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ENTERPRISE

Documenting Road Weather Information System Technologies

Supporting Intelligent Transportation Systems and Operations

ENTERPRISE TRANSPORTATION POOLED FUND STUDY TPF-5(490)

FINAL REPORT

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16. Abstract

Road Weather Information Systems (RWIS) are widely relied on for agency operations and need to be accurate and reliable to the end of their lifecycle given maintenance and funding considerations. RWIS are used to support ITS and operations, and the solutions available from different vendors vary in terms of accuracy, reliability, and costs.

This project conducted a high-level literature review and a survey of agency practitioners to understand the accuracy, reliability, and cost tradeoffs of deployed RWIS solutions, with an emphasis on RWIS that support ITS solutions. This report presents the survey responses and an analysis of the 19 agency responses received. Overall, RWIS are an integral part of operations and maintenance business practices at many agencies. In particular, 81 percent of survey respondents said that the primary use of RWIS is for decision making by winter maintenance operations staff. Agency respondents indicated overall satisfaction with the devices, with 87 percent of survey respondents indicating that their RWIS devices tend to be reliable for the duration of the lifecycle, while 93 percent reported their devices provide accurate data for the duration of the lifecycle.

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Project Champion

Kevin Price from the Illinois Department of Transportation was the ENTERPRISE Project Champion for this effort. The Project Champion served as the overall lead for the project.

ENTERPRISE Members

The ENTERPRISE Board consists of a representative from each of the following member entities.

- Illinois Department of Transportation
- Iowa Department of Transportation
- Kansas Department of Transportation
- Michigan Department of Transportation
- Minnesota Department of Transportation
- Ontario Ministry of Transportation
- Texas Department of Transportation
- Wisconsin Department of Transportation

Project Input

ENTERPRISE would like to thank the State Departments of Transportation that provided input to the project through an online survey.

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List of Abbreviations

ATMS	Advanced Traffic Management System
BLM	Bureau of Land Management
CCTV	Closed Circuit Television
DMS	Dynamic Message Sign
DOT	Departments of Transportation
ENTERPRISE	Evaluating New Technologies for Roads Program Initiatives in Safety and Efficiency
EPA	Environmental Protection Agency
ESS	Environmental Sensor Stations
ITS	Intelligent Transportation Systems
MDSS	Maintenance Decision Support System
MDT	Montana Department of Transportation
MI	Michigan
NDOT	Nevada Department of Transportation
NIST	National Institute of Standards and Technologies
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PTZ	Pan-Tilt-Zoom
RWIS	Road Weather Information System
SP	Special Provisions
TAMP	Transportation Asset Management Plan
TPF	Transportation Pooled Fund
USFS	United States Forest Service
USGS	United States Geological Survey
VSL	Variable Speed Limit

Chapter 1: Introduction

This project conducted a high-level literature review and a survey of agency practitioners to understand the accuracy, reliability, and cost tradeoffs of deployed RWIS solutions in the field, with an emphasis on RWIS that support ITS solutions.

A Road Weather Information System (RWIS) is typically comprised of a suite of sensors deployed in the field called Environmental Sensor Stations (ESS), as well as a communication system for data transfer and central systems to collect field data from numerous ESS. RWIS are used by agencies to measure atmospheric, pavement and/or water level conditions, while RWIS hardware and software are used to process observations from ESS to develop forecasts, understand current conditions, and display or disseminate road weather information in a format that can be easily interpreted by a manager to support decision making.

As such, RWIS are widely relied on for transportation agency operations and need to be accurate and reliable to the end of their lifecycle given maintenance and funding considerations. RWIS are deployed by many transportation agencies and used to support intelligent transportation systems (ITS) and operations, and different vendor solutions vary in terms of accuracy, reliability, and costs.

This project was undertaken by the ENTERPRISE Pooled Fund Study to better understand the accuracy, reliability, and cost tradeoffs of deployed RWIS solutions in the field by documenting available RWIS solutions and surveying state DOT practitioners. The emphasis of this effort was to document how RWIS supports ITS solutions. Additionally, this effort was not intended to develop a catalog of all available sensors and products, but instead, to generate survey findings to document different sensor types that have been deployed by agencies, noting features, challenges, and vendors, as known.

1.1 Report Organization

This report includes the following sections:

- Chapter 2: Project Approach – Describes the approach used to develop a survey for this effort, as well as literature review findings.
- Chapter 3: Analysis of Survey Findings – Presents findings of an analysis of survey responses.
- Chapter 4: Survey Responses – Includes the raw survey responses received from 16 state departments of transportation (DOTs) and one toll authority.
- Chapter 5: Project Summary and Implementation – Presents a summary of key project findings and how to use these to support implementation.
- Appendix A: Survey Respondents – Presents information about survey respondents in this effort.
- Appendix B: Survey Instrument – Presents the SurveyMonkey online instrument that was distributed to practitioners for this effort.

Chapter 2: Project Approach

This section describes the approach to develop and conduct a survey of agency practitioners to understand the accuracy, reliability, and cost tradeoffs of deployed RWIS solutions in the field. The findings of a high-level literature review that was conducted to support this effort are also presented.

2.1 Agency Survey

This project developed a survey that was distributed to state transportation agency practitioners. Specifically, this survey included 27 questions that focused on the following topics:

- Use of RWIS (i.e., to make decisions, by external users).
- Types of RWIS deployed (vendor, sensor types).
- Challenges with technology or sensor types.
- Maintenance needs, reliability, and service life.
- Accuracy issues.
- Relative costs to deploy and maintain.
- Quality control systems to screen RWIS data and how they function.

This web survey was developed using SurveyMonkey, reviewed by ENTERPRISE Board Members, and then distributed to operations and maintenance practitioners. Screenshots of the web survey that were used for this effort are presented in Appendix B. The survey was distributed via email to the following entities to solicit responses:

- ENTERPRISE Pooled Fund Study members.
- Transportation Management Center Pooled Fund Study members.
- Aurora Pooled Fund Study members.

19 responses received

- Alaska
- Arizona
- Caltrans (2)
- Delaware
- Florida
- Illinois DOT
- Illinois Tollway
- Iowa
- Kansas
- Louisiana
- Maryland
- Michigan (2)
- Minnesota
- Ohio
- Pennsylvania
- Utah
- Wisconsin

The survey was open for practitioners to respond in August and September 2024. In total, 19 responses were received from 16 state DOTs and one toll authority. An analysis of survey findings is presented in Chapter 3 and the raw survey results are presented in Chapter 4.

2.2 Resources Reviewed

This project conducted a literature search to identify available information about RWIS accuracy, asset management findings regarding reliability, and costs including maintenance costs. Four resources provided information for this project:

- Life Cycle Planning for Intelligent Transportation System Assets: Survey of Practice
- Fully-Compliant Transportation Asset Management Plan
- Assessment of Montana Road Weather Information System
- Non-Invasive Sensor Deployment in Aurora Member States

Life Cycle Planning for Intelligent Transportation System Assets: Survey of Practice (Caltrans, 2021). Caltrans explored methodologies for assessing the life span of ITS assets, including RWIS by seeking information from other DOTs about practices that estimate the life span of ITS assets installed on state highways. The information Caltrans was interested in identifying from other DOTs included the methodologies used to conduct a life expectancy analysis of various components of an ITS asset, the frameworks that identify an asset's life expectancy, how other agencies calculate remaining service life and schedule maintenance and replacement, and the performance measures used to track ITS assets.

During their evaluation of asset condition, Caltrans identified nine states that gather data to conduct RWIS life cycle planning. Some states grouped multiple components together for life cycle planning while other states reported that they tracked the life span of each component part. The most common criteria that states used to assess asset condition were inspection reports, age-based assessments, and engineering judgment. Additional criteria included performance, manufacturer's recommendations, and annual maintenance visits. The Caltrans survey of state DOTs found that the frequency of RWIS inspections varied from regular annual inspections to inspecting systems as needed or when an issue arose. Some states performed preventative maintenance during annual maintenance visits while other states improved the RWIS condition as connectivity improvements became available, when assets were not functioning as intended, or when components failed.

Various approaches to administering the RWIS program were uncovered through Caltrans' survey of state DOTs. Some unique approaches included:

- The RWIS program in Pennsylvania is administered by another division within the agency, not by Traffic Operations/ITS. These devices are tracked based on a multi-year contract.
- South Dakota DOT designs, integrates, installs, and maintains its own RWIS installations, which makes most component replacements straightforward. They have not completely replaced the assets since adopting the current modular design and can evolve with technological advances, replacing components as necessary.

Caltrans discovered that the estimated service life of RWIS that was reported ranged from 10 years to more than 20 years. Key factors that affect the remaining RWIS service life include condition, age, engineering judgment, manufacturer support, and physical environment. This report concluded that agencies most frequently replace RWIS at the end of its useful life, in connection with a roadway replacement or new construction project, or when the asset no longer functions as originally intended.

This source also included several tables of information that depict a description of RWIS components, RWIS condition assessment methodologies, the RWIS inspection interval, RWIS preventative maintenance frequency, factors affecting the RWIS remaining service life, and the RWIS replacement interval.

Fully-Compliant Transportation Asset Management Plan (Nevada DOT, 2019). To help plan investments in its transportation assets, Nevada Department of Transportation (NDOT) prepared a Transportation Asset Management Plan (TAMP) that summarizes the condition of certain assets and the agency's plans for managing these assets for the next 10 years. NDOT's Traffic Operations Division maintains and manages several types of ITS assets, including RWIS, to address highway safety and mobility needs.

NDOT's RWIS asset management practices are documented in this source through tables including descriptions of the inspection of maintenance activities by ITS device type and the average maintenance cost by ITS device type. Additional tables of information for 2017-2026 regarding the RWIS estimated condition, summary of current replacement value of assets, average annual investment needs for RWIS, budget to maintain current conditions of ITS assets, and average maintenance cost by ITS device type are also included in this TAMP.

Assessment of Montana Road Weather Information System (Montana DOT, 2017). This project performed a comprehensive review and assessment of Montana DOT's (MDT's) RWIS program to ensure the efficient use of weather data in various transportation applications and the optimum use of MDT resources. Six major project tasks were completed for this project including a state-of-the-art review, a state of the practice review, a Montana RWIS needs assessment, a weather data and software analysis, a benefit cost analysis, and the development of a site prioritization model. Methods and findings from each task are detailed in this report along with a set of recommendations including considerations for the future direction of the MDT RWIS system.

MDT's RWIS program currently includes 73 ESS that provide data for winter maintenance personnel and traveler information systems within MDT. Virtually all ESS include an air temperature and humidity sensor, wind speed and direction sensor, in-pavement sensor, subsurface temperature sensor, precipitation occurrence sensor, and a camera. MDT RWIS programs expanded and evolved since their initial focus on winter maintenance support to include other uses like traveler information, operations activities, advanced ITS applications, and third-party weather service providers.

