the location, function, purpose, observations desired, physical description, site metadata, sensor considerations, and other considerations such as aesthetics, right-of-way issues, existing or planned improvements, and security concerns. Several fields were provided for miscellaneous comments. Development of the checklists confirmed that the purpose of most of the sites was for maintenance, with traveler information being a distant second, and that the function of the sites was predominantly local. In addition to the checklist, sketches and photos were taken of each site and the surrounding area.

The Site Assessment Report was largely composed of these checklists. In the report, ITD did an excellent job of documenting the processes and results of their site investigations and assessment. The report includes a comprehensive summary of the sites, providing the estimated cost and installation year for each site. In support of this analysis, ITD gave descriptions by district of each site being considered and the intended siting criteria.

4.2.2.3 Recommended Siting Criteria

ITD ESS siting criteria have been directed primarily at supporting highway winter maintenance. Within the maintenance context, supporting capabilities, such as providing information for pavement temperature forecasts, were considered on a case-by-case basis. The detailed Site Assessment Report results for each potential site configuration were evaluated for types of sensors, cameras, power and communication services, and installation and maintenance.

Standard atmospheric sensors considered in the report include:

- Air Temperature
- Relative Humidity
- Precipitation (Y/N)
- Wind Speed and Direction
- Barometric Pressure

"Special" sensors in the context of the Site Assessment Report are characterized by increased cost and technical complexity beyond that of the standard atmospheric sensors. Such sensors include:

- Present Weather Sensors
  - Precipitation Type and Rate
  - Visibility
- Solar Radiation
- Sub-Grade Moisture and Temperature
- Others

Pavement sensors, where desired, were assumed for site evaluation purposes to be in-pavement pucks providing information such as temperature, chemical composition, moisture, and freeze point. ITD would like guidance on selection of sensors to support particular applications to be included in the Guide.

Traditional utility-based power was preferred at all sites. In those cases where access to utility power service was limited, other options were evaluated for consistent installation and maintenance cost bases.

Telephone landlines were the preferred means of communications between the RWIS ESS and central system servers. In those cases where access to landline service was limited, cellular and radio services were evaluated for consistent installation and maintenance cost bases.

Cameras were included in each site assessment, distinguishing only between use of fixed versus pan-tilt-zoom (PTZ) models. The intended direction of view for the cameras and the need for street lighting were noted, if appropriate. ITD would like guidance on selection of cameras to support particular applications to be included in the Guide.

Installation features in the base siting criteria included a simple foundation, fold-over tower, and fencing, with notations for significant grading or clearing requirements.

4.2.2.4 Additional Considerations

There were several challenges during right-of-way negotiations, one of which proved to be especially difficult. Due to the large amount of federal land in Idaho, each county and/or division is responsible for negotiations and has its own unique rules.

The selected contractor and ITD differed on their interpretations of the Request for Proposal (RFP) regarding designing and building tasks for the ESS deployment. Due to the differing interpretations, negotiations took longer than expected. If possible, ITD would like guidance on ESS deployment proposal and procurement requests added to the Guide, or another set of guidelines produced for this purpose.

A site had to be placed in a different location due to archaeological evidence of ancient human migration. More information in the Guide would be helpful.

Soil evaluation was not specifically done at each site. ITD ran into some problems with lava rock and had to spend more money during construction. More information in the Guide would be helpful.

Roadside safety clear zones were not specified in the RFP. A change order was required to address this issue and caused a delay in the project. More information in the Guide would be helpful.

A reference to the National Pollutant Discharge Elimination System (NPDES) Stormwater Guide should be provided in the Section 4.1 of the Guide (relative to the discussion of standing water) for stormwater management at sites. [2]

Coordinating the construction of a site with the installation of power and communications was a major challenge. Documenting risks and assumptions associated with these services in a Project Management Plan is important in managing deployment activities. A reminder to address these factors early in the deployment process would be helpful in Section 5 of the Guide.

With the rising cost of fuel for generated power, the decreased amount of sun for solar panels, and the security issues with publishing power line locations, selecting the correct power source for each site was another challenge. Another consideration was the amount of snow, up to 15 feet, that might accumulate at the site that could affect the power. Section 5.2 of the Guide should address the potential impact of weather conditions on availability of power source alternatives.

Communication between the remote processing unit (RPU) and the server was the most difficult challenge. Wherever there was fiber, the choice was simple. Although cell phones are more expensive than fiber, they are the only other viable option as the amount of snow in Idaho would make using satellites very problematic. During future deployments, ITD will prioritize locations with fiber communications.

4.2.3 Conclusions and Recommendations

In summary, ITD suggests the following additions to the Guide as discussed elsewhere in this section:

- Guidance on selection of cameras to support particular applications
- Guidance on selection of sensors to support particular applications
- Guidance on creating RFPs for ESS deployment
- Guidance on archaeological impacts on siting (“ancient migrations”)
- Guidance on soil evaluations
- Guidance on roadway clear zones
- Reference to the NPDES Stormwater Guide

[2] The Stormwater Guide is available at http://www.epa.gov/npdes/pubs/sw_swppp_guide.pdf.

Throughout this process, ITD has learned that deploying an RWIS system is hard work. They have also learned that communications and power issues need to be determined early in the project.

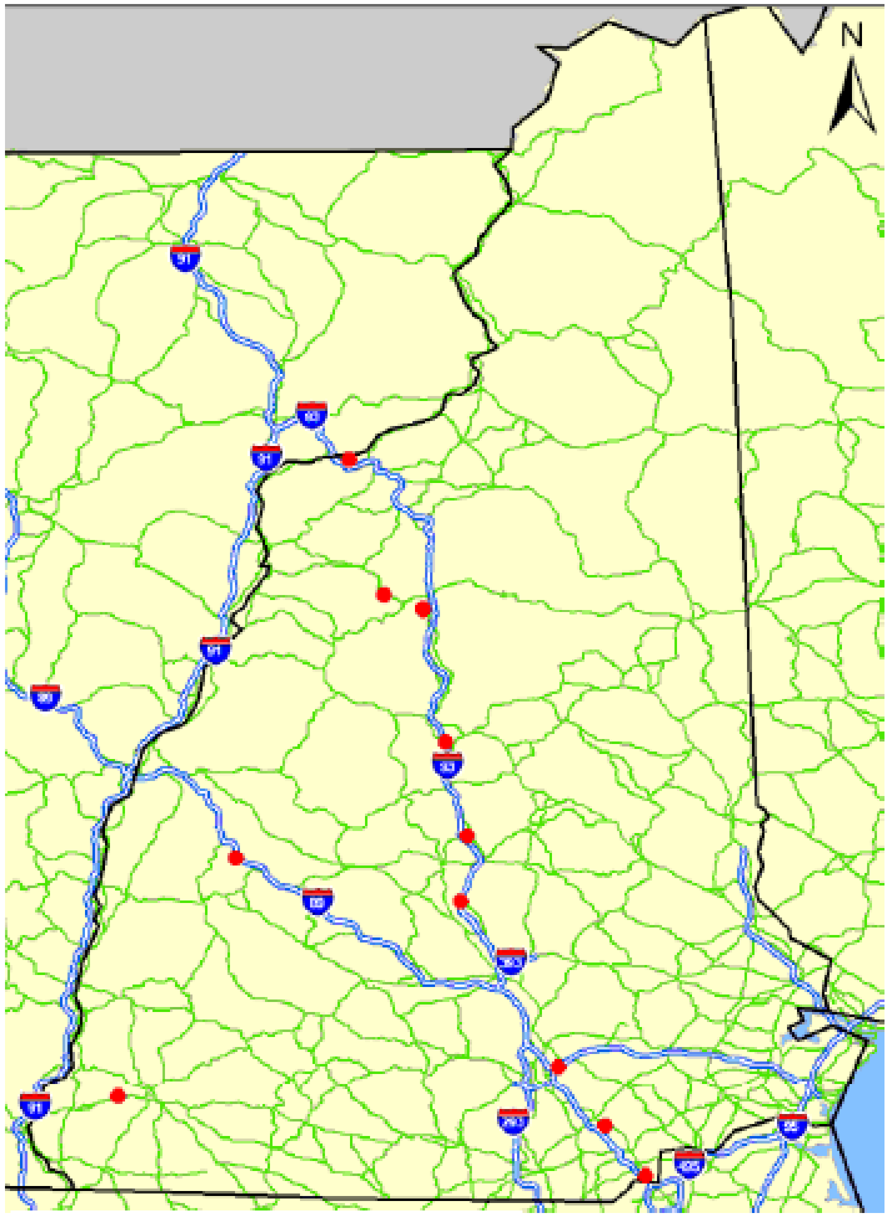
4.3 New Hampshire Department of Transportation Evaluation

