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16. Abstract (Limit: 200 words) Abstract Research activities were completed to provide to the Federal Highway Administration's <i>Clarus</i> System environmental sensor station (ESS) metadata in support of the North/West Passage Clarus Regional Demonstration Concept of Operations Development. Efforts were focused on developing sensor and collector environmental metadata consisting of critical owner provided fields and ESS site and climate record environmental metadata as outlined by the <i>Clarus</i> System Design Data Dictionary. Challenges encountered during the research activities were centered on the changing status of the RWIS networks in the various North/West Passage States. The significance of the ESS metadata development was that it provided a consolidation of critical metadata across the North/West Passage states and provides for the improvement of road weather forecasting or to assist in decision-making by local state agencies in determining appropriate responses to varying road and weather conditions. Recommendations resulting from the research include maintaining future accurate and timely updates to the ESS metadata, establishing of state procedures to provide these updates, a call for annual reviews of state agency ESS metadata, and for a periodic evaluation by the national stakeholder community of the effectiveness of the ESS			
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North/West Passage *Clarus* Regional Demonstration Environmental Sensor Station Metadata Development

Draft Report

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Executive Summary

Road Weather Information System (RWIS) networks exist across the United States (U.S.). These RWIS networks are comprised of numerous Environmental Sensor Stations (ESS), which provide valuable atmospheric and pavement observations supporting highway maintenance activities. However, the data collected from each ESS are the property of the State in which it resides and/or the RWIS network vendor. Weather and pavement data are rarely shared among States, nor is there a central location for anyone such as the weather or transportation communities to access the data.

In an attempt to break the information sharing barriers to accessing multi-state ESS data through the creation of a central data repository, the Federal Highway Administration (FHWA) Road Weather Management Program (RWMP) created the *Clarus* Initiative. The *Clarus* Initiative was established for three primary reasons:

1. Surface transportation-based weather observations will enhance and extend the existing National Surface Weather Observation System (NSWOS) database supporting general purpose weather forecasting, thereby enhancing the protection of life and property;
2. A national collection of real-time surface transportation-based weather observations will provide for unfettered access of data for support of real-time responses to observed weather conditions; and,
3. Integration of surface transportation-based weather observations with existing NSWOS observed data will permit broader support for surface transportation specific models predicting impacts of weather on maintenance and traffic-related concerns. [1]

The University of North Dakota (UND) Surface Transportation Weather Research Center (STWRC) was contracted by the Minnesota Department of Transportation to perform two tasks as part of the North/West Passage *Clarus* Regional Demonstration Environmental Sensor Station Metadata Development. Task 1 was Sensor and Collector Environmental Metadata consisting of Critical Owner Provided Fields as outlined by the Federal Highway Administration (FHWA) *Clarus* System Design Data Dictionary. Task 2 was the development of ESS Site and Climate Record Environmental Metadata as outlined by the FHWA *Clarus* System Design Data Dictionary to provide site-specific climate information.

Metadata obtained were compiled into master spreadsheets created for each North/West Passage state. The data were formatted to satisfy input requirements for the *Clarus* System and were provided to the FHWA *Clarus* System contractor for input into the *Clarus* System.

Challenges encountered during the contract were centered on the changing status of the RWIS networks in the various North/West Passage states. Several North/West Passage states were in the midst of upgrading their system(s) remote processing units (RPU), their Environmental Sensor Stations (ESS), or their entire Road Weather Information Station (RWIS) network. Acquiring the required metadata or obtaining it from the appropriate vendors was delayed and the completion of Task 1 was subsequently delayed.

The significance of the North/West Passage *Clarus* Regional Demonstration Environmental Sensor Station Metadata Development was that it provided a consolidation of critical ESS metadata across the North/West Passage states. The general weather and transportation communities and State agencies will benefit from having these ESS metadata in a central data repository. This information will aid in improving road weather forecasting or assisting local state agencies' decision-making by determining appropriate responses to varying road and weather conditions.