Project findings determined:

- While pan-tilt-zoom (PTZ) cameras are the most problematic pieces of equipment from a maintenance perspective, they are also the most valuable.
- RWIS data outages are primarily due to cellular communications issues which are outside MDT's control.
- Sensor and camera technologies that may be desired include non-invasive sensors, more robust precipitation sensors, visibility sensors, live video, and cameras with the ability to produce images in the dark.
- Though MDT desires the ability to display RWIS data for maintenance personnel on mobile devices, this information may be partially available via the traveler information mobile app.
- MDT would like more RWIS sites, especially near maintenance section boundaries.
- The public prefers cameras for information and would prefer more camera-only sites and fewer fully instrumented sites.
- The greatest agency-specific benefit-cost ratios resulted from the forecasting and automated performance metric functionalities.

Non-Invasive Sensor Deployment in Aurora Member States (Aurora Pooled Fund Study, 2022). This project pursued a large-scale effort to deploy non-invasive sensors adjacent to invasive sensors (embedded in the pavement) located at existing RWIS stations and to consider agency suitability between

the different sensors. While some RWIS stations may have multiple invasive sensors measuring pavement temperature at various locations (e.g., bridge deck and approach), this deployment was unique in that both the invasive and non-invasive sensors were measuring the same, proximate physical locations. A total of 65 non-invasive sensors, representing 51 potential sites, were purchased from four different vendors and distributed to 16 participating states.

Many participating states provided positive feedback with respect to non-invasive sensors and their reported data. Some of the challenges that were shared included identifying a suitable installation location due to sensor specifications, initial sensor operation, and integration and data retrieval.

Through this project, participating agencies gained:

- Experience working with new vendors.
- An opportunity to evaluate the different products, encounter potential issues, and identify possible solutions through a low-risk environment.
- An introduction to new data, such as friction measurements, through the deployment of non-invasive sensors.

Potential actions resulting from this project included:

- Some participating state DOTs decided to adopt non-invasive sensors, expand their deployment of them, or even consider applications beyond those planned with this project.
- One participating agency with limited non-invasive sensor experience is planning on statewide deployment for real-time friction measurements for use in agency decision making.
- This project will support future research on both pavement temperatures and friction across the U.S. based on data from the same makes and models of non-invasive equipment.
- One agency began to use these data to trigger messaging and anticipated a future, larger deployment, given the real-time friction measurement capability, for speed management and truck restrictions.

This project also suggested research opportunities to compare invasive sensors with non-invasive sensors and to assess site performance relative to different service conditions and installation practices. Continued communication between participating agencies could also encourage tracking non-invasive sensor installations and facilitate additional data comparisons.

Chapter 3: Analysis of Survey Findings

Survey responses were received from 19 agencies. This section provides anaysis of survey findings.

3.1 Uses and Benefits of RWIS

Survey data from 19 agencies revealed that the use of RWIS is of vital importance to help address roadway conditions during severe weather conditions. In fact, 81 percent of respondents (13 of 16 respondents) said that the primary use of these devices is for decision making by winter maintenance operations staff. Other use categories of RWIS devices indicated by respondents included:

- Construction and maintenance staff decision making (6 of 18 respondents).
- Integration with ATMS (10 of 18 respondents).
- Support maintenance decision support systems (6 of 18 respondents).
- Support variable speed limit deployments (5 of 18 respondents).
- Support other ITS devices (7 of 18 respondents).
- Provide traveler information (11 of 18 respondents).

Overall, RWIS are an integral part of operations and maintenance business practices at many agencies. As an example, one respondent noted:

> "Our RWIS network is robust and has many uses. Our Weather Services Contractor (which also performs our RWIS maintenance) uses them for forecasting efforts and verification, our maintenance staff uses it for standard maintenance purposes, and provides good situational awareness for traffic operations and traveler information."

Understanding benefits can be helpful to justify funding for continued deployment, operations, and maintenance needs of RWIS devices. While quantitative data was not available, 83 percent of respondents indicate that the benefits provided by RWIS for more efficient maintenance operations outweigh the cost expenditures. Additionally, 75 percent of respondents said that RWIS devices are needed to support critical agency assets such as VSLs during severe weather events. To help manage RWIS deployment costs, the most influential factor in selecting an RWIS vendor was a low-cost bid. Some agencies are also exploring the deployment of "light" RWIS, which generally includes fewer sensors and only the most critical sensor types, as a potential cost-saving alternative to an RWIS with more robust sensor suites.

3.2 Sensor Types

Agencies deploy many different types of ESS as part of their RWIS devices, as seen in Figure 1. Specifically, all respondents at agencies that deploy RWIS stated that they always include ESS to measure:

- Air temperature.
- Wind speed and direction.
- Pavement temperature.

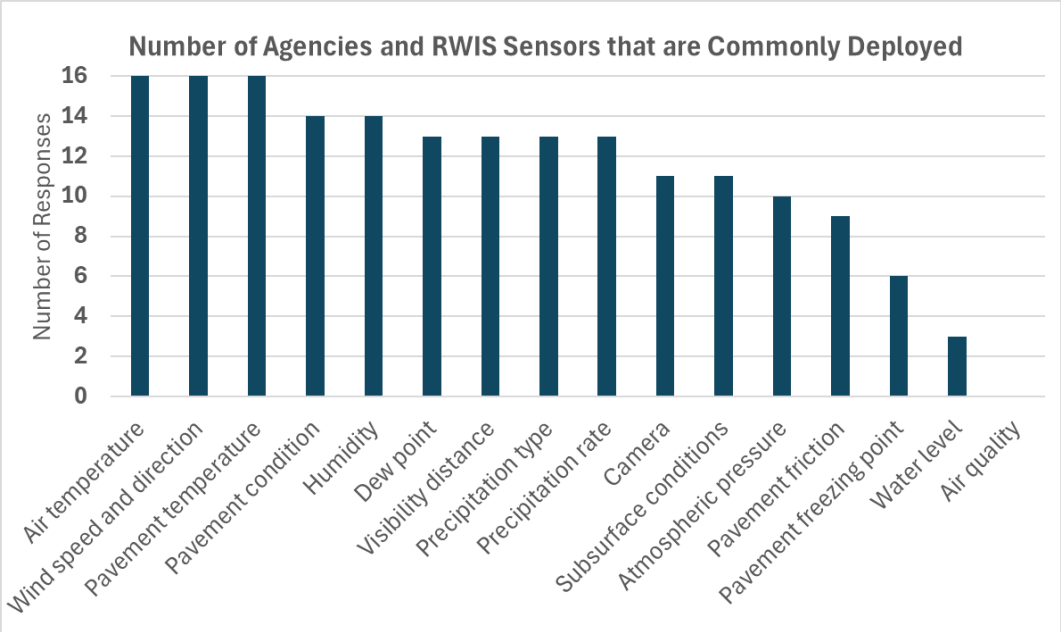

Figure 1. Survey Respondents Deploy 15 Types of RWIS Sensors

3.3 Accuracy and Reliability

Despite the widespread deployment of RWIS, certain sensors sometimes experience accuracy or reliability concerns, or both. While the accuracy and reliability of specific RWIS sensors over their lifecycle was a focus of this effort, survey responses show relatively minimal issues overall. The number of agencies that noted various sensors to experience issues is displayed in Figure 2. Specifically, out of the 15 RWIS sensor types deployed by responding agencies, only five sensor types were noted to experience accuracy or reliability issues:

- Wind speed and direction (1 respondent).
- Pavement condition (3 respondents).
- Visibility distance (1 respondent).
- Precipitation type (3 respondents).
- Pavement friction (3 respondents).

Overall, specific sensor types noted to have issues is relatively low as compared to the number of responses for agencies that use those sensors. Very few agencies experienced common challenges or difficulties with certain products, but several sensor types stood out as having multiple responses indicating challenges (i.e., pavement condition, precipitation type, and pavement friction sensors). For the five sensor types reported to have accuracy or reliability issues, at most three agency respondents reported experiencing any issues for any one type of sensor. In particular, two of the sensor types experiencing the highest number of issues are pavement friction (3 of 9 respondents, 33%) and pavement condition (3 of 14, 21%), which may be deployed in the pavement and be more exposed to vehicle and de-icing material impacts.

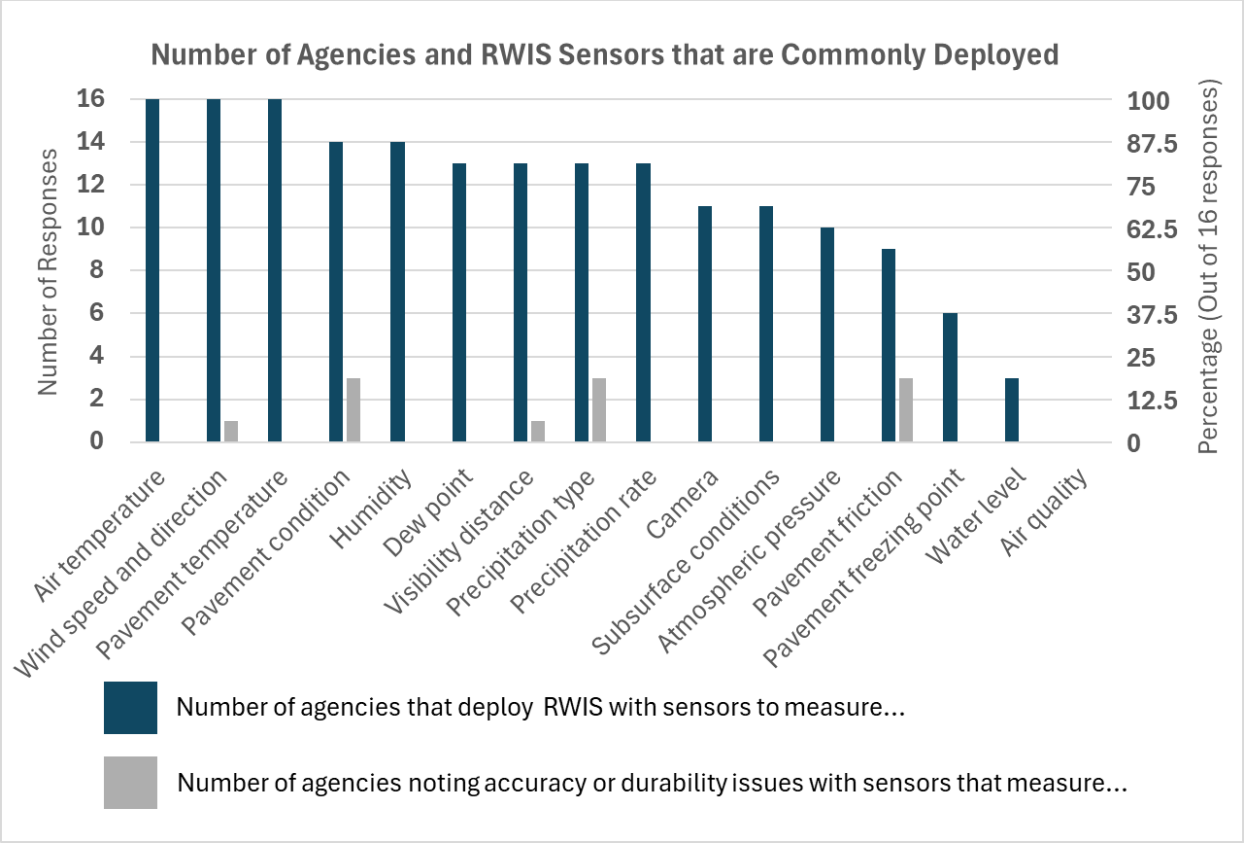

Figure 2. Survey Respondents Deploy 15 Types of RWIS Sensors and Report Relatively Minimal Accuracy and Durability Issues with Deployed Sensors