4.3.1 Background

New Hampshire's RWIS program was developed primarily to address traveler information and winter maintenance needs in a state that can experience severe winter weather any time between October and April. It was financially important to the state to optimize allocation of maintenance resources, including chemical applications, during winter. New Hampshire DOT (NHDOT) also saw an opportunity to include weather considerations in work planning during construction season. Areas of traveler information support include identification of adverse weather conditions, issuance of traveler advisories, pavement forecasts for specific roadway segments, and dissemination of data to other government agencies and educational institutions.

The RWIS program was a development from the Tri-State Rural Advanced Traveler Information System (TRIO), a Multi-State ITS project carried out jointly by New Hampshire, Maine, and Vermont. NHDOT deployed a pilot ESS on the Little Bay Bridge in Newington, NH in 1997 and then initiated plans for a larger, statewide system.

The deployment of 12 ESSs in New Hampshire in 2005-2006 represented a successful collaboration of a number of groups, including NHDOT divisions and outside agencies. Highway design, highway maintenance, materials and research, and the Bureau of Environment all participated from within NHDOT. FHWA and the Highway Patrol also provided support and Plymouth State University (PSU) served as the DOT's meteorological consultant. One of the PSU staff members visited potential sites with NHDOT. ESS locations are shown in Figure 1. Most of the ESSs were sited to be representative of meteorological conditions over a wide area. There was also a focus on serving the heavily traveled I-93 corridor, New Hampshire's main north-south highway. The stretch of I-93 between the Massachusetts State Line and Manchester, NH is a major commuter artery with some of the highest traffic volumes in the State. I-93 also serves as a major recreational route. Keeping this route open to the winter recreational areas in the Lakes Region and the White Mountains is very important to New Hampshire's economy.



Source: New Hampshire DOT.

Figure 1 – New Hampshire ESS Sites

4.3.2 Experience Relative to the Guide

4.3.2.1 Requirements Assessment

NHDOT recognizes that siting of ESSs is a balancing act with multiple objectives. Their goal is to obtain representative data for forecasting and resource deployment decisions, while also serving specific trouble spots that are remote from maintenance facilities. The Guide was not complete at the time that NHDOT sited its ESSs. NHDOT's Project Manager attended a seminar on ESS siting at their vendor's headquarters. He obtained a site survey checklist that he used in the process and filled out for each prospective site.

4.3.2.1.1 Maintenance Support Characteristics

Local NHDOT maintenance personnel were consulted during the siting process and their knowledge of roadway characteristics was considered by NHDOT headquarters personnel to be very helpful. NHDOT also wanted to involve local maintenance supervisors as a way of educating them about RWISs and future maintenance requirements. The primary users of RWISs are winter maintenance personnel. Summer maintenance and construction personnel are likely to take advantage of the information as well.

NHDOT currently has a maintenance contract providing access to remote diagnostics over the phone, reducing the costs for NHDOT. Some basic preventive maintenance such as camera lens cleaning is done by NHDOT and they are starting to train some of the maintenance personnel in the signal/traffic bureau to service electronics as well.

Maintenance personnel also played a key role in the deployment of first-phase ESSs. NHDOT bridge maintenance personnel ended up pouring all of the concrete pads for the ESSs since they could do it much less expensively than the vendors. Coordination was important to make sure that mechanical and electrical connections were compatible with the vendors' designs. While the Guide does not need to address these types of design issues in detail, identification of these issues and some high level guidance would be helpful.

4.3.2.1.2 Weather Characteristics

NHDOT's ESSs include sensors that provide wind speed and direction, humidity, pressure, air temperature, dewpoint temperature and visibility. An ultrasonic anemometer was selected for inclusion for enhanced reliability. Precipitation sensors differentiate between rain, snow, and drizzle and measure actual precipitation rates as water accumulation. A minimum of two pavement sensors and one subsurface sensor at 47cm depth are included at each ESS station. Ozone sensors were provided as part of a cooperative agreement with Plymouth State University. Roadway sensors provide pavement temperature, freeze point temperature, and chemical concentration data. NHDOT has found the pavement sensors to be very reliable. Traffic count data are also collected at ESSs.

NHDOT has found that no product performs all tasks well. Some products are stronger in some areas and weaker in others. Agencies have to understand their priorities and look for combinations that best meet their needs. A better understanding is needed of active and passive sensors, and the tradeoffs involved.

4.3.2.1.3 Road Characteristics

The NHDOT RWIS program is focused on the Interstate system and major trunk highways. The limited-access highway system does not extend, however, to the southwest and far northern portions of the state. As a result, tradeoffs need to be made between the need to represent statewide meteorological conditions, service the largest number of users, and address critical locations in the system.

4.3.2.1.4 Logistical Characteristics

Power, communications, available real estate, and easy access were also considered as primary siting requirements. Power availability was an absolute requirement and was not a problem at most sites. NHDOT generally sited ESSs on its own property, with several of them located at rest areas or maintenance sheds. They avoided using easement rights of way but this may be an option in the future.

One of the goals of NHDOT in siting ESSs is to reduce recurring costs, of which communications is a major component. Vendors bidding on the initial deployment had to provide a communications plan for each site. Two sites have direct access to NHDOT facilities while most others use cell phones for communication. One site, Franconia Notch, does not have cell phone coverage and uses satellite communication. In siting future ESSs, NHDOT will try to avoid satellite communications since this costs \$50 to \$60 per month compared to only \$15 to \$18 per month for cell phone coverage. Stations generally report at 15 minute intervals although they are polled more frequently.

4.3.2.2 Site Selection

Most of the initial ESSs deployed were sited to be representative of meteorological conditions over a wide area. There was also a focus on serving the heavily traveled I-93 corridor, New Hampshire's main north-south highway. Two locations were selected to address specific, localized problems. One is located along Route 9 in Chesterfield in southwest New Hampshire. The ESS is located on top of a hill above the Connecticut River Valley where a combination of heavy truck traffic and wet, icy conditions can create safety problems. The other spot location is along Route 112 at Lost River in northwestern New Hampshire. This is a roadway trouble spot at high elevation and is about an hour from the nearest patrol shed.