Recommendations: To provide the most effective use of environmental sensor stations it will be imperative that the ESS metadata be maintained in an accurate and timely manner. It is recommended that every North/West Passage state establish a procedure for the revision of their ESS metadata records upon every maintenance action and/or ESS modification that is made. It is also recommended that each North/West Passage state perform an annual review of their ESS metadata to ensure that it is accurate. It is further recommended that as ESS metadata changes occur that these changes be conveyed to the FHWA *Clarus* System for incorporation in their ESS metadata records. Finally, it is recommended that once the *Clarus* System has conducted an operational multi-state regional demonstration that the FHWA conduct a review with the participating states and the broader user community on the effectiveness of the *Clarus* System to maintain current ESS metadata, conduct a gap analysis on ESS metadata requirements, and evaluate the effectiveness by state agencies on providing updated ESS metadata to the *Clarus* System.

Chapter 1 Introduction

Road Weather Information System (RWIS) networks exist in most states across the United States. Each of these RWIS networks are comprised of numerous Environmental Sensor Stations (ESSs) located at various locales intended to support transportation agency action by providing valuable atmospheric and pavement observations. The data collected from each ESS are the property of the State in which the ESS resides, or in some special situations these data are the property the State's RWIS network vendor. In either situation, the weather and pavement data from these ESSs are rarely shared among states and generally not made available to the public or the private sectors. And unlike most other routinely collected weather data (i.e., hourly airport weather observations) there is not a national central collection location for these data to support access by the weather or transportation communities.

In an attempt to remove the ESS information sharing barriers through the formation of a national ESS data repository, the Federal Highway Administration (FHWA) Road Weather Management Program (RWMP) created the *Clarus* Initiative. The *Clarus* Initiative, which is intended to become part of the National Surface Weather Observation System (NSWOS), was “launched for three primary reasons:

1. Surface transportation-based weather observations will enhance and extend the existing NSWOS database supporting general purpose weather forecasting, thereby enhancing the protection of life and property;
2. A national collection of real-time surface transportation-based weather observations will provide for unfettered access for data for support of real-time responses to observed weather conditions; and,
3. Integration of surface transportation-based weather observations with existing NSWOS observed data will permit broader support for surface transportation specific models predicting impacts of weather on maintenance and traffic-related concerns.” [1]

The objectives of the *Clarus* Multi-State Regional Demonstration are to ensure that the *Clarus* System works as designed, foster proactive transportation system management, and encourage improved private sector services for road weather information. In the first phase of the demonstration, three teams of transportation agencies were selected to develop Concepts of Operations that define a set of business-to-government services for surface transportation weather information products that are common across a region. The North/West Passage Transportation Pooled-Fund Study Program (North/West Passage) was awarded a cooperative agreement with FHWA to serve as one of the three teams in developing a multi-state demonstration concept of operations.

The North/West Passage encompasses the eight states along I-90/I-94 (Fig. 1.1) from Wisconsin to Washington. The I-94/I-90 corridors span extended rural settings as well as densely populated metropolitan areas that require knowledge of road and weather conditions in adjacent states. Such knowledge is critical for planning, conducting, and evaluating the effectiveness of activities

such as winter road maintenance, weather-responsive traffic management, traveler information dissemination, safety management, transit vehicle dispatching, and flood control.

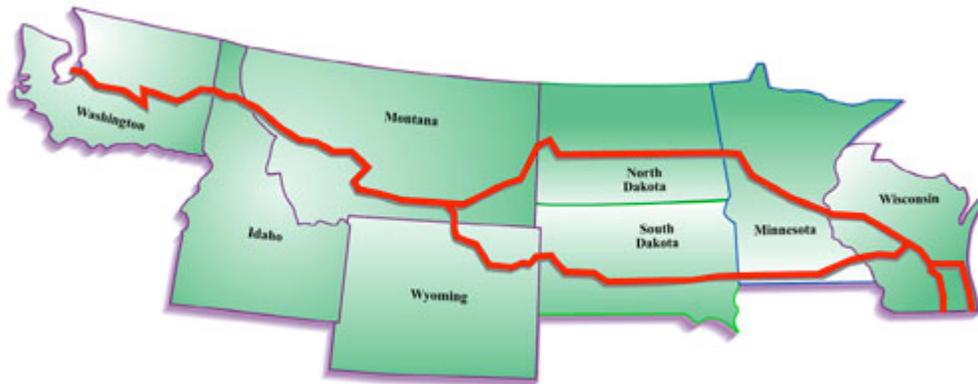


Figure 1.1 The routes of Interstate 94 and Interstate 90 as they extend across the eight states that comprise the North/West Passage Transportation Pooled-Fund Study.