Agency respondents indicated overall satisfaction with the devices, as depicted in Figure 3. Specifically, 87 percent of respondents indicated that their RWIS devices generally tend to be reliable for the duration of the lifecycle, while 93 percent reported their devices generally provide accurate data for the duration of the lifecycle.

It should be noted that use of the word “generally” in the survey questions may have skewed results, as respondents may be accustomed to routine sensor failures and fixes being needed. That is, it is possible that respondents may have made a distinction between sensor failures that routinely occur “generally” versus failures that are more systematic or sensors being particularly prone to early failure. As one example, if an agency has many RWIS deployed around the state, each of which has many sensors, there may be a number of RWIS sensors or components down at any given time, but overall RWIS sensor assets are generally good. This explanation cannot be confirmed, but is possible.

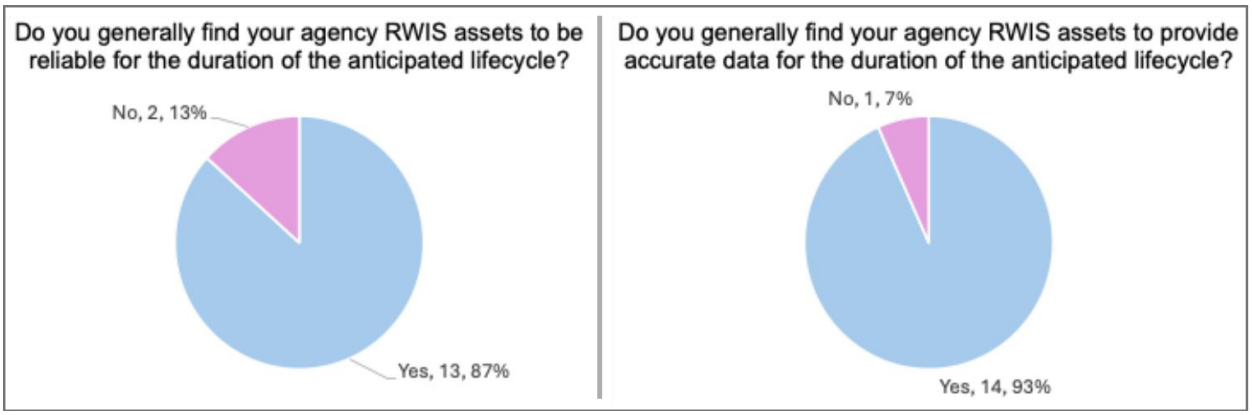

Figure 3. Most Survey Respondents find RWIS Assets to be Reliable and Provide Accurate Data for the Anticipated Lifecycle

3.4 Cost and Maintenance Resources

Cost expenditure and time spent were concerns expressed when considering RWIS inspection and maintenance needs. Inspection and maintenance frequency by agencies were generally reported to be between 6-months to 1-year, as displayed in the left image of Figure 4. However, some respondents indicated their agencies do not inspect or maintain RWIS devices until the system starts to fail (i.e., as-needed). Those that selected the as-needed option cited cost and/or staff availability constraints, as more frequent inspection requires additional staff time and money.

Additionally, the annual RWIS maintenance cost for different agencies is described in the right image of Figure 4. The responses indicating high annual maintenance costs ($5,000 and above) were further examined to understand driving factors behind these high estimates. One commonality across these responses is a full-service contract that may contribute to higher annual cost. Additionally, the highest reported annual maintenance cost ($8,000) was from Alaska DOT and Public Facilities, which has more remote RWIS sites, limited expertise for covering such a large geographic area, and more severe weather that negatively affects RWIS equipment, particularly when compared with other respondents.

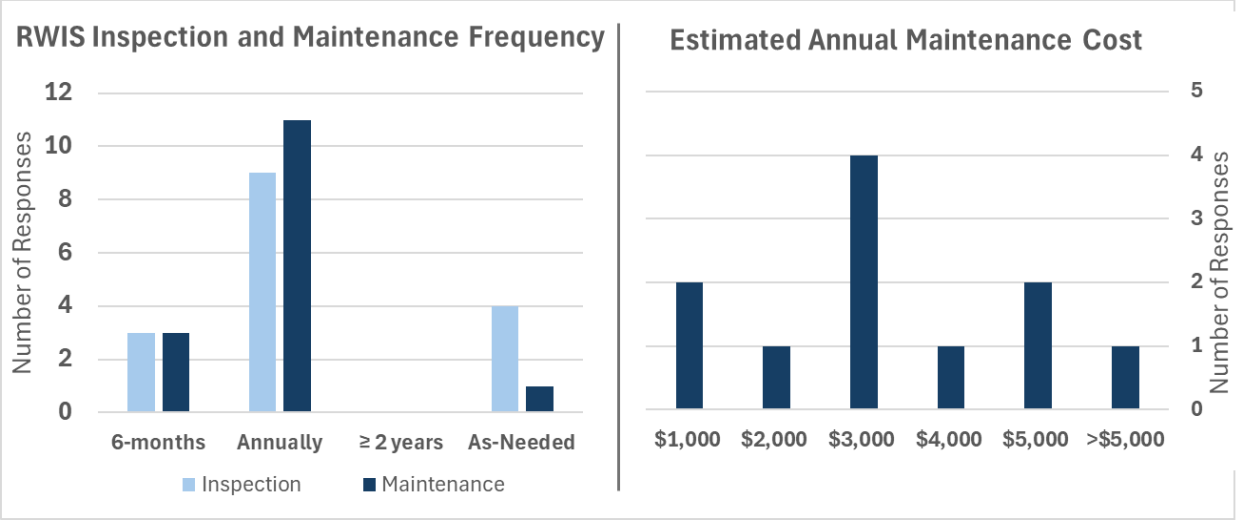

Figure 4. Most Survey Respondents Inspect and Maintain RWIS Assets Every 6-12 Months at $1,000 to $5,000 per RWIS per Year

It should be noted that though capabilities are available to perform automated checks of RWIS data to identify maintenance needs, only about 20 percent of agencies use automated assessment. One agency indicated that there are sometimes RWIS data that they know to be problematic, that they can ignore until it can be fixed, which speaks to the importance of institutional knowledge. However, given staffing issues and high turnover at some agencies, automated processes may be more important so that less experienced users can rely on the RWIS data. Automated processes may help to identify issues to improve the overall data accuracy and reliability from RWIS devices, as automated procedures that highlight when a system is failing can provide time and cost savings. Combined with other preventative inspection and maintenance practices, this may also help to prolong RWIS device lifecycle.

Chapter 4: Survey Responses

This section presents all of the responses received from the survey distributed and conducted in August and September 2024. In total, 19 responses were received from DOT staff in the 16 state DOTs shown in Figure 5, including two responses from different DOT Districts in Michigan and California, as well as the Illinois Toll Authority.

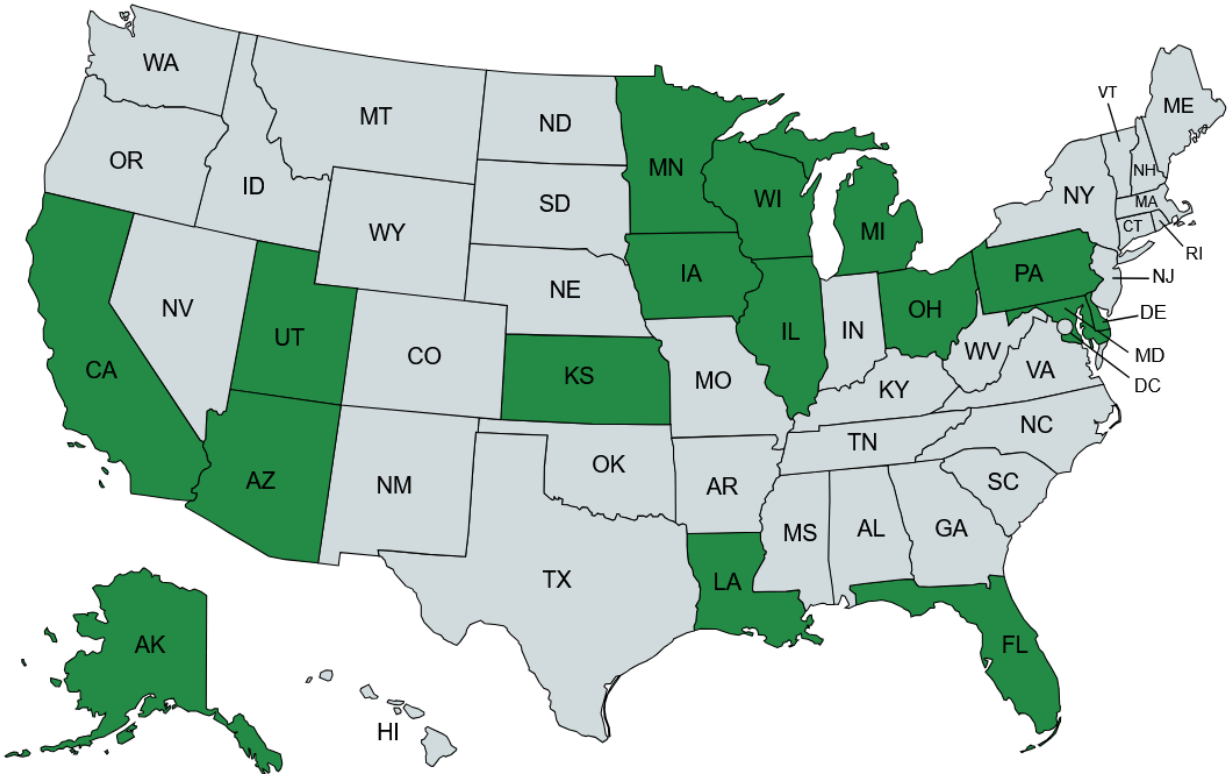

Figure 5. Survey Respondents Represented 16 States

The responses for each question are summarized in the following subsections, with only minimal editing performed for information that was manually entered by respondents:

4.1 RWIS Uses

A total of 18 respondents answered how their agency uses RWIS and were able to select multiple responses. Results are presented in Figure 6. Most responding agencies use RWIS in multiple ways, but one agency does not use or deploy RWIS.