NHDOT is generally happy with the locations selected. However, two sites have not proven to be satisfactory to NHDOT. One is located at the patrol shed along Route 101 in Manchester. This ESS is located 150 feet from the roadway in a tree-shaded area and as a result does not effectively represent the nearby roadways. One of the ESSs along I-93 was located in the median near Woodstock. This site is subject to localized air turbulence generated by traffic, which may not be representative of conditions in the general area. Adding some examples to help illustrate the limitations created by compromised siting could be a helpful addition to the Guide.

4.3.2.3 Recommended Siting Criteria

NHDOT is planning to deploy 10 additional ESSs when funding becomes available. The Guide will be used but not applied strictly. Future deployments are being planned based primarily on geographic priorities which are listed below:

- I-93 corridor (major construction will be occurring over the next several years at the southern end of the corridor)

- A minimum of two sites per district are needed to provide information to local maintenance personnel. There are six districts.
- More ESSs are needed in the western part of the State since weather generally moves across the State from west to east.

4.3.2.4 Additional Considerations

NHDOT expects to use the ESSs to support traveler information services. Wind speed information can be used to issue warnings to trucks. They are considering linking ESSs to DMS warning signs that would be used when ice or high winds are experienced. While areas where these weather conditions may occur are generally known, siting of the ESS is critical in providing accurate indications of those conditions. One of the initial ESSs was deployed in the roadway median in a valley and is not necessarily representative of conditions facing vehicles along the roadway or in the general area.

Plymouth State University is currently looking into data quality requirements, as well as data archiving. There is currently no central repository in the DOT for weather information. NHDOT believes this would be useful for evaluating maintenance strategies and providing improved traveler information services.

NHDOT would also like to share information with other States. They are sharing information with National Weather Service through Plymouth State University and have recently made an arrangement with the Massachusetts Highway Department. There are several issues in information sharing including firewall/security within the Department and the fact that presentation formats need to be simplified in order to be useful. Personnel do not have time to interpret complex information at times of approaching severe weather when the information is most urgently needed.

4.3.3 Conclusions and Recommendations

NHDOT was not able to use the Guide in siting the initial set of ESSs but plans to use it in combination with their own criteria in the future. NHDOT believes the Guide can be helpful to address site-specific concerns; specifically the tradeoff between meteorological integrity and logistical concerns.

The following additions to the Guide are suggested as reflections of NHDOT's experience with ESS siting:

- Guidance on selection of sensors from among alternatives measuring the same meteorological parameters
- Examples of the tradeoffs between site selection constraints and the typicality of meteorological conditions at the site

5 RECOMMENDATIONS FOR SITING GUIDE ENHANCEMENTS

The existing Guide provides a wealth of information for DOTs deploying ESSs. It has been useful to DOTs as reference material and in providing specific guidance in siting and design. Significant new opportunities in ESS deployment are presenting themselves, however, to the transportation and meteorological communities. Expansion and clarification of the Guide in key areas would substantially assist in capturing those opportunities.

Specific recommendations for changes to the Guide are shown in Table 2.

Table 2 - Recommended Changes to Guide

Guide Section	Recommendation (including section of this report in which it is discussed)	Disposition	Change to Guide? (Y or N)
2.2; 5.3	Include discussion of bridge anti-icing systems (Section 3.1.1)	Deployment of an ESS in conjunction with an anti-icing system would be part of a discussion of local site requirements and should be part of Section 2.2. It is also similar to ESS deployment with other ITS as described in Section 5.3. The discussion there should include anti-icing systems.	Y
n/a	Include discussion of mobile sensors (Section 3.1.2)	The purpose of the Guide is to assist in siting of fixed ESSs. Mobile sensors, while providing some of the same meteorological data, do not have any of the same siting issues. The recommendation is out of scope for this Guide.	N
1	Add a discussion of “How to Use this Guide” (Section 3.2)	The Guide would benefit from implementation of this recommendation as part of the introductory material in Section 1.	Y
1	Include a description of how the Guide fits the systems engineering of ESS deployments and the National ITS Architecture (Section 3.2)	This is entirely consistent with FHWA guidelines for ITS deployments and should be added to Section 1.	Y

Guide Section	Recommendation (including section of this report in which it is discussed)	Disposition	Change to Guide? (Y or N)
5.4	Include more information on maintenance of ESS (Section 3.2.1)	Discussion of how maintenance consideration may impact siting is relevant and can be an expansion on the text already in Section 5.4 of the Guide. Detailed discussion of maintenance procedures is, however, out of scope of the Siting Guide.	Y
2.3	Include discussion of *Clarus* in the Guide (Section 3.2.1)	A discussion of *Clarus* can be added to the existing discussion of meteorological information partnerships in Section 2.3.	Y
Appendix D	Include items for (a) constraints and prioritization (Section 3.2.1) and (b) integration with other ITS (Section 3.2.2) in the ESS Checklist (Section 3.2.6)	Additional checklist items, consistent with other changes being made to the Guide, are appropriate.	Y
2.2; 5.3	Include discussion of ESS deployment in conjunction with other ITS (Section 4.1.3)	Deployment of an ESS in conjunction with any other ITS (in this case, DMS) could be part of a discussion of local site requirements and should be part of Section 2.2. ESS deployment with other ITS is already described in Section 5.3.	Y
4.2	Update the discussion to include new sensor designs (Section 4.1.3)	While it might be desirable to cover all sensor designs in the Guide, siting criteria originate with the manufacturers of those sensors. The Guide should be updated to direct readers to the manufacturer’s guidelines for installation and calibration.	Y

Guide Section	Recommendation (including section of this report in which it is discussed)	Disposition	Change to Guide? (Y or N)
n/a	Include discussion of creating RFPs for ESS procurement and deployment (Section 4.2.3)	Creation of the RFP is outside the scope of this Guide, although the Guide may support or be referenced in an RFP.	N
5.4	Include discussion of archaeological constraints (in this case, ancient human migration routes) in siting (Section 4.2.3)	The discussion of Section 5.4 should be expanded (and renamed) to include siting considerations that are not specific to meteorology (which is discussed in Section 5.1) and supporting services (power in Section 5.2 and communication in Section 5.3).	Y
5.4	Include discussion of soil conditions in siting (Section 4.2.3)	The discussion of Section 5.4 should be expanded (and renamed) to include siting considerations that are not specific to meteorology (which is discussed in Section 5.1) and supporting services (power in Section 5.2 and communication in Section 5.3).	Y
5.4	Include discussion of clear zones in siting (Section 4.2.3)	The discussion of Section 5.4 should be expanded (and renamed) to include siting considerations that are not specific to meteorology (which is discussed in Section 5.1) and supporting services (power in Section 5.2 and communication in Section 5.3).	Y

Guide Section	Recommendation (including section of this report in which it is discussed)	Disposition	Change to Guide? (Y or N)
4.1, 5.4	Include a reference to the NPDES Stormwater Guide for stormwater management at the ESS site (Section 4.2.3)	Stormwater is relevant to both the discussion of standing water in Section 4.1 and to discussion of “other” siting considerations in Section 5.4, and should be added in both places.	Y
2.1	Include more information on camera and sensor descriptions and applications (Section 4.2.3)	The discussion in Section 2.1 provides substantial discussion of cameras, sensors, and their applications. More detailed information than is already given in that section would be better obtained from the manufacturers of those instruments.	N
3.0	Include some examples of tradeoffs or limitations created by compromised siting (Section 4.3.3)	The two examples mentioned by NHDOT in this report should be added to the Guide in Section 3.0.	Y

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6 RECOMMENDATIONS FOR ESS METADATA

The Guide noted that "an important aspect of the effective use of road weather data from ESS is the documentation and distribution of the site's metadata." Metadata is structured information that describes, explains, locates, or otherwise makes it easier to retrieve, use, or manage an information resource. Metadata is often called data about data or information about information[3]. Users of weather data, particularly those involved in sophisticated forecasting, generally want to know as much about the characteristics of the site, station, sensors, and the observations, as possible. Information related to the site and station location and description of the sensors included on the station are generally considered essential items. Information about the quality of the data and how it is monitored is also considered important. The list of desired metadata items can become rather long, however, and if implemented can increase capital costs and place a burden on data processing requirements. As a result, agencies must assess the tradeoffs between the desired level of metadata collection and the increased capital and operating costs that can result as the number and complexity of metadata elements increases.