A multi-state *Clarus* demonstration across the North/West Passage states will provide a clear example how an open and integrated approach to observational data management can be used to overcome deficiencies and improve road weather information products. In these states there are numerous systems for collecting, processing and integrating traveler and road maintenance information, and for delivering the information to users. In fact, the participating North/West Passage states have made a significant investment in ESS with approximately one-quarter of the nation's total number of ESS located in the eight states. However, this information is not readily shared across state borders, including the Environmental Sensor Station (ESS) data, which is fundamental to the *Clarus* System.

As part of the North/West Passage cooperative agreement with the FHWA *Clarus* Initiative, a requirement was the development and collection of ESS metadata for each participating state and transmittal of these metadata to the FHWA *Clarus* System. During a prior *Clarus* Initiative activity, the Minnesota Department of Transportation ESS metadata was previously provided to the *Clarus* System resulting in the need to develop/collect ESS metadata only for the remaining seven states.

To perform this collection and submittal of ESS metadata data to the *Clarus* System, the Minnesota Department of Transportation, on behalf of North/West Passage, contracted with the University of North Dakota Surface Transportation Weather Research Center (UND STWRC) to coordinate and complete the ESS metadata transmittal to the *Clarus* System from the seven remaining North/West Passage states. UND STWRC provided technical assistance to North/West Passage by compiling metadata according to specifications provided by the *Clarus* System Design Team facilitating interaction and connectivity with the *Clarus* System.

This report details the efforts by UND STWRC to collect, format, and submit ESS metadata for input into the *Clarus* System. A description of the processes involved during the contract period to provide the ESS metadata, a discussion of challenges faced during the project, and a summary of findings and recommendations regarding the *Clarus* System ESS metadata development and maintenance.

Chapter 2

Research Objectives

The research objectives of the project were associated with four project tasks. These tasks were to 1) furnish metadata to the FHWA technical representative and to the FHWA technical representative's designee that will operate the *Clarus* system; 2) develop ESS Site and Climate Record Environmental Metadata as outlined by the FHWA *Clarus* System Design Data Dictionary to provide site-specific climate information; 3) provide a draft summary report of ESS metadata development; and, 4) provide revisions to the draft summary report in the form of a final project report.

The central approach to completing the project was to establish and maintain open lines of communication between the participating North/West Passage states and UND STWRC. Representatives from each of the North/West Passage states provided the majority of the information utilized in the ESS metadata development. As such, the success of the project depended upon the efficiency of the communications and exchange of information.

The primary activities for this project were conducted under Task 1 and Task 2. These two tasks are described below. Specific actions performed for each of these two tasks are provided in the subsequent chapters.

Task 1. Sensor and Collector Environmental Metadata

As part of the project activity, the UND STWRC was to work with the North/West Passage participating states to accumulate their ESS metadata and construct the required *Clarus* System formatted tables of ESS metadata. Many of the North/West Passage states already have these data organized in a convenient and exportable format, others have it stored in a number of different and non-combinable databases, some without convenient export tools. Furthermore, some states do not have a single point of contact that can access all the data needed for all sites. During the proposed project, the UND STWRC was to collect the outstanding elements of metadata, combine all state data, and format them for input to satisfy the sensor and collector environmental metadata described in the draft *Clarus* System Design Description. The Critical Owner Provided Fields in the metadata dictionary were to be collected and organized by the UND STWRC for existing ESS across the North/West Passage states. This includes the ftp formats, addresses, logins, passwords, and update patterns for the data files, the format of the data files, contact information, and basic location data for each ESS.