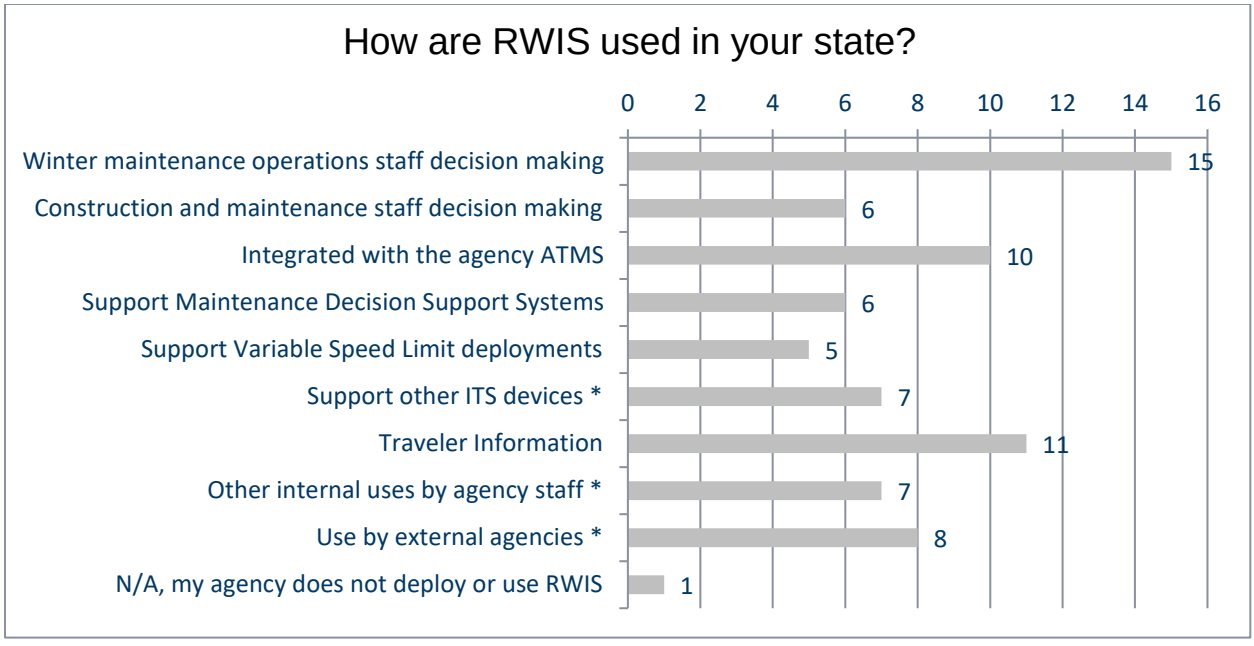

Figure 6. Survey Responses on Agency Uses of RWIS

Additional explanations were requested from respondents who selected an option denoted with an asterisk in Figure 6. These explanations were:

- RWIS help our snow operations make decisions about the amount of salt needed on our system.
- Used for winter indices and salt use tracking tools. Other non-maintenance use on a case-by-case basis.
- We will use RWIS in future winter driving conditions along with possible dynamic message sign (DMS) notifications.
- Used as a supplement for winter maintenance operations decisions.
- Hurricane response.
- We have a pilot program for flooding in our area.
- Other internal uses by agency staff – review data provided by the RWIS site and traffic information to determine if the roads are being cleared timely, which is utilized for employee performance measurements.
- Used by our Bridge staff to monitor high rainfall amounts in conjunction with National Weather Service (NWS) data.
- Support other ITS devices: We use them with automating DMS messages and de-icing operations.
- DMS and closed circuit television (CCTV) cameras.
- We do not have a maintenance decision support system (MDSS). Other ITS Devices: we use RWIS to automatically trigger a standing water sign on the nearby DMS sign.
- Bridge wind warning signs.
- ESS data is used to trigger automated weather messages on DMS.
- Use by external agencies: National Oceanic and Atmospheric Administration (NOAA) uses our weather data along with universities doing studies.
- Used a lot by researchers, university, and NWS. Also part of statewide weather observation databases.
- Our data is made available to NWS, private weather supplier and the State Emergency Management Agency.

4.2 Primary Reason for Deploying and Maintaining RWIS

A total of 16 respondents answered how the primary reason their agency has for deploying and maintaining RWIS, as seen in Figure 7. The vast majority of agencies primarily deploy and maintain RWIS to support winter maintenance operations staff decision making (13 agencies). Other respondents cited integration with the agency Advanced Traffic Management System (ATMS) (1 agency) and to support MDSS (2 agencies). Additional explanations provided by respondents included:

- For winter maintenance and traveler information. We also use for variable speed limits (VSLs) in our dust system corridor.

- The primary purpose varies by RWIS site location.

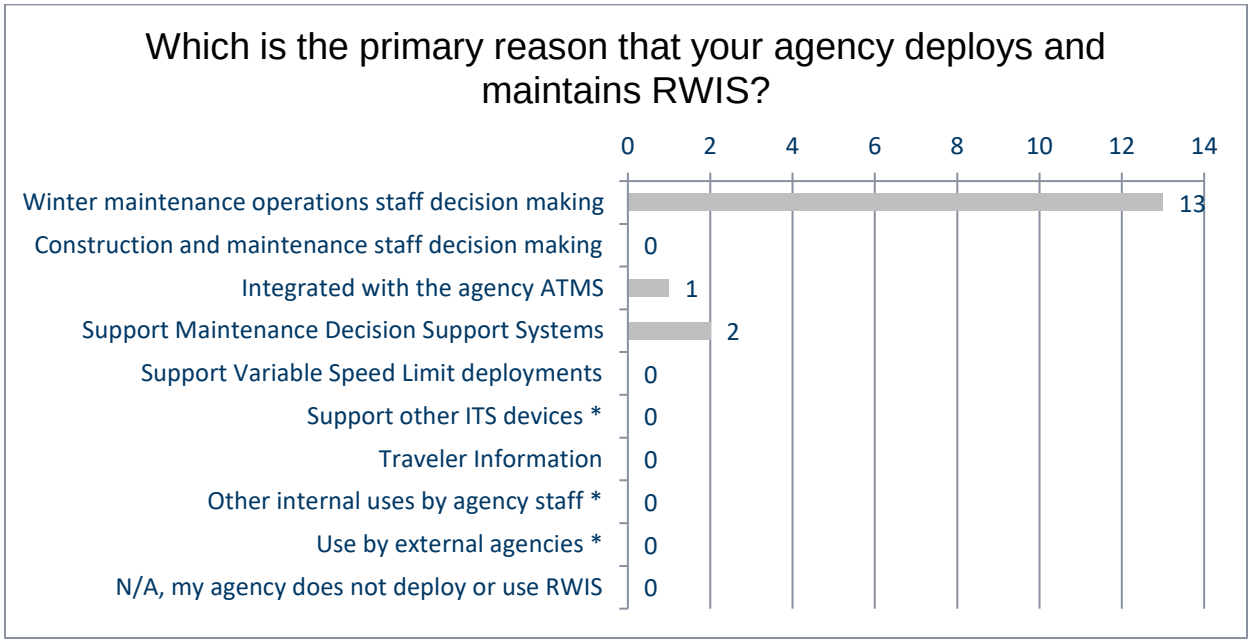

Figure 7. Survey Responses on Primary Reason that Agencies Deploy and Maintain RWIS

4.3 Agency Collaboration to Understand RWIS Data Needs, the Value of the Data, and How it is Used

There was a total of 16 responses to a question about who agencies collaborate with to understand RWIS data needs, the value of the RWIS data, and how it is used. Respondents were able to select multiple responses. Most responding agencies collaborate with internal or contracted winter maintenance staff (12 agencies) and NWS (11 agencies). Results are presented in Figure 8.

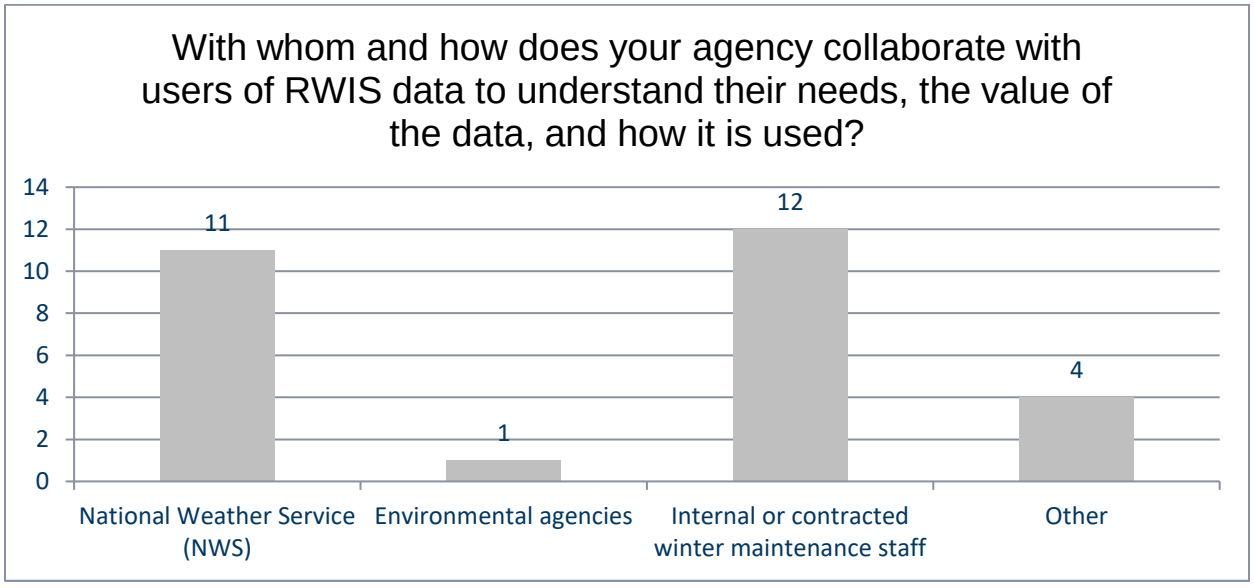

Figure 8. Survey Responses on Entities that Agencies Collaborate with when Deploying RWIS

Explanations provided for "other" responses were:

- Local governments, trucker's union, universities, NOAA, and Weathershare.org use our data for studies and traveler information. We have meetings with them and coordinate updates and changes.
- We collaborate with several agencies when responding to a burn scar that could produce debris flows on state highways and other infrastructure. We tend to collaborate with the United States Forest Service (USFS), Bureau of Land Management (BLM) and local emergency managers.
- United States Geological Survey (USGS) and State Geological Survey, university for research.
- Traveling public.