The Guide provided a table of desired metadata items based on input from a variety of sources. During the development of the *Clarus* System, the importance of metadata was further emphasized. Since one of the goals of *Clarus* was to conduct quality checks on various surface weather observations, agreement on standard metadata items was a major point of discussion. A task force was formed to determine critical and optional metadata elements for *Clarus*. These elements represent the result of substantial discussion between the meteorological community and the transportation community represented by FHWA, State DOTs and meteorological experts. The tradeoffs between meteorological accuracy and cost were thoroughly discussed and a set of metadata requirements were developed that define critical and optional categories. *Clarus* data elements had to be defined in greater detail than those in the Guide. Data formats and naming conventions had to be specifically defined. These data elements are defined in greater detail than those in the Guide in order to allow *Clarus* to receive data in standard formats. Some of the data elements originally identified as requirements in the Guide are considered either "recommended" or "optional" by *Clarus.* Agencies implementing ESSs may find that some of the recommended or optional data items are important to their specific purposes and may want to add them to their specifications. It should also be noted that *Clarus* uses metadata during the collecting, quality checking, and dissemination of observations. Some of the "required" fields may not be supplied directly by the ESS owner or may be calculated for the purpose of assessing data quality.

Table 1 shows that the metadata items proposed in the original Guide have largely been addressed by the *Clarus* project, which required more detailed definition of metadata requirements. A few of the items originally specified in the Guide are not mentioned in the *Clarus* guidelines and there are some differences in what is

[3] *Understanding Metadata*. National Information Standards Organization, 2004.

considered critical, recommended or optional. Recommendations for deleting items from the Guide are bolded in Table 1 below. These are mostly very specific items related to a single type of observation. It is recommended they be dropped from the Guide although there may be specific locations and circumstances where the information is helpful.

The *Clarus* metadata tables were developed after extensive discussion between transportation and meteorology professionals. During the development of the *Clarus* System, many of the participating State DOTs and other agencies saw great value in a national database that could provide consistent ESS data from nearby states in a common format. Therefore, it is recommended that the *Clarus* guidelines be followed as closely as possible by transportation agencies implementing new ESSs and should be substituted for the existing metadata tables in the next version of the Guide. It will be noted in the text, as well as in the tables, that not all fields need to be supplied by the owner of *the* ESS. The *Clarus* metadata tables are shown in Tables 2 and 3. Table 2 includes critical data elements for *Clarus* while Table 3 includes elements which are recommended or optional. There are a number of items in Table 3 listed as optional or recommended which are not of significant value to *Clarus.* They would, however, be very helpful to the owner in enhancing operations and maintenance. These items are in shaded cells with white print and should be considered a higher priority for implementation.

Table 3 – Metadata Recommended in Original Guide and *Clarus* Equivalents

ESS Siting Item	Description	*Clarus* Equivalent Items	*Clarus* Description	Comments and Recommendations
Name and/or Numbers	Name and/or numbers that uniquely describe the site. May include WMO/International Civil Aviation Organization or NWS station identifiers	Description	Description of site as used by the contributor	These four items should be included specifically in Guide.
		StateSiteID	Contributor's identifier for site	
		Category	Permanent, transportable, mobile or other	
		StationCode	Contributor's station identifier (may be more than one station at Site)	
Geopolitical Placement	City, county, state, country	State (recommended)	State of site location	Should be recommended in Guide.
		County (optional)	County or jurisdictional name of site location	Should be optional in Guide. Other ways of locating such as lat/long may be adequate. States that use or contract with County agencies for operations and maintenance probably want to specify County.
		Country (recommended)	Country of site location	Should be recommended in Guide.
Location	Lat/Long coordinates	LocBaseLat	Latitude location at base or station tower or RPU stand in decimal degrees	Should be included in Guide.

ESS Siting Item	Description	*Clarus* Equivalent Items	*Clarus* Description	Comments and Recommendations
		locBaselong	Latitude location at base or station tower or RPU stand in decimal degrees	Should be included in Guide.
		roadwayDesc (recommended)	Name/number of highway nearest to site	Should be recommended in Guide.
		roadwayMilepost (optional)	Nearest mile marker to the site	Maintain as optional in Guide. Agencies have different methods of identifying location.
Elevation	Elevation above mean sea level	locBaseElev	Elevation location in the station base in meters from sea level	Should be included in Guide.
Site Description	Textual description of site	Description	Description of site, as used by the contributor	Should be included in Guide.
Platform owner Involved parties	Contact information Contact information of those who maintain the site, its data and its metadata	**Clarus* requires information be repeated if Contributor is different than organization – for example if mesonet is contributor but station belongs to DOT. If there is a separate contact for metadata, information below is required for this individual as well.		
		name	Organization name	Should be included in Guide.
		contactName	Contact person	Should be included in Guide.
		title	Contact person title	Should be included in Guide.
		phonePrimary	Contact phone number	Should be included in Guide.
		email	Contact email address	Should be included in Guide.
Exposure	Description of the exposure of the site in	Effectiveness (recommended)	Unique meteorological or topographical feature(s)	Should be recommended in Guide.

ESS Siting Item	Description	*Clarus* Equivalent Items	*Clarus* Description	Comments and Recommendations
	terms of obstructions to wind, sun, and artificial temp/moisture sources	Obstructions (recommended)	Description of physical properties that might affect the accuracy of observations	Should be recommended in Guide.
		Landscape (optional)	Description of surrounding landscape	Should be optional in Guide.
Exposure indicator	An indicator of quality of the exposure of the site			Not included in *Clarus.* Subjective nature of element limits usefulness. **Recommend dropping from Guide.**
Location digital panoramic photos and drawings	Photos and graphic drawings that display the exposure, surrounding environment. May include aerial photography or topographic analysis.	Link URL to image (optional)	URL for image	Should be optional in Guide.
		Description (recommended)	Description of image	Should be recommended in Guide.
Height of base of tower to mean level of surrounding land	Elevation of base minus elevation of surrounding land out to approx 300 feet	roadwayHeight (optional)	Elevation difference in meters between the closest point on the center surface of the roadway to the site reference point (e.g. base of RWIS station)	Should be optional in Guide.
Station reporting frequency	Frequency at which observations are disseminated	obsCollFreq	The number of minutes between collection cycles at the Agency's host server	Should be included in Guide.