Task 2. Site and Climate Record Environmental Metadata

The site information required by the *Clarus* project represents critical, basic information about a station that any complete metadata set would include. The required site and climate record environmental metadata represents a new frontier in quality assurance. The UND STWRC was to construct in this task the required site and climate record environmental metadata to support the *Clarus* System requirements using *Clarus* System provided information and appropriate climate data available from the National Climate Data Center. These data were to be developed

for each ESS site location for all North/West Passage state not presently within the *Clarus* System. These data were to be provided in a printed hardcopy format and an electronic spreadsheet format. A copy will be provided to each North/West Passage State, to the FHWA technical representative, and to the FHWA technical representative's agent designated as the *Clarus* operator.

Chapter 3

Sensor and Collector Environmental Metadata

The first task for UND STWRC under the *Clarus* Multi-State Demonstration was sensor and collector environmental metadata. These data were previously defined by the FHWA as part of an assessment of a metadata dictionary [2] and included as primary data the metadata categories of station, sensor, observations type (obsType), sensor type (sensorType), collector, and collector configuration (collectorConfig) data. Of these six categories, UND STWRC was responsible for collecting, formatting, and then submitting the appropriate metadata for five of the categories.

There were two types of metadata collected from the states: Critical Owner Provided Fields and Optional Owner Provided Fields. Most of the states provided the critical metadata fields and did not provide any optional metadata. The most convenient way to collect the metadata from each state was to provide them a spreadsheet with the required data field columns and have state personnel populate the spreadsheet with the appropriate information. Typically for sensors and observation data, UND STWRC requested the name, manufacturer, and model number of the sensor and the observation(s) corresponding to the sensor. UND STWRC then used FHWA provided values corresponding to the state provided metadata to map the state provided metadata into the desired format for the *Clarus* System. Table 3.1 outlines the Critical Owner Provided Fields that UND collected from each state along with a brief description of each.

Table 3.1 Critical Owner Provided Fields UND obtained from each North/West Passage state.

obsType Type of observation collected by a given sensor	sensorIndex The order of like sensors	distGroup Identifies what data types can be viewed by others and ones that cannot be viewed	Mfr Manufacturer of a given sensor	Model Model number of a given sensor
Description Description of a site as given by the state	Category The category of a station, i.e. is it permanent, transportable, mobile, or other	stationCode The station's identifier; may be the same or different from the stateSiteId	locBaseLat Latitude of a given site	locBaseLong Longitude of a given site
locBaseElev Elevation of a given site in meters	contactName Contact person(s) for a given state and/or site(s) within a state	Title The title of the contact person(s)	phonePrimary Contact person(s) phone number	Email Contact person(s) email address
Address Contact person(s) address				

Other metadata required for the *Clarus* system but not provided by the states were site identification (siteId), station identification (stationed), observation type identification (obsTypeId), sensor type identification (sensorTypeId), and quality checking parameters (qchparm). The siteId and stationId were identifiers for the *Clarus* system that were unique for each site. The FHWA *Clarus* System contractor, Mixon/Hill, Inc. (Mixon/Hill), provided this information to UND STWRC based on the number of sites that were being handled at a given

time. Due to Mixon/Hill handling states outside the North/West Passage states, siteIds and stationIds were not always in chronological order from one site to the next in a given state. This would happen when states added ESS locations later in the metadata collection process. The sensorTypeId and qchparm values were provided by Mixon/Hill, while the obsTypeIds were specified from the National Telecommunications for ITS Protocol standard (NTCIP 1204 v3). The qchparm values for a given sensor were based on the following:

- minRange – The minimum value for a sensor range (hardware) test.
- maxRange – The maximum value for a sensor range (hardware) test.
- ratePos – The maximum positive rate of change during the time period defined by rateInterval.
- rateNeg – The maximum negative rate of change during the time period defined by rateInterval.
- rateInterval – The interval of time, in seconds, over which ratePos and rateNeg apply in the step test.
- persistInterval – The amount of time, in seconds, that the observed value can remain constant.
- persistThreshold – The smallest amount of change that is allowed between observations.
- likeThreshold – The largest observed difference that is permitted among like instruments.