Additional explanations provided by respondents about how their agencies collaborate were:

- Decisions related to new RWIS installations are done with input from maintenance staff and traffic management centers. Our data is shared directly with NWS through our RWIS vendor.
- Winter staff has access to Viewmondo and are able to see the weather data as needed.
- Usually informal. Meetings, calls, emails.

4.4 Nature of RWIS Deployments

There was a total of 17 responses to a question about the nature of agencies' RWIS deployments. Results are presented in Figure 9.

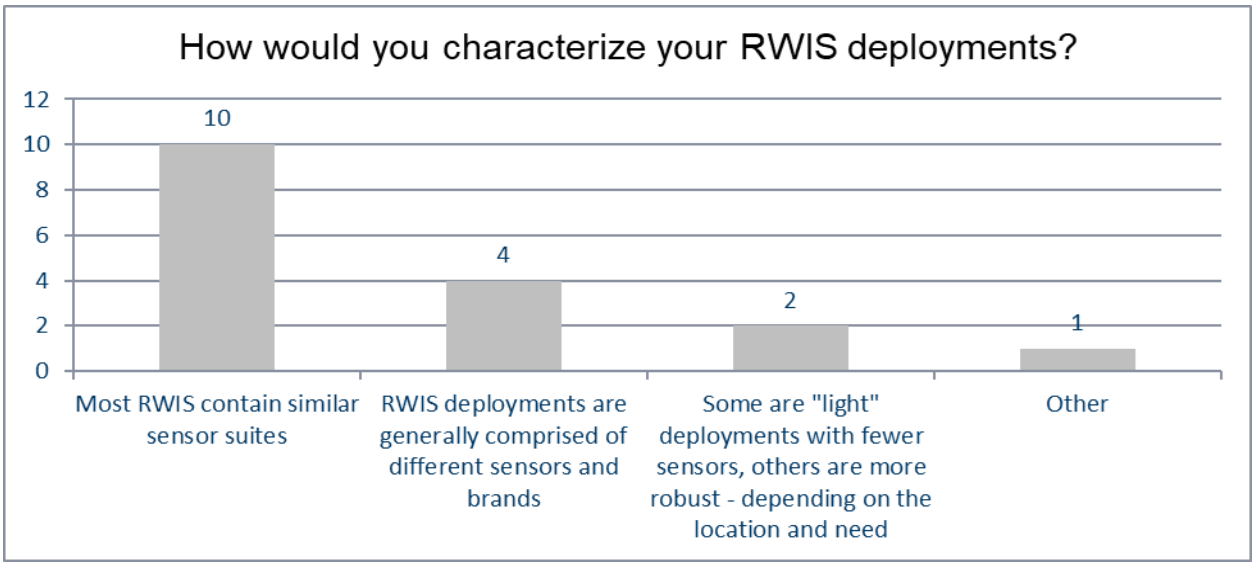

Figure 9. Survey Responses on Characterization of Agency RWIS Deployments

The agency that responded "other" noted: "Each of our districts use a familiar sensor suite to their district. Some districts use the same sensor suite after seeing how beneficial the sensors are compared to their existing sensor."

Additional explanations provided by respondents included:

- We have RWIS sites with various capabilities throughout our network, depending on need.
- We sample the same data points at all RWIS stations. We have different brands and multiple different models.
- Our sensor suite has evolved over the years, and some are optional, such as frost depth sensors and bridge deck systems.
- Some are "light" deployments with fewer sensors, others are more robust – depending on the location and need – is also true.
- We are starting to test "light" deployments at locations that are not practical for full deployment.
- We have chosen to repair units, rather than replace 10 to 15 at a time.

4.5 RWIS Deployment Approach

There was a total of 17 responses to a question about how agencies choose where to deploy new RWIS. Results are presented in Figure 10.

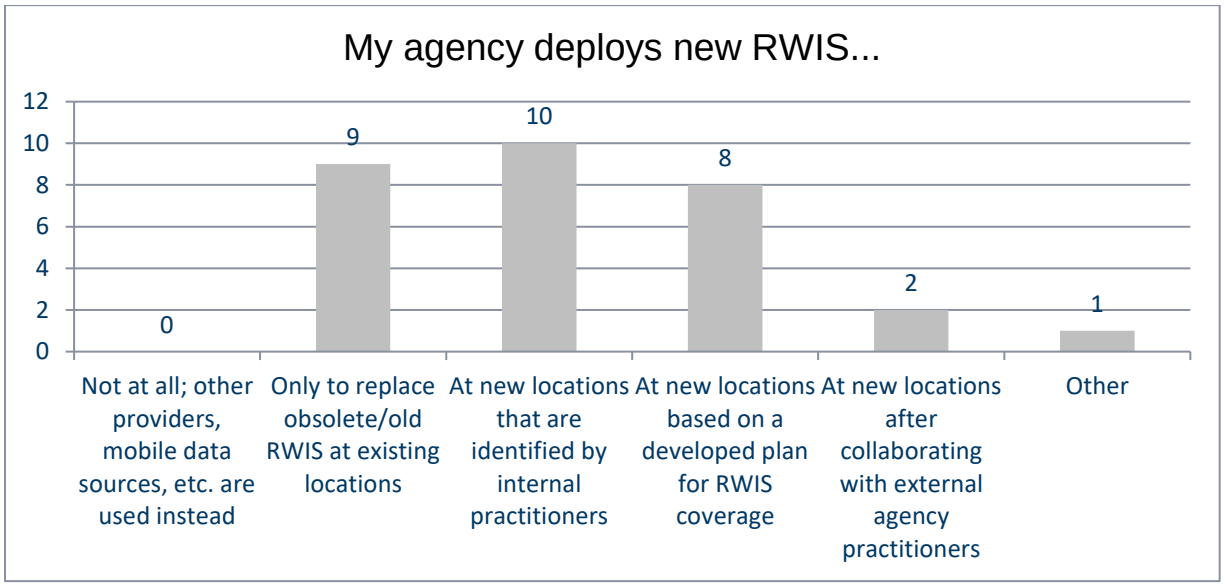

Figure 10. Survey Responses on Agency Approaches to Deploying RWIS

The agency that responded "other" noted: "Also to replace obsolete/old RWIS at existing locations." Additional explanations provided by respondents included:

- We recently completed a 4-year expansion project of 61 new sites.
- We rarely install RWIS at new locations. However, we would if needed.

- We have too many old "full RWIS" locations currently, too expensive to maintain and frequent troubleshooting. The DOT has started using mini-RWIS throughout the state, primarily Frost Solutions. We have stopped any "full RWIS" installations that were in design or in progress by a capital project but had not started the RWIS yet. If the mini-RWIS works well over the next year, we intend to retire most of the "full RWIS" over the next 5-10 years.

4.6 Commonly Deployed RWIS Sensors

There was a total of 16 responses to a question about the types of RWIS sensors that are commonly deployed by agencies. Respondents were able to select multiple choices. Results are presented in Figure 11.

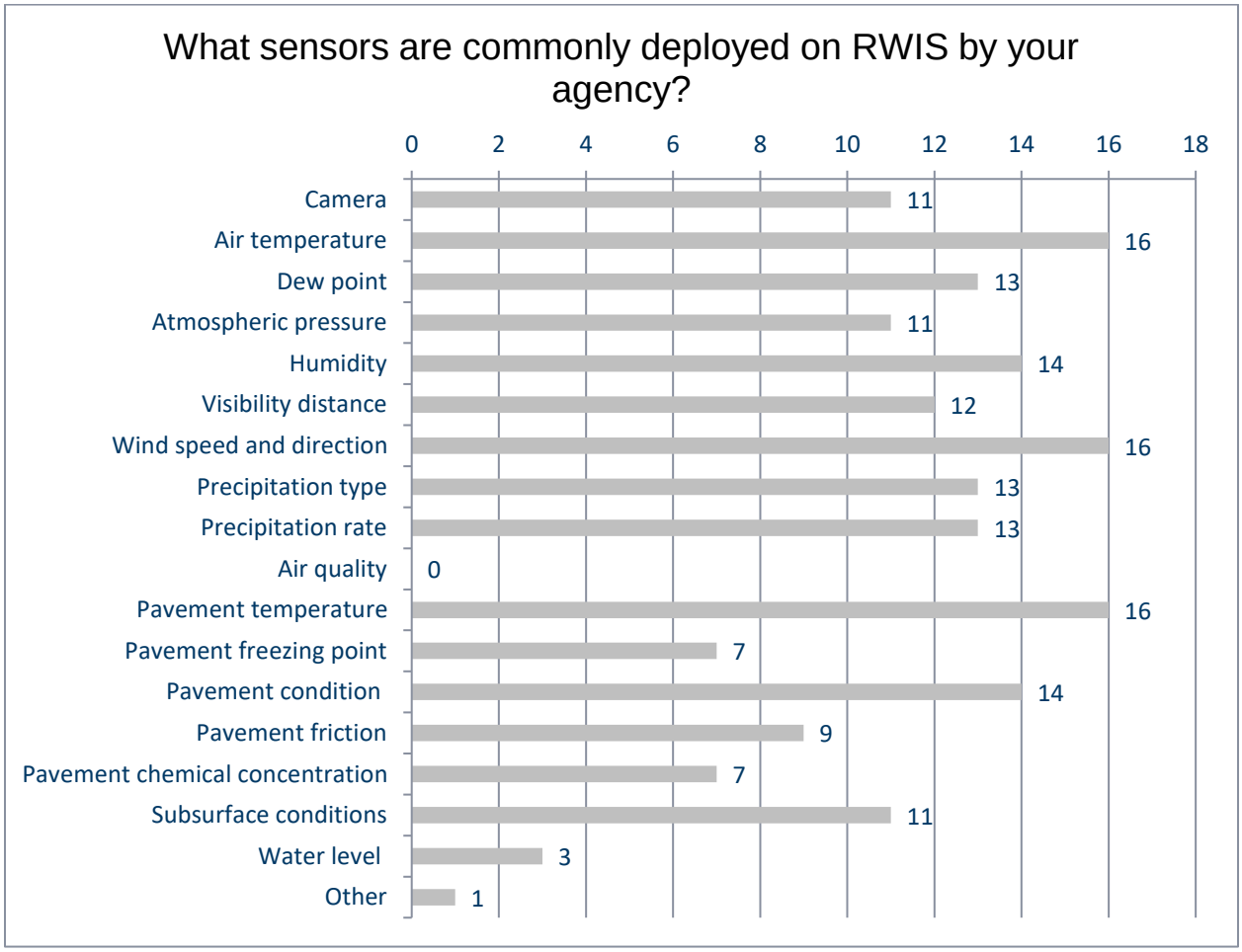

Figure 11. Survey Responses on Sensors Commonly Deployed by Agencies on RWIS

The respondent who selected “other” explained: “I have instruments to measure soil moisture (blowing dust), solar radiation, and snow depth.”