ESS Siting Item	Description	*Clarus* Equivalent Items	*Clarus* Description	Comments and Recommendations
Data observing and dissemination practices	Description of observation and dissemination practices used at this site	protocol	Description of the protocol used to retrieve observations (ftp, http, https)	Should be included in Guide.
Description of observation time stamps	Universal Time coordinate or Local Time plus Daylight Savings Time information	obsCollOffset	Number of minutes after midnight UTC that the 1st collection occurs (range 0 to 60)	Guide should state that the *Clarus* time stamp procedure be followed. If not possible, time stamps in UTC format should be minimum provided.
		UTCOffset	The number of minutes offset from UTC for the agency's collector host server in standard time	
		DST	Daylight savings time on the server is/is not observed	
		timeZone	The 3 or 4 letter identifier for the standard time zone where the agency's collector host is located.	
Description	Elements sensed and units of measurement	ObsType	Type of observation collected by this sensor; based on NTCIP 1204 types	Should be included in Guide. NOTE: Many sensors generate multiple observation types.

ESS Siting Item	Description	*Clarus* Equivalent Items	*Clarus* Description	Comments and Recommendations
Sensor Type and Model Number	Short description of type of sensor	Collector Config	Describes the format of the DOT WX data file; one set of entries is required for each observation type in the file (i.e. – CSV, XML, CMML)	Should be included in Guide.
		model	Manufacturer's model number of sensor	Should be included in Guide.
Manufacturer	Who built the sensor	mfr	Manufacturer of sensor	Should be included in Guide.
Relation of sensor to roadway	Description of relationship of sensor to roadway surface	roadwayOffset	Distance in meters between closest point on center surface of roadway to site reference point	Should be included in Guide.
Height or depth	Height or depth of the sensor to roadway surface	elevOffset (recommended)	Vertical distance from the pavement surface in meters	Should be recommended in Guide.
		surfaceOffset (recommended)	Vertical distance from the pavement surface in meters	Should be recommended in Guide.
Exposure (if different from site exposure)	Description of exposure of the sensor in terms of obstructions to wind, sun and artificial temperature/moisture sources	Representativeness (recommended)	Describe any unique meteorological or topographical features	Should be recommended in Guide.
		windRoughnessclass	Roughness of wind in four directions (expressed in whole percent)	Should be included in Guide.

ESS Siting Item	Description	*Clarus* Equivalent Items	*Clarus* Description	Comments and Recommendations
Exposure Indicator (if different from site exposure indicator)	An indicator of quality of the exposure of the sensor (not yet developed)			**Recommend dropping from Guide**. Index has not been developed and it was not included in *Clarus* requirements.
Accuracy	Design accuracy of sensor	Accuracy (Optional)	The known potential variation of the observation	Should be optional in Guide.
Resolution	Resolution of the sensor	Resolution (optional)	The smallest increment or measurement that can be obtained from a particular sensor	Should be optional in Guide.
Measurement range	Measurement range for sensor	minRange	Minimum value for sensor range test, as defined by the sensor manufacturer or the instrument owner	Should be included in Guide.
		maxRange	Maximum value for sensor range test, as defined by the sensor manufacturer or the instrument owner	Should be included in Guide.
Sampling time interval	Sampling Time and/or interval of the sensor data	SamplingInterval (optional)	Interval time, in seconds, between consecutive sensor readings	Should be optional in Guide.

Table 4 – Supplemental Information Recommended in Guide

ESS Siting Item	Description	*Clarus* Equivalent Items	*Clarus* Description	Comments and Recommendations
Site Category	If site is part of bigger network, use to discriminate between categories/type of sites	category	The category of station – Permanent, Mobile, Transportable or Other	Should be included in Guide.
Usage Category	Indicator to describe primary use of site	Description (recommended)	Description of station	Should be recommended in Guide.
		Type (recommended)	Type of station (refers to method of data collection)	Should be recommended in Guide.
Data Inventory	Description of what data originate at site	Collector config	Describes format of DOT WX data file; one set of entries for each observation type in file	Guide should state that the *Clarus* required file format be followed. If not possible, clear file description with all information requested by *Clarus* should be included.
		headerIndex	Positional order of observation type in the collected observation file	
		Receiveunits	Type of units for conversion purposes	
		receiveLabel	Column label from collected observation file	
Data Storage Practices	Description of where data are stored and how	protocol	Description of protocol used to retrieve observations	Guide should state that the *Clarus* required reporting of data storage

ESS Siting Item	Description	*Clarus* Equivalent Items	*Clarus* Description	Comments and Recommendations
	to access it	hostName	Network DNS name or IP address of the collector host server	practices be followed. If not possible, clear description of storage practices and access procedures requested by *Clarus* should be included.
		hostPort	Logical network address port on the collector host server	
		fileLocator	Logical directory path to the observation file	
		filename	Filename or the rule for generating file names that contain the observations	
		username	The identifier name that is used to log into the collector host server	
		password	The password that is used to log on to the host server	
Nearby stations	List of stations that can be used as a backup to the site			**Recommend dropping from Guide.** *Clarus* will provide information in other formats.
Level of Quality Control, Maintenance, Calibration, Validation	Description of procedures or specifications for these functions	maintPrevFreq (Optional)	Description of preventative maintenance intervals	Should be optional in Guide.
		maintCalibFreq (Optional)	Description of calibration maintenance intervals	Should be optional in Guide.

ESS Siting Item	Description	*Clarus* Equivalent Items	*Clarus* Description	Comments and Recommendations
Algorithms used	Algorithms used to create derived data			Should be optional in Guide. (Many sensors derive observations such as dewpoint from temperature and relative humidity.)
Hardware Software version	Name and version of hardware and software used by sensor	mfrModel (Optional)	Model number or software version	Should be optional in Guide.
Date of installation	Date of sensor installation	maintinstallDate (Optional)	Date of initial installation	Should be optional in Guide.
		Maintinstall (Optional)	Install installation date for sensor	Should be optional in Guide.
Date of purchase	Date of sensor purchase			Should be included in Guide since agencies need information for warranty purposes.

Table 5 – Supplemental Sensor Information for Specific Sensor Types and *Clarus* Equivalents

ESS Siting Item	Description	*Clarus* Equivalent Items	*Clarus* Description	Comments and Recommendations
Temperature Relative Humidity – Ventilation type	Type of ventilation used in temperature moisture sensors			**Recommend dropping from Guide.**
Temperature Relative Humidity – Soil and Vegetation Types	Types of soil and vegetation under the temperature and moisture sensors	soilType	Type of soil in which site is located as described by USDA National Resource Conservation Service soil texture classification	Should be optional in Guide.
Wind – Dimensions of supporting building if any	Dimensions of supporting building			**Recommend dropping from Guide.**
Radiation – horizon sketch	Sketch of the angle of the horizon in all directions			**Recommend dropping from Guide.**

Table 6 – *Clarus* Metadata Requirements - Critical Metadata Fields

Remark	*Clarus* Metadata Library Field Name	Data Type	Field Description	Example/Format
climateRecord				
Critical - but not necessarily owner provided	minObsRecord	real	The minimum observed value of this observation type for this period (month). Precision & bounds dependent on data type	Minimum Monthly Temp (in Deg C) = -2.9
Critical - but not necessarily owner provided	maxObsRecord	real	The maximum observed value of this observation type for this period (month). Precision & bounds dependent on data type	Maximum Monthly Temp (in Deg C) = 38.2
Critical - but not necessarily owner provided	period	integer	The month to which this climate record applies (1=Jan ... 12=Dec)	May = 5
collector (data access from transportation agency to *Clarus*)				
Critical	protocol	text(10)	Description (in lower case) of the protocol used to retrieve observations (examples of input include: ftp, http, or https)	https