As UND STWRC received metadata from each state, the appropriate mapping of the state ESS metadata were used to convert the data fields into the *Clarus* System metadata format. Sensor information (manufacturer and model number) was converted into a corresponding sensorTypeId number. The observation(s) for each sensor were converted to the NTCIP naming convention then changed to reflect its corresponding obsTypeId. With the known sensorTypeId and the obsTypeId a qchparm value was then determined. Table 3.2 shows the format changes that took place between metadata gathered from the states and the data provided by the FHWA *Clarus* System contractor to be put into the *Clarus* System.

Table 3.2 UND STWRC formatting changes made to metadata received from North/West Passage states to match the required format for the *Clarus* system. Note that this is only an example; states had differing sensors and observations at their ESS locations.

sensorType	sensorTypeId	Observations	obsType	obsTypeId	qchparm
HMP45D	21	Air temperature	essAirTemperature	5733	83
HMP45D	21	Relative Humidity	essRelativeHumidity	581	82
DRD11A	26	Precipitation rate	essPrecipRate	587	318
DRD11A	26	Precipitation start time	essPrecipitationStartTime	5811	321

DST111 Cyclo	87	Surface Temperature	essSurfaceTemperature	51138	364
PWD12	88	Adjacent Snow Depth	essAdjacentSnowDepth	583	391
PMB100	78	Atmospheric Pressure	essAtmosphericPressure	554	296

In the situation where more than one of the same observation type (i.e. pavement temperature or pavement condition) existed at a given ESS site, a different sensorIndex was assigned to each observation type to distinguish between the two. For example, if a site had two pavement sensors and each pavement sensor reported pavement temperature, one entry would have a sensorIndex of 0 and the second would have a sensorIndex of 1. If there was only one sensor type and one observation, for example, only one wind sensor and one wind speed observation, the sensorIndex for that entry would be 0. Depending on the ESS vendor, it was not uncommon to come across an air temperature sensor with an air temperature observation having a sensorIndex of 1. This was predetermined by the given vendor.

A final master spreadsheet was submitted to the FHWA *Clarus* System contractor ,Mixon/Hill, when all the metadata had been compiled and formatted for a given state. Both Task 1 and Task 2 had to be complete before the metadata was sent.

Chapter 4

Site and Climate Record Environmental Metadata

Site and Climate Record Environmental Metadata was the second task performed by UND STWRC for the North/West Passage *Clarus* Regional Demonstration Environmental Sensor Station MetaData Development. This task involved the collection of site, climate record, and observation type (obsType) metadata from each state. Two other categories, climate and image, were not collected by UND STWRC as they were not requested by the *Clarus* System. The obsType metadata was collected as part of the Sensor and Collector Environmental Metadata task.

The Critical Owner Provided site metadata included the following:

- state site identification (stateSiteId)
- contributor identification number (contribId)
- description
- climate identification (climateId) (also falls under Climate Record)

StateSiteId is the identifier a state uses for its ESS where every ESS has its own unique stateSiteId. This may have been provided by the state or provided by the ESS vendor for a given state. The contribId is the contributing organization's identification number based on the agency and its name. The FHWA *Clarus* System contractor provided this information to UND STWRC [3]. Description metadata is the description of a given site as used by the states. An example would be "Seward Highway @ Portage Glacier Road."

Optional Owner Provided metadata (and associated variable name) that falls under Site and Climate Record include:

- roadway description (roadwayDesc)
- roadway milepost (roadwayMilepost)
- roadway offset (roadwayOffset)
- roadway height (roadwayHeight)
- county
- state
- country

Of the Optional Owner Provided metadata listed, some states provided all except for roadwayOffset and roadwayHeight, while other states provided only the Critical Owner Provided fields. roadwayDesc is the name or number of the highway or interstate closest to the site and roadwayMilepost is the nearest mile reference marker.