4.7 Sensors Deployed Only in Limited Locations

There was a total of 11 responses to a question about the types of RWIS sensors that are only deployed by their agencies in limited locations. Respondents were able to select multiple choices. Results are presented in Figure 12.

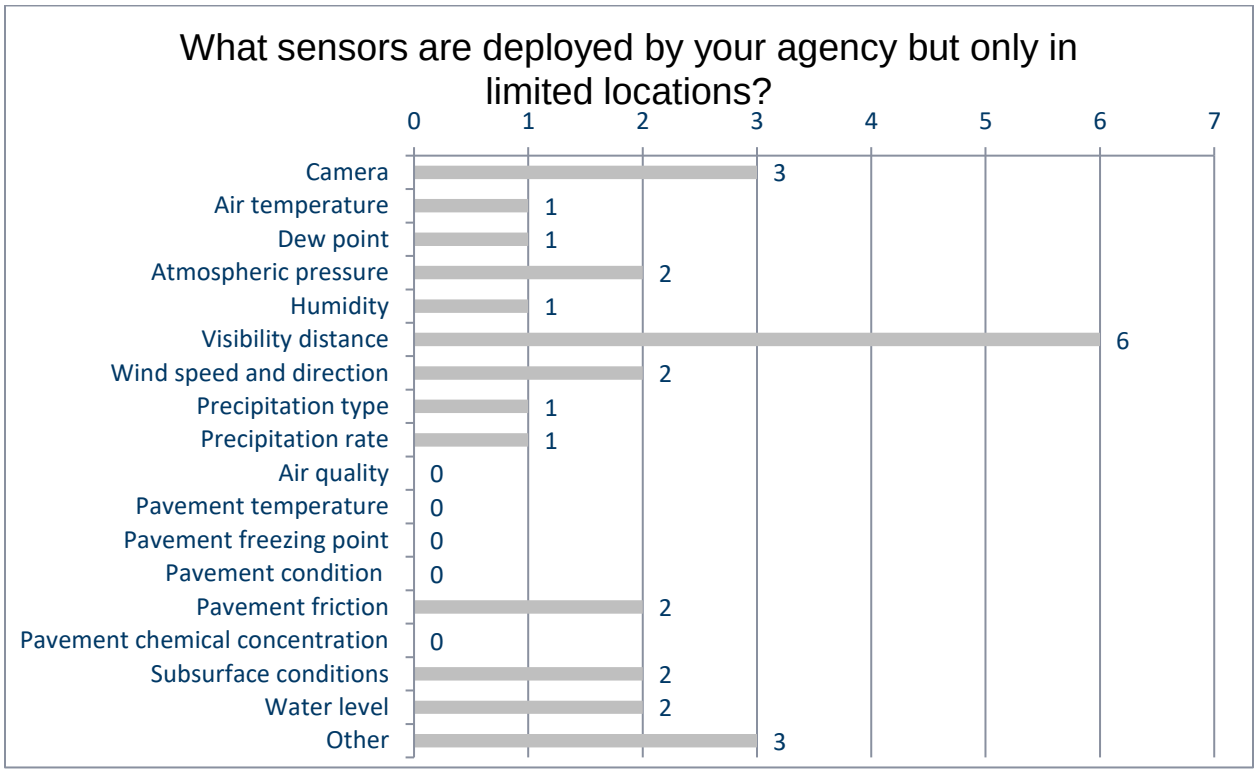

Figure 12. Survey Responses on Sensors Deployed Only in Limited Locations

Respondents who selected "other" noted the following:

- Scour.
- Bridge deck conditions.
- I do have instruments to measure soil moisture (blowing dust), solar radiation and snow depth.

Additional explanations provided by respondents included:

- The DOT has deployed a dust warning system that has VSL. The VSL is based off of visibility.
- We have a few that have fog warning systems.
- When RWIS deployment is used strictly for VSL deployment.
- Many of our weather stations are co-located with traffic cameras. The new mini-RWIS have cameras and record a photo every 5-10 minutes.

4.8 RWIS Vendor Used

There was a total of 16 responses to a question about the RWIS vendors that agencies use. Respondents were able to select multiple choices. Results are presented in Table 1 and Figure 13.

Table 1. RWIS Vendors Used by Agency Respondents

Response Option	Number of Responses
Vaisala	14
Campbell Scientific	9
Lufft	9
High Sierra	2
Other (as listed below) • Frost Solutions • Canary Systems, Helix Innovations • Microcom • OTT, Theis • Teconer	6 (2) (1) (1) (1) (1)

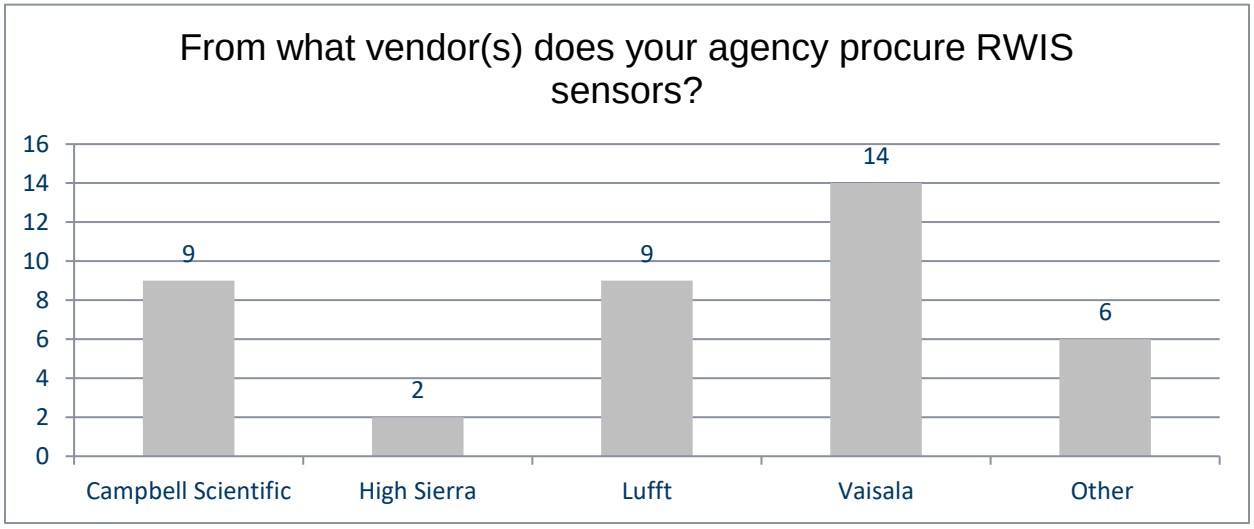

Figure 13. Survey Responses on RWIS Vendors Used by Agencies

4.9 Influences on RWIS Vendor Selection

There was a total of 16 responses to a question about the influences on RWIS vendor selection. Respondents were able to select multiple choices. Results are presented in Figure 14.

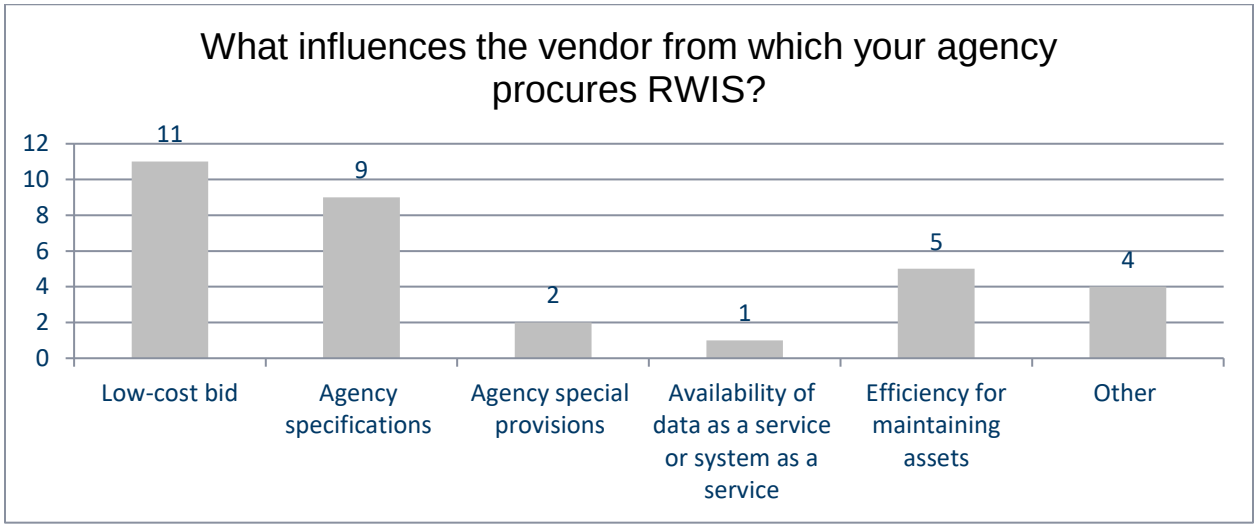

Figure 14. Survey Responses on Influences on RWIS Vendor Selection

Respondents who selected "other" explained:

- Availability of low powered instruments are considered, due to solar power on many of our RWIS sites. We require devices that are compatible with Campbell Scientific dataloggers.
- Documentation, specific site's requirements, ease of use, sensor cost, and compatibility with existing equipment/servers to name a few.
- Roughly the first half of the DOT's full RWIS are High Sierra, then the second half are Vaisala. Now we are not building anymore full RWIS and planning to proceed with mini RWIS, eventually retiring all our full RWIS.
- Lufft is the vendor we have used for years and that we have hardware contracts with.