Remark	*Clarus* Metadata Library Field Name	Data Type	Field Description	Example/Format
Critical	hostName	text(50)	The network DNS name or IP address of the collector host server	www.fhwa.dot.gov or 64.126.107.233
Critical - if required by owner	hostPort	integer	The logical network address port on the collector host server	http = 80, ftp = 22, https = 443, or owner defined integer
Critical	fileLocator	text(50)	The logical directory path to the observation file	path = /stateDOT/RWIS/obs/
Critical	filename	text(50)	The filename or the rule for generating file names that contain the observations	ESS_Observations.txt
Critical - if required by owner	username	text(50)	The identifier name that is used to log into the collector host server	username = Clarus
Critical - if required by owner	password	text(50)	The password that is used to log into the collector host server	password = iHavePermission

Remark	*Clarus* Metadata Library Field Name	Data Type	Field Description	Example/Format
Critical	obsCollFreq	integer	The number of minutes between collection cycles at the agency's collector host server (when a new file is ready for retrieval by *Clarus*). Maximum allowed is 60 minutes.	minutes = 13
Critical	obsCollOffset	integer	The number of minutes after midnight UTC that the first collection occurs (for *Clarus* retrieval purposes). Minutes range from 0-60.	minutes = 2
Critical	UTCOffset	integer	The number of minutes offset from UTC for the agency's collector host server in Standard time. Areas in the U.S. (west of Greenwich) use negative values. Valid range is -720 to +720 minutes.	minutes = -240
Critical	DST	bit	Daylight Savings Time on the server is observed (True or False)	1=True, 0=False

Remark	***Clarus* Metadata Library Field Name**	**Data Type**	**Field Description**	**Example/Format**
Critical - only if DST field is TRUE	startDST	datetime	Starting date and time for DST	4/12/2006 2:00
Critical - only if DST field is TRUE	endDST	datetime	Ending date and time for DST	10/15/2006 14:15
collectorConfig			Describes the format of the DOT WX data file; one set of entries is required for each observation type in the file	
Critical	headerIndex	integer	The positional order (comma delimited) of observation type in the collected observation file (leftmost column = 1)	the temperature column = 5
Critical	receiveUnits	text(50)	Type of units for conversion purposes; Most 1204 units are included	Degrees Celsius
Critical	receiveLabel	text(50)	Column label name from collected observation file	column = AirTemp

Remark	***Clarus*** **Metadata Library Field Name**	**Data Type**	**Field Description**	**Example/Format**
Critical	unitsMultiplier	real	The multiplier used to adjust the decimal position (e.g., multiply 209 by 0.1 to get 20.9 Deg C)	times 0.1
metadata contact information (from agency)				
Critical - administrator access only	name	text(50)	Contact person	Mr. Fred Flintstone
Critical - administrator access only	title	text(50)	Contact person title	Owner of the Bedrock Mesonet
Critical - administrator access only	phonePrimary	text(10)	Contact phone (including area code)	2025551301 (no dashes)
Critical - administrator access only	email	text(50)	Contact email address	Fred.Flintstone@bedrock.com
contributor				
Critical - administrator access only	name	text(50)	Name of the contributing agency or group within the agency providing observations	Bedrock Quarry Company

Remark	***Clarus* Metadata Library Field Name**	Data Type	Field Description	Example/Format
Critical - administrator access only	contactName	text(50)	Contact person	Mr. Barney Rubble
Critical - administrator access only	title	text(50)	Contact person title	Bedrock Mesonet Operator
Critical - administrator access only	phonePrimary	text(10)	Contact phone (including area code)	2025551302 (no dashes)
Critical - administrator access only	email	text(50)	Contact email address	Barney.Rubble@bedrock.com
organization				
Critical - administrator access only	name	text(50)	Organization name	Loyal Order of Water Buffalo
Critical - administrator access only	contactName	text(50)	Contact person	Mr. Slate
Critical - administrator access only	title	text(50)	Contact person title	Organization that owns the Bedrock Quarry
Critical - administrator access only	phonePrimary	text(10)	Contact phone (including area code)	2025551300 (no dashes)
Critical - administrator access only	email	text(50)	Contact email address	Slate@bedrock.com

Remark	***Clarus*** **Metadata Library Field Name**	**Data Type**	**Field Description**	**Example/Format**
sensor-specific information				
Critical	obsType	text(50)	Type of observation collected by this sensor; based on NTCIP 1204 types (see 1204 worksheet)	essAirTemperature
Critical	sensorIndex	integer	The order of like sensors; used to distinguish one of a set of like sensors associated with a particular station	when multiple sensors are involved at one station: puck 0, puck 1, puck 2, puck 3
Critical	minRange	real	Minimum value for sensor range (hardware) test, as defined by the sensor manufacturer or the instrument owner	minimum sensor range temp = -160.0 Degrees or the minimum sensor range temp set by the operator = -100.00 (whichever is most restrictive)
Critical	maxRange	real	Maximum value for sensor range (hardware) test, as defined by the sensor manufacturer or the instrument owner	maximum sensor range temp = 220.0 or maximum sensor range temp reporting = 150.0 (whichever is most restrictive)

Remark	*Clarus* Metadata Library Field Name	Data Type	Field Description	Example/Format
Critical	distGroup	integer	Identifies distribution group to whom data from this sensor can be provided	1 = DON'T distribute, 2 = distribute to everyone, etc.
Critical - but not necessarily owner provided	ratePos	real	Maximum positive rate of change during the time period defined by rateInterval, and as used by step test	20.0 degrees
Critical - but not necessarily owner provided	rateNeg	real	Maximum negative rate of change during the time period defined by rateInterval, and as used by step test; reported as a negative number	-20.0 degrees
Critical - but not necessarily owner provided	rateInterval	real	Interval of time, in seconds, over which ratePos & rateNeg apply in the step test	3600.0 seconds or 1 hour

Remark	*Clarus* Metadata Library Field Name	Data Type	Field Description	Example/Format
Critical - but not necessarily owner provided	persistInterval	real	Amount of time, in seconds, that the observed value can remain constant (not change). Used for the persistence test	14000.0 seconds or 4 hours
Critical - but not necessarily owner provided	persistThreshold	real	Smallest amount of change that is allowed between observations. Used for the persistence test	0.2 degrees
Critical - but not necessarily owner provided	likeThreshold	real	Largest observed difference that is permitted among like instruments. Used during the like instrument test	1.0 degree
sensorType				
Critical	mfr	text(50)	Manufacturer of sensor	Vaisala
Critical	model	text(50)	Manufacturer's model number of sensor	DSC111
site-specific information				
Critical	description	text(50)	Description of site, as used by the contributor (e.g., "Seward Highway @ Portage Glacier Road")	Fairfax County Parkway @ Reston Avenue

Remark	*Clarus* Metadata Library Field Name	Data Type	Field Description	Example/Format
Critical - but not necessarily owner provided	stateSiteId	text(50)	Contributor's identifier for the site	stateSiteId = 315
station-specific information				
Critical	category	text(1)	The category of station - "P" permanent, "T" transportable, "M" mobile, "O" other	P
Critical	stationCode	text(50)	The contributor's station identifier; this may be different than the stateSiteID to allow more than one station at a given site	stationCode = 48
Critical	rpuUTCOffset	integer	The number of minutes offset from UTC for the remote processing unit (RPU). Areas in the U.S. (west of Greenwich) use negative values. Range from -720 to +720	-60