The second portion of this task was determining the climate record. Under this task the climate region for a given ESS had to be determined then converted into its corresponding climateId (falls under climate record). To determine the climate region the following information was needed for each ESS:

- latitude (locBaseLat) and
- longitude (locBaseLong)

UND STWRC used a geopolitical geographical information system (GIS) database that outlined climate regions for each state throughout the country. Spreadsheets for each state were created with all ESS and their respective locBaseLat and locBaseLong information and saved in a comma separated variable (CSV) format conducive to the ESRI ArcView GIS software system to map the ESS locations in each state. Using the ArcView software, georeferenced maps displaying location points for each ESS were created. A GIS dataset of state climate divisions available from the National Oceanic and Atmospheric Administration was added as an additional data layer to display each ESS in its corresponding state climate region. Figures 4.1 and 4.2 show the North/West Passage states with their climate divisions and climate divisions with ESS location points, respectively.

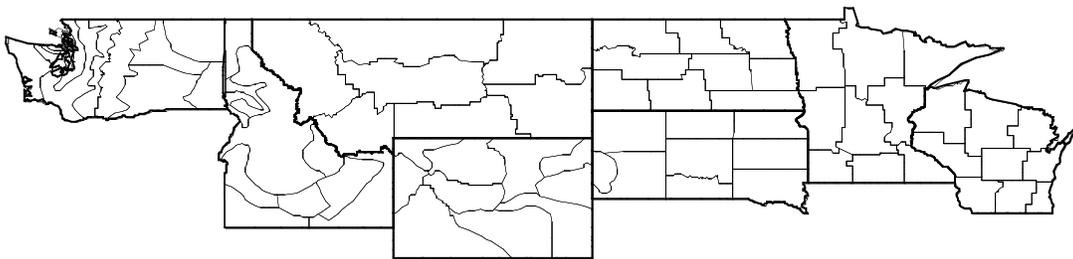


Figure 4.1. North/West Passage states climate divisions.

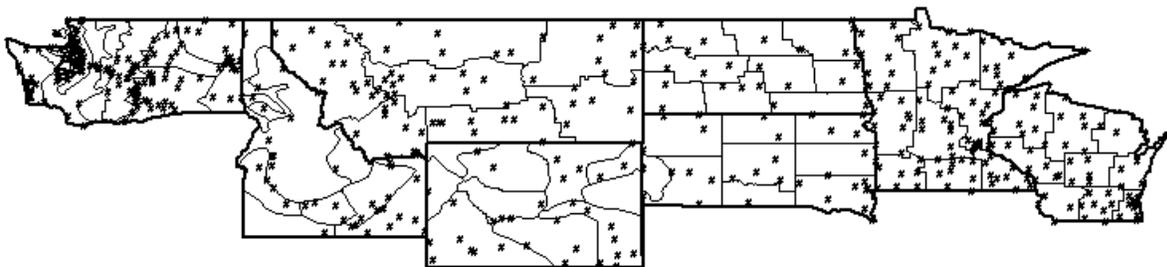


Figure 4.2. North/West Passage states climate divisions and ESS points.

UND STWRC then compared the ESS locations in the GIS maps to a similar GIS map provided by the FHWA *Clarus* System contractor that had numbers associated with each states' climate division. Every state has its own climate region identifier that preceded the climate division for that state. The U.S. climatological division numbers provided to UND STWRC by the FHWA *Clarus* System contractor are outlined in Table 4.1.

Table 4.1. The U.S. climatological division numbers provided to UND by the FHWA *Clarus* System via the *Clarus* training manual.