Additional explanations provided by respondents included:

- Cost does have some to do with selection but is not the main contributing factor.
- Technical special provisions are created on an as needed basis.
- We prefer open data source sensors. We also pick sensors to be compatible with our systems.
- Current special provisions (SPs) are here: https://mdotjboss.state.mi.us/SpecProv/specProvHome.htm. Scroll down to and click on ITS Special Provision. There is a section on Environmental Sensor Stations.

4.10 RWIS Maintenance

There was a total of 16 responses to a question about what entity conducts RWIS maintenance. Results are presented in Figure 15.

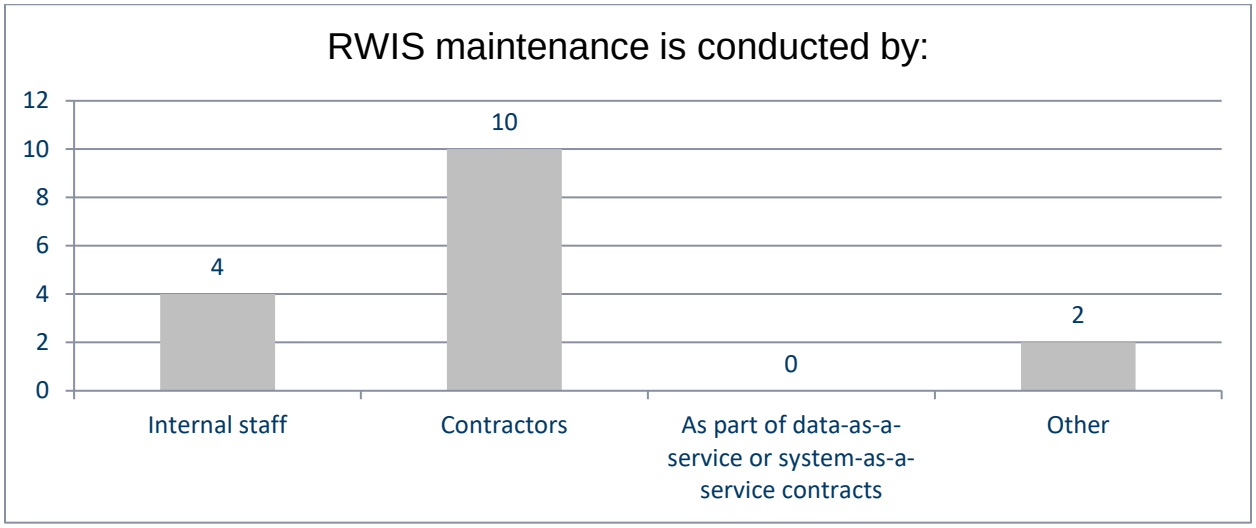

Figure 15. Survey Responses on How RWIS are Maintained

The two respondents that selected "other" noted the following:

- They are maintained by both contractors and internal staff. We also have frequent preventative maintenance done by our contractor.
- Combination, staff can fix some very basic maintenance and troubleshooting, we previously had a maintenance contract on a 1- or 3-year basis, now we are doing a year-by-year preventative maintenance and troubleshooting task order for a contractor. This is the first time we are trying the annual task order, recently issued to Drive Integration. All of this is referring to full RWIS, the mini RWIS require no maintenance or troubleshooting, any problems just send it back and they send a new one.

4.11 RWIS Asset Inspection Interval

There was a total of 16 responses to a question about how often RWIS assets are inspected. Results are presented in Figure 16.

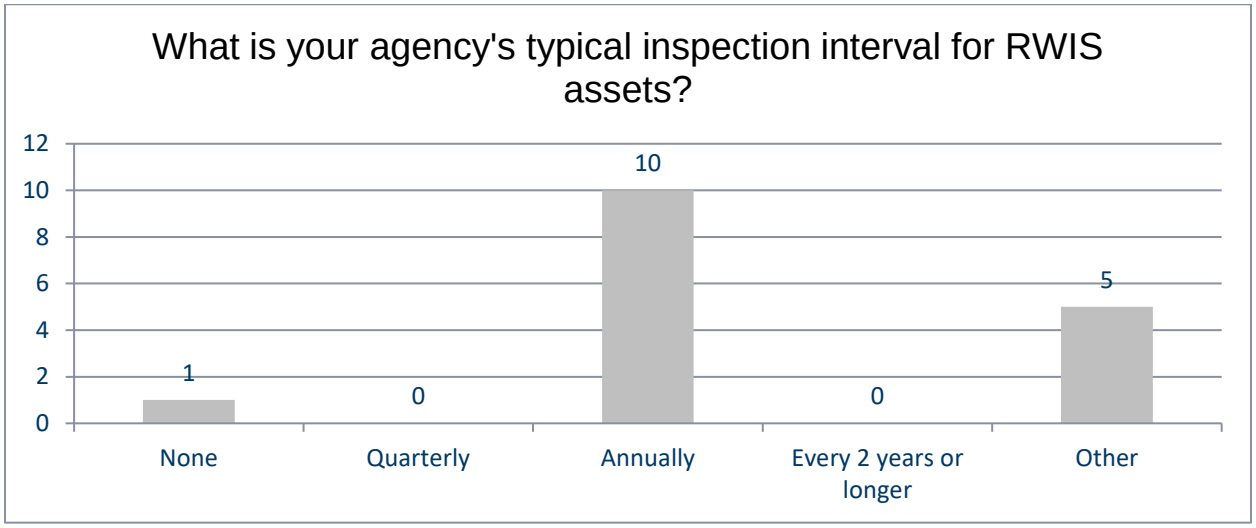

Figure 16. Survey Responses on Typical Inspection Intervals for RWIS

Additional explanations provided by respondents included:

- We inspected the sites in the spring and fall.
- Biannually.
- This depends on RWIS site type but typically we perform preventative maintenance once or twice a year. If this is referring to response maintenance, we complete as necessary. We average more than 95% of our devices online at any given time.
- Annual PMs in contract.
- Trying to get to annually for full RWIS. Many stations have not been inspected for several years at least. Most is only responsive maintenance.
- Typically, sites are not updated/replaced with the estimated lifecycle, so inherently they are lasting longer than expected.
- We will troubleshoot as alerts are noticed.
- When an issue arises.
- When there are interruptions to service.

4.12 RWIS Preventative Maintenance Frequency

There was a total of 15 responses to a question about how often preventative maintenance is conducted for RWIS. Results are presented in Figure 17.

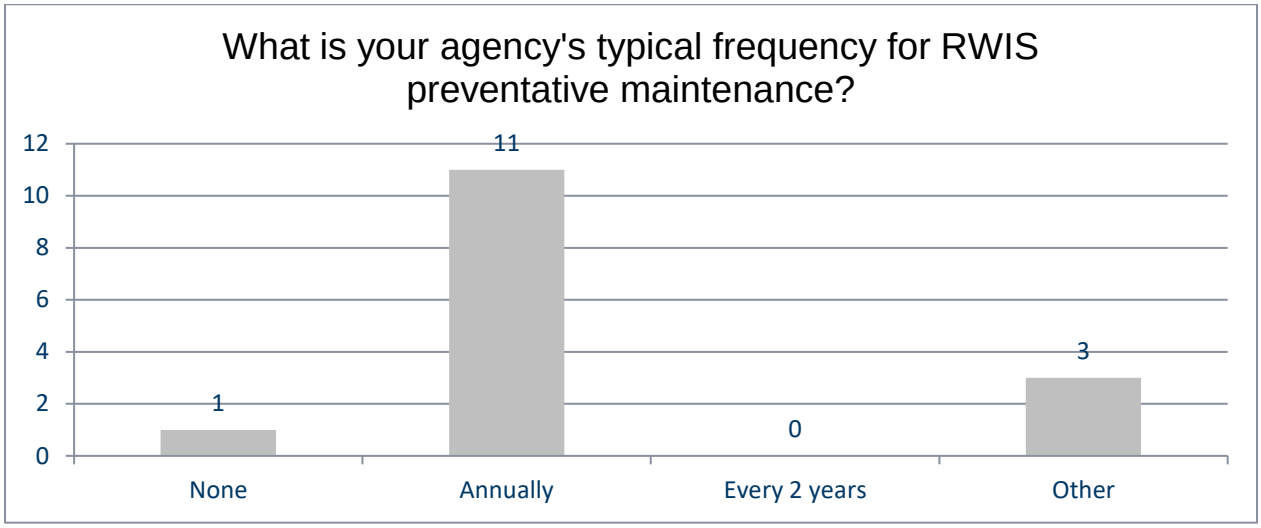

Figure 17. Survey Responses on Preventative Maintenance for RWIS

Explanations provided by respondents who selected "other" were:

- Quarterly to six months.
- Biannually.
- As needed.

Two respondents also provided the following comments:

- This depends on RWIS site type but typically we perform preventative maintenance once or twice a year.
- Trying to get to annually for full RWIS. Many stations have not been inspected for several years at least. Most is only responsive maintenance.

4.13 Improving RWIS Asset Condition

There were 14 responses to a question about what point, or under what circumstances, agencies attempt to improve RWIS asset condition:

- Our RWIS is maintained under a full-service contract.
- We have a budget for replacing assets once they reach the determined end of life age. We will relocate or re-install RWIS sites depending on need such as ease of maintenance, safety concerns, construction activity, etc.
- We are coming up on end of life for our ESS (RWS100) units. Some of our sensors are also going end of life. We will need to be upgrading our systems.

- We have around older LX model RPUs that we have been updating to RWS200 when money allows. [Note that these are specific vendor product acronyms.]
- We are working to update outdated equipment, and we also ensure repairs as needed.
- Yes, by evaluating and updating technology solutions.
- We will make upgrades as parts fail or when funding is identified for RWIS, such as upgrading batteries and solar panels.
- When devices are not performing as expected or reach end of design life.
- Will start swapping for better technology or new capability. Usually occurs over the course of several years or as the old stuff needs replaced.
- When it fails.
- Under erroneous data conditions, comments from the public or other agencies, and during the calibration specified by the Environmental Protection Agency (EPA).
- When we come across issues with data.
- Currently at no point, we are hoping to retire our full RWIS locations.
- As needed.
- As needed.

4.14 RWIS Reliability Over the Anticipated Lifecycle

There was a total of 15 responses to a question about whether agencies find RWIS to be reliable over the duration of its anticipated lifecycle. Most respondents indicated affirmatively (13 agencies). Results are presented in Figure 18.