Remark	***Clarus* Metadata Library Field Name**	**Data Type**	**Field Description**	**Example/Format**
Critical	rpuDST	bit	Does the RPU need adjustment for Daylight Savings Time(DST)? [(0=no, 1=yes]	1
Critical - only if rpuDST field is TRUE	rpuStartDST	datetime	Starting date and time for DST (for the RPU)	4/12/2006 2:00
Critical - only if rpuDST field is TRUE	rpuEndDST	datetime	Ending date and time for DST (for the RPU)	10/15/2006 14:15
Critical	locBaseLat	real	The latitude location of the base of the station tower or RPU stand, in decimal degrees (e.g., 34.567); positive values are North latitudes. Value can hold up to 9 digits of precision	37.4821
Critical	locBaseLong	real	The longitude location of the base of the station tower or RPU stand, in decimal degrees (e.g., -123.456); negative values are West longitudes. Value can hold up to 9 digits of precision	-113.22

Remark	*Clarus* Metadata Library Field Name	Data Type	Field Description	Example/Format
Critical	locBaseElev	real	The elevation location of the station base (tower or RPU stand) in meters from mean sea level	135.5

Table 7 – *Clarus* Optional and Recommended Owner-Provided Fields

Remark	Field Name	Data Type	Description	Example/Format
collector (data access from transportation agency to *Clarus*)				
	description	text(50)	Description of collector	This collector will work with all ESS on the XX DOT network
	maintInstallDate	datetime	Date of initial installation	5/4/2003 12:24
	mfrName	text(50)	The name of manufacturer	Facundo Computing
	mfrProduct	text(50)	The name of the product	JF Blade Series 1000
	mfrModel	text(50)	The model number or software version	123456HH0JM2
Supplemental contact information (Network Owner)				
	phoneAlt	text(10)	Contact phone alternate (including area code)	2025551212 (no dashes)
	phoneMobile	text(10)	Contact mobile phone number (including area code)	2025554444 (no dashes)
	fax	text(10)	Contact phone fax (including area code)	2025553333 (no dashes)
	pagerId	text(10)	Contact pager identifier	2025551111 (no dashes)
	pager	text(10)	Contact pager number	556687

Remark	Field Name	Data Type	Description	Example/Format
	radioUnit	text(50)	Contact radio unit identifier	2025555555 (no dashes)
	address1	text(50)	Contact mailing address line1	123 1st Street
	address2	text(50)	Contact mailing address line2	Suite 450
	city	text(50)	Contact mailing address city	Apple
	state	text(2)	Contact mailing address state	OR
	zip	text(10)	Contact mailing address zip	99999-4444
	country	text(3)	Contact mailing address country	USA
Contributing organization				
	location	text(50)	Organization location	MODOT
	purpose	text(50)	Organization purpose	To provide a world-class transportation experience that delights our customers and promotes a prosperous Missouri.
	centerId	text(50)	Organization center identifier	4
	centerName	text(50)	Organization center name	KC Scout
	updateDate	datetime	Organization information	10/23/2005 14:25

Remark	Field Name	Data Type	Description	Example/Format
			last updated	
	contactId	integer	Contact identifier	Contact name for organizational issues that is included in the contact list - the id of the contact name will be put here
Sensor-specific information				
Recommended for owner maintenance records	calibDate	datetime	The last date of calibration of the sensor	9/3/2006 10:30
Recommended for owner maintenance records	maintDate	datetime	The last date of maintenance performed on the sensor	9/4/2006 4:00
Recommended for owner maintenance records	serial	text(50)	Manufacturer's serial number for sensor	55335668
	resolution	real	The smallest increment or measurement that can be obtained from a particular sensor	tenths of degrees = .1
	accuracy	real	The known potential variation of the observation	0.05
	minDisplay	real	Minimum value for sensor display	-52.85

Remark	Field Name	Data Type	Description	Example/Format
	maxDisplay	real	Maximum value for sensor display	120.22
Recommended	nsOffset	real	The north/south distance from the station reference location in meters	15.0 meters
Recommended	ewOffset	real	The east/west distance from the station reference location in meters	8.0 meters
Recommended	elevOffset	real	The vertical distance from the station reference location in meters	3.0 meters
Recommended	surfaceOffset	real	The vertical distance from the pavement surface in meters	0.5 meters
	embeddedMaterial	text(100)	Description (including depth) of material sensor is embedded in.	rubber cement
	outputAvgInterval	integer	Milliseconds used to describe average interval of observations	300,000 milliseconds = 5 minutes
	outputInternalUnits	text(8)	Internal units reported to data logger	Celsius
Recommended for owner maintenance records	maintInstall	datetime	Initial installation date for sensor	2/8/2003 8:45

Remark	Field Name	Data Type	Description	Example/Format
Recommended	maintBegin	datetime	Date sensor is taken out of service; sensors for which maintBegin < currentDate < maintEnd will not be checked for data quality. Use if sensor will be out of service for a significant period of time.	10/15/2006 14:15
Recommended	maintEnd	datetime	Date sensor is put back into service; sensors for which maintBegin < currentDate < maintEnd will not be checked for data quality	10/15/2006 18:15
	samplingInterval	real	Interval time, in seconds, between consecutive sensor readings	15.0 seconds
Recommended	sensorDescription	text(100)	Plain text description of the sensor (e.g., thermometer, CCTV camera)	PTZ fixed IR camera
Optional - unless the sensor is a CCTV then mandatory	linkURL	text(255)	Link to CCTV images	Direct URL link to a CCTV image

Remark	Field Name	Data Type	Description	Example/Format
Site-specific information				
Recommended	roadwayDesc	text(50)	Name/number of the highway nearest to the site (e.g., "Interstate 35," "U.S. Hwy 59," "State Hwy 81," "Haines Highway")	State Hwy 81
	roadwayMilepost	integer	Nearest mile marker to the site	45
Optional - but must be included if roadwayMilepost is used	roadwayMilepostUnits	text(50)	Units reported for roadwayMilepost	Miles
	roadwayOffset	real	The distance, in meters, between the closest point on the center surface of the roadway to the site reference point (e.g., base of an RWIS station)	37.53 meters
	roadwayHeight	real	The elevation difference, in meters, between the closest point on the center surface of the roadway to the site reference point (e.g., base of an RWIS station)	22.8 meters
	county	text(100)	The county or jurisdictional name of the site location	Fairfax County or Centreville Township

Remark	Field Name	Data Type	Description	Example/Format
Recommended	state	text(2)	State of the site location (2 letter postal ID)	VA
Recommended	country	text(3)	The country of the site location (e.g., USA, CA, MX)	USA
Recommended for owner maintenance records	accessDirections	text(50)	Directions to access the site from a major roadway	Turn left at the cow, proceed three miles to Joe's Grocery, turn right on State Hwy 81, go 3 miles, on left
Recommended	representativeness	text(255)	Describe any unique meteorological or topographical feature(s).	Between 2 & 4 PM during the summer months, the ESS is shaded
Recommended	obstructions	text(100)	Description of physical properties (e.g., trees, buildings) that might affect the accuracy of observations	Large outhouse parked on SW side of ESS
	landscape	text(100)	Description of surrounding landscape	sandy area except for obstruction of oak tree and outhouse
	accessControlled	bit	Ability for contributor to access the site (e.g., locked fence around site)	0 = no access, 1 = full access
	terrainSlope	integer	The grade of the surrounding land, in whole degrees from horizontal	10 degrees