State	Idaho	Minnesota	Montana	North Dakota	South Dakota	Washington	Wisconsin	Wyoming
State Identifier	10	21	24	32	39	45	47	48
Climate Division								
01	Panhandle	Northwest	Western	Northwest	Northwest	West Olympic Coastal	Northwest	Yellowstone Drainage
02	North Central Prairies	North Central	Southwestern	North Central	North Central	NE Olympic San Juan	North Central	Snake Drainage
03	North Central Canyons	Northeast	North Central	Northeast	Northeast	Puget Sound Lowlands	Northeast	Green and Bear Drainage
04	Central Mountains	West Central	Central	West Central	Black Hills	E Olympic Cascade Foothills	West Central	Big Horn
05	Southwestern Valleys	Central	South Central	Central	Southwest	Cascade Mountains West	Central	Powdr. Ltl. Mo. Tongue Drng.
06	Southwestern Highlands	East Central	Northeastern	East Central	Central	East Slope Cascades	East Central	Belle Fourche Drainage
07	Central Plains	Southwest	Southeastern	Southwest	East Central	Okanogan Big Bend	Southwest	Cheyenne & Niobrara Drng.
08	Northeastern Valleys	South Central		South Central	South Central	Central Basin	South Central	Lower Platte
09	Upper snake River Plains	Southeast		Southeast	Southeast	North Eastern	Southeast	Wind River

10	Eastern Highlands					Palouse Blue Mountains		Upper Platte
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The climateId format required for the *Clarus* system included eight digits: two for the state identifier, two for the climate division in the corresponding state, and four zeros. For example, if an ESS location in Washington (state identifier 45) were located in the Pudget Sound Lowlands (climate division 03), the climate division number of the ESS for the *Clarus* System would be 45030000.

Once all the site and climate metadata were collected and mapped out, UND STWRC sent a final copy to the FHWA *Clarus* System contractor. If any changes needed to be made, the spreadsheet(s) were sent back to UND STWRC for changes and/or clarification from the states. Both Task 1 and Task 2 had to be complete before the metadata was sent to the *Clarus* System contractor. The *Clarus* System contractor notified each state when their metadata was in the *Clarus* system.

Chapter 5 Findings and Conclusions

UND STWRC completed its submittal of ESS metadata for the seven North/West Passage states as part of the North/West Passage *Clarus* Regional Demonstration Concept of Operations Development as of July 31, 2008. Minor adjustments and revisions were further provided to the *Clarus* System during the month of August 2008. Table 5.1 outlines when each state's metadata was submitted. Note that Minnesota was in the *Clarus* system prior to the regional demonstration.

Table 5.1. North/West Passage states and their submission to *Clarus* by UND STWRC.

North/West Passage States	Date Submitted to <i>Clarus</i>
Idaho	April 2008
Minnesota	Prior to the <i>Clarus</i> Regional Demonstration
Montana	January 2008
North Dakota	January 2008
South Dakota	April 2008
Washington	April 2008
Wisconsin	August 2007
Wyoming	July 2008

The metadata collection process was lengthy and not without obstacles. Two of the North/West Passage states were in the midst of upgrading their ESS with new sensors and/or system RPU's during the contract period. This posed a challenge in states' ability to collect and provide their ESS metadata and resulting in a delay in providing the metadata to UND STWRC. The delays were largely due to personnel who were providing the metadata were the ones making the upgrades and were not available due to time commitments. In other instances the metadata had not been compiled for the new systems. One state did not house the metadata at their facility, therefore having to work through their ESS vendor. This was not an issue right away until the vendor's personnel became too busy to focus on pulling together the required metadata. There was also some confusion regarding exactly what data UND STWRC was requiring. Improved clarification and better communication between UND, the vendor, and the corresponding state was successful in removing confusion on metadata needs.

Access to ESS data files was also challenging in the project outset. Some states' data files are protected by the vendor where only the vendor and/or state can gain access. This was a problem when trying to determine what observations came from sensors at a given ESS where the only information provided by a state or vendor was the sensor manufacturer and model number. One state's vendor does not allow the state to give public access to the data files. This was a challenge as UND STWRC had to wait for the state agency contact to be available and to have access to the files to show the ESS vendor what was needed in terms of a certain field.

Agency management of data also posed a problem in some instances. One state had data in numerous spreadsheets and documents, none of which had all the same information. Each document sited a different number of ESS within the state and different sensors. It took considerable time (on the order of a few months) to sort through documents and determine which sites were still commissioned and what sensors and observations were at each site. County ESS sites were also in the state ESS documentation and had to be removed from the state data before project completion.