Remark	Field Name	Data Type	Description	Example/Format
	terrainSlopeDirection	integer	The direction of the grade, in degrees from North (e.g., slope down from west to east is noted as 270)	85 degrees
	windRoughnessClass	text(50)	Roughness of the wind in four directions (expressed in whole percent)	24 percent
	soilType	integer	The type of soil on which the site is located, as described by the USDA National Resource Conservation Service soil texture classification (e.g., sandy loam, silt) or by percent sand, silt, and clay	Full enumeration list is not yet available
	stateSystemId	text(45)	Site identifier used by the State DOT (or other data contributor)	22
	linearReference	real	Linear reference marker number	4.3
Station-specific information				
Recommended	description	text(100)	The description of the station	The ESS has a 30 m tower with 10 sensors

Remark	Field Name	Data Type	Description	Example/Format
Recommended	type	integer	The type of station - "0" data collected electronically/mechanically, "1" collected by humans, "3" type of station is unknown	0
	locBaseDatum	text(10)	The datum geocoordinate referencing model	WGS 1984
Recommended for owner maintenance records	powerType	text(1)	The type of power for the station - "B" battery, "L" line	B
	doorOpen	bit	The status of the door (0=closed, 1=open)	0
	batteryStatus	integer	The percentage of full charge of the battery (101 = error)	78
	lineVolts	integer	The typical voltage for the power source (0 to 100)	12 volts
	maintArea	text(50)	The description of the maintenance group for this station (for the site maintenance personnel)	Substation 52
Recommended for owner maintenance records	maintPrevFreq	text(50)	The description of preventative maintenance intervals	The station is serviced every year in the spring or when the station fails completely

Remark	Field Name	Data Type	Description	Example/Format
Recommended for owner maintenance records	maintCalibFreq	text(50)	The description of the calibration maintenance intervals	The station is calibrated every spring and fall
Recommended for owner maintenance records	maintStatus	bit	The maintenance status of the station - "0" out of service, "1" in service	0
Recommended for owner maintenance records	maintInstallDate	datetime	The initial installation date of the station	3/8/2004 8:00
	rpuNumCards	integer	The number of sensor interface devices	2
Recommended for owner maintenance records	rpuCommType	integer	The communication type for the station - "1" phone, "2" IP address	2
Recommended for owner maintenance records	rpuPhoneNum	text(10)	The phone number to contact the rpu	2025555555
Recommended for owner maintenance records	rpuIPAddress	text(15)	The IP address to contact the rpu	64.126.107.233
	rpuMfr	text(50)	The manufacturer of the rpu	XYZ Manufacturer
	obsCollFreq	integer	The number of minutes between collection cycles (rpu to agency server)	2 minutes

Remark	Field Name	Data Type	Description	Example/Format
	obsCollOffset	integer	The number of minutes after UTC midnight that the first collection occurs	1 minute
	obsTransFreq	integer	The number of minutes between transmission cycles	15 minutes
	obsTransOffset	integer	The number of minutes after UTC midnight that the first transmission occurs	16 minutes
	obsTransFormat	text(50)	The description of the transmission format from the station to the network data logger	The ESS will communicate with the data logger by way of remote control
	maintContactId	integer	The contact person for maintenance from contact table; is implemented in the database as a link to a contact person	Contact name for maintenance issues that is included in the contact list - the id of the contact name will be put here
Image information				
Recommended	description	text(50)	Description of image	The image represents the Cumberland Pass in southwest Virginia

Remark	Field Name	Data Type	Description	Example/Format
Optional - but must be included if image description is provided	linkURL	text(255)	URL for image	www.i70ess248.gov

APPENDIX A DISCUSSION GUIDE FOR ESS INTERVIEWS

Guidelines

1. Are you familiar with the Guidelines issued by FHWA in April, 2005? (Road Weather Information System Environmental Sensor Station Siting Guidelines, April, 2005, FHWA-HOP-05-026)

2. Have you read the Guidelines?

    a. In detail?

    b. Read parts relevant to your needs?

    c. Skimmed through?

    d. If yes to one of the above..

        i. In what ways are the Guidelines useful for an agency that is deploying or considering deployment of ESS?

        ii. Do you find the Guidelines easy to follow through the implementation process?

        iii. How do the Guidelines reflect the needs of transportation agencies?

        iv. What might be missing from the Guidelines that you feel would be useful?

        v. What material in the Guidelines might not be useful and should perhaps be eliminated?

3. Are you in the process of deploying additional RWIS, or do you have a deployment planned?

    a. If yes do you

        i. At what stage is your deployment?

            1. Construction

            2. Contractor negotiation

            3. Procurement

4. Design
5. Planning

ii. Plan to use the Guidelines for your deployment?

1. If so, for what specific activities?

iii. How do you plan to use them?

1. What specific components of the siting decision would you use the Guidelines for?

4. Do you apply siting standards now?
   a. For what components?
   b. How are they like or unlike the Guidelines?
   c. Can you provide a reference to or a copy of those siting standards?

APPENDIX B ACRONYMS AND ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
CCTV	Closed-circuit television
Clarus	An integrated surface transportation weather observing, forecasting, and data management sharing system that collects, evaluates, and disseminates environmental data gathered from a geographically diverse set of sensors
Clarus Initiative	Development of tools, models, and decision support that leverage the *Clarus* System, end-to-end processes spanning data gathering to road weather information products and services, and research activities that support creation of road weather information products and services
cm	centimeter
CMML	Canadian Meteorological Markup Language – a meteorological encoding mechanism based on XML, used to exchange data between Canadian Provinces and Territories and Environment Canada
COO	Concept of Operations
CSV	Comma Separated Value (file format) – a file type that stores tabular data
DMS	Dynamic Message Sign
DNS	Domain Name System
DOT	Department of Transportation
DST	Daylight Savings Time
ESS	Environmental Sensor Station
FHWA	Federal Highway Administration
FTP	File Transfer Protocol
HTTP	Hyper Text Transfer Protocol – communication standard for transmitting and receiving documents and other types of data over the Internet
HTTPS	Secure Hyper Text Transfer Protocol
IP	Internet Protocol
IR	Infrared
ITD	Idaho Transportation Department
ITS	Intelligent Transportation System
m	meter
MDOT	Michigan DOT
MDSS	Maintenance Decision Support Systems

NHDOT	New Hampshire Department of Transportation
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NTCIP	National Transportation Communications for ITS Protocol
NWS	National Weather Service
PSU	Plymouth State University
PTZ	pan-tilt-zoom
RFP	Request for Proposal
RPU	Remote Processing Unit
RWIDS	Road-Weather Integrated Data System
RWIS	Road Weather Information System
SICOP	Snow and Ice Cooperative Program
SSI	Surface Systems, Inc.
TRIO	Tri-State Rural Advanced Traveler Information System
URL	Uniform Resource Locator – typically, an Internet address
USDA	United States Department of Agriculture
UTC	Universal Time Code – coordinated universal time; a high-precision atomic time standard whre all values are referenced to the Greenwich Meridian
WMO	World Meteorological Organization
WX	Weather
XML	eXtensible Markup Language – a flexible text markup language used to create standard information formats that share both the format and the information to enable the interchange of structured data

APPENDIX C REFERENCES AND RELATED DOCUMENTS

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