Explanations for each metadata field were pretty straight forward with one exception, the *sensorIndex*. This field was more difficult to determine than other fields as the location of the information was not always known initially. It was later determined the information could be found in the ESS data files or on website data pages.

The conduct of this project was a joint effort between UND STWRC and the state transportation agencies comprising the North/West Passage Transportation Pooled Fund Study. The willing enthusiasm demonstrated by each representative of the state agencies made the success of this project possible. The longer-term benefit to the states involved will be an important aspect to watch in the future. This is not only for the potential benefit from the *Clarus* System as it becomes an operationally established entity, but also for the apparent structure resulting from this project in how states maintain their ESS metadata. It is therefore concluded that this project provided both the opportunity for the North/West Passage states to participate in developing the *Clarus* System, but also provided them an opportunity to better organize and understand their ESS metadata where it may have not been possible before.

The effort by UND STWRC in working with the FHWA *Clarus* System also provided an opportunity for UND STWRC to better understand the structure of the *Clarus* System. It also provided feedback to Mixon/Hill, Inc. as the *Clarus* System contractor to understand issues and concerns from state agencies. Some of these concerns are associated with how to best update ESS metadata in an efficient and effective manner when ESS sites are changed, become inactive, or new sites/sensors come online. As a demonstration system, the *Clarus* System still has not fully been utilized in an operational environment where maintenance of current ESS configurations is critical. This effectiveness of state agencies to provide current and/or updated ESS metadata will be crucial in the success of adoption of the *Clarus* System to provide solutions to surface transportation weather applications and decision-making.

Chapter 6

Recommendations

The actions of the completed project have yielded significant insight into the ESS metadata management by state agencies and the effectiveness by which this information can be provided to the *Clarus* System. As a result of this study, the following recommendations are provided to encourage both state and federal follow-up to ensure the successful application of ESS data to support surface transportation weather applications and decision-making.

Recommendation 1: Maintenance of Accurate and Timely ESS Metadata Records.

To provide the most effective use of environmental sensor stations it will be imperative that the ESS metadata be maintained in an accurate and timely manner. It is recommended that every North/West Passage state establish a procedure for the timely revision and update of their ESS metadata records upon every maintenance action and/or ESS modification that is made.

Recommendation 2: Annual ESS Metadata Audits and Reviews

To provide appropriate assessment and performance evaluation of statewide RWIS, each North/West Passage state should perform an annual review of their ESS metadata to ensure that it is accurate. It is recommended that this annual review include an audit of current ESS within the statewide RWIS to validate the sensor existence, operational capabilities, and performance quality. From this annual review and audit it is expected that planning for future enhancements and/or expansion would be best evaluated based upon need and capabilities of the existing system.

Recommendation 3: Maintenance of Accurate *Clarus* System ESS Metadata

To enable the *Clarus* System to be most beneficial, it is imperative that the ESS metadata changes from state agencies be provided in a timely manner. It is recommended that as ESS metadata changes occur that these changes be conveyed to the FHWA *Clarus* System for incorporation in their ESS metadata records, and that FHWA ensures that this updating is as efficient as possible without the need to encumber unwarranted amounts of time from state agency personnel.

Recommendation 4: *Clarus* System Evaluation and Review by the Stakeholder Community

To ensure user community acceptance it is critical that FHWA be open to an independent evaluation by the user community on the effectiveness of the *Clarus* System. It is recommended that once the *Clarus* System has conducted an operational multi-state regional demonstration that FHWA conduct a review with the participating states and the broader user community on the effectiveness of *Clarus* System to maintain current ESS metadata, conduct a gap analysis on ESS metadata requirements, and evaluate the effectiveness by state agencies on providing updated ESS metadata to the *Clarus* System.

References

1. Mn/DOT, State of Minnesota Work Order Contract, Mn/DOT Contract No. 89262 Work Order No. 1, CFMS Contract No. B03118.
2. <http://www.Clarusinitiative.org/documents.htm#metadata>
3. Mixon/Hill, Inc., *Clarus* Training Manual, 2007