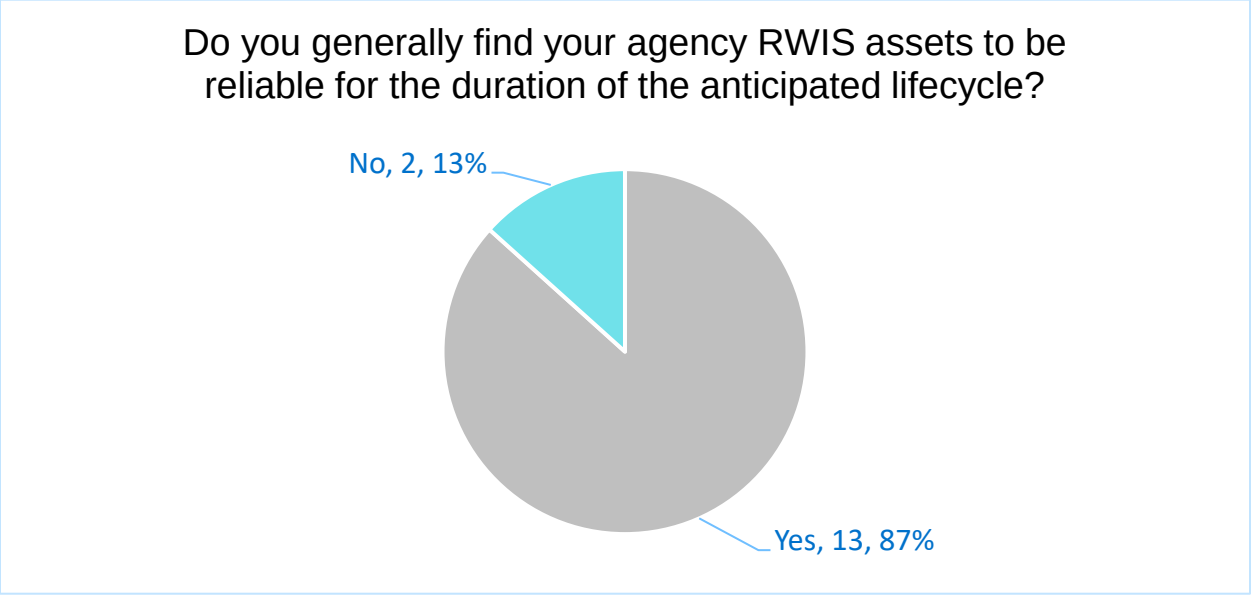

Figure 18. Survey Responses on RWIS Reliability

Additional explanations provided by respondents included:

- We average more than 95% online time with our RWIS devices.
- This technology does require annual service. The instrumentation is operating in the harshest conditions. It does require service. It may be a simple item. Water infiltration, temperature extremes, lighting strike.
- Use it until it breaks. We tend to lose pavement sensors both due to road work and failure the quickest.
- Precipitation sensors, visibility are the least reliable.
- We found that the High Sierra IceSights were not reliable. We have also found that our outdated solar sites were not staying up when needed. We have since had a solar site installed by Campbell Scientific that has been staying up when the other solar sites were not during the last winter season.
- No issues.

4.15 RWIS Data Accuracy Over the Anticipated Lifecycle

There was a total of 15 responses to a question about whether RWIS assets provide accurate data for the duration of the anticipated lifecycle. The vast majority of agencies responded affirmatively (14 agencies). Results are presented in Figure 19.

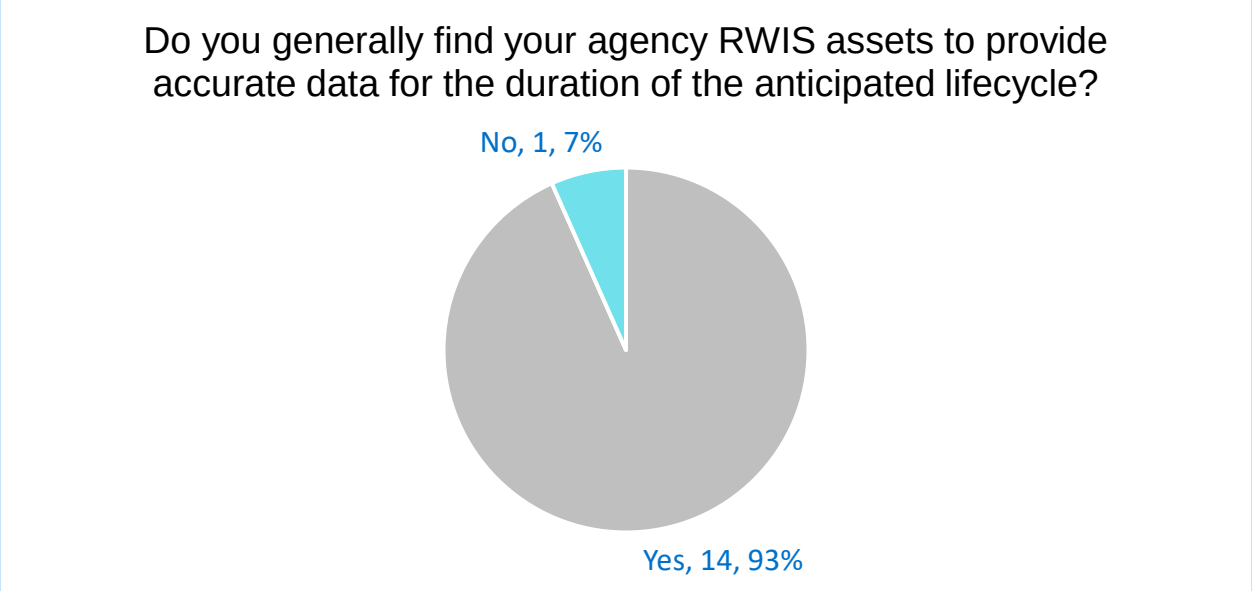

Figure 19. Survey Responses on RWIS Data Accuracy

Additional explanations provided by respondents included:

- We calibrate the systems each winter. We are looking for the system to be accurate through the winter season. We are not looking for a 10-year period without some calibration.
- We have had some issues with accurate precipitation reporting.
- Least accurate are likely the precipitation sensors.
- Precipitation sensors, visibility the least accurate or prone to mis-calibration.
- Sometimes the grip sensor seems to vary, especially if it is aimed at the roadway and a vehicle is passing by. We also note that data or RWIS feeds can go down from time to time.
- We have had some issues with translation of data between the field sensors and our software systems (MDSS and ATMS).

4.16 Lengthening RWIS Lifecycle

There was a total of 10 responses to a question about whether agencies are routinely able to add time to the RWIS lifecycle, what has proven to be most effective, and how much longer agencies can typically rely on RWIS beyond their typical lifecycle. Preventative maintenance was a common response. Results are presented below.

- Our RWIS is maintained under a full-service performance-based contract so sensors are replaced as needed by Vaisala as they determine it is appropriate to continue to meet performance standards.
- Annual maintenance.
- Completing routine preventative maintenance and including specifications that exceed the anticipated conditions that the RWIS will encounter.
- We ensure regular preventative maintenance.
- Regular preventative maintenance. We switched from lead acid to lithium batteries. This reduced the need for maintenance and extended the life of the battery by 2 to 3 times.
- Preventative maintenance seems to add to the life cycle.
- Surge protection.
- We have changed out batteries, sensor types and solar panels. This seems to help the longevity of the RWIS.
- We are still using the ESS (RWS100) Linux based RPUs. We found that we needed to replace the read/write memory cards. That was able to stabilize the system. Now their sensors are going end of life so we will be upgrading these units.
- It is common for individual components to last way longer than expected, but also some shorter. It is quite variable so 'lifespan' is kind of just a ballpark average.
- Not sure what the typical lifecycles are.

4.17 Replacing RWIS Assets

There was a total of 15 responses to a question about when agencies replace RWIS assets. Respondents were able to select more than one choice. Results are presented in Figure 20.

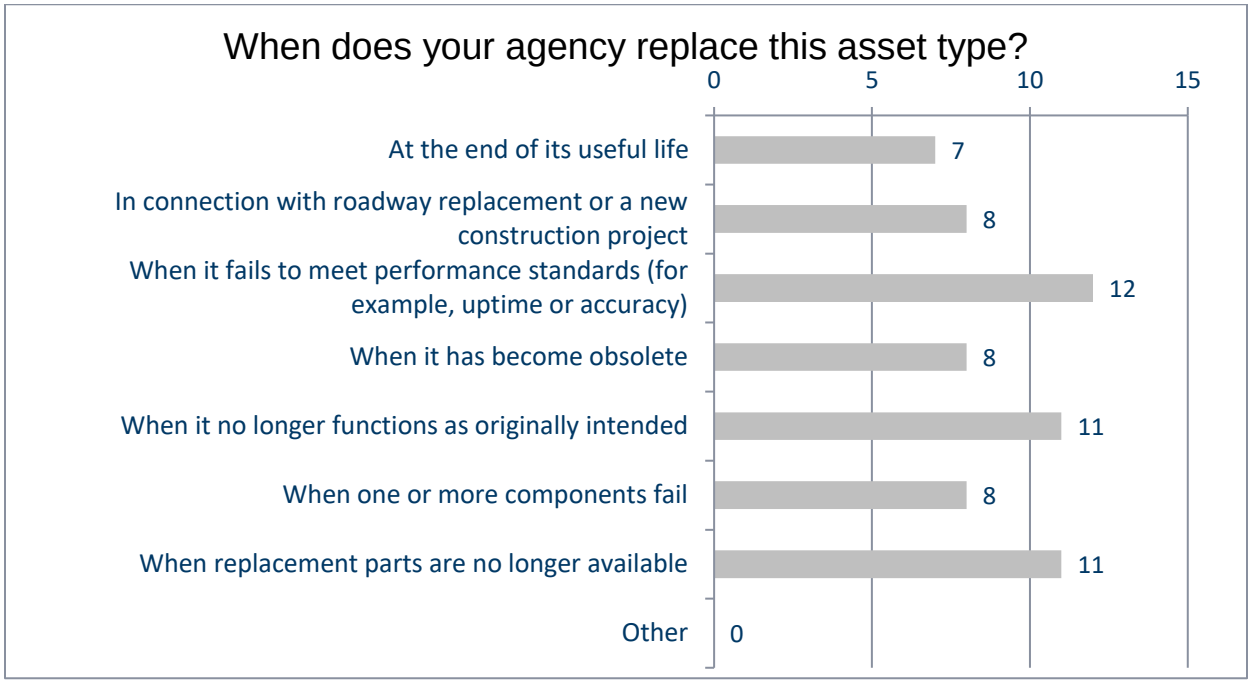

Figure 20. Survey Responses on Replacing RWIS Assets

4.18 Quality Checking RWIS Data

There was a total of 15 responses to a question about how agencies quality check RWIS data to identify bad data or sensor maintenance needs. Results are presented in Figure 21.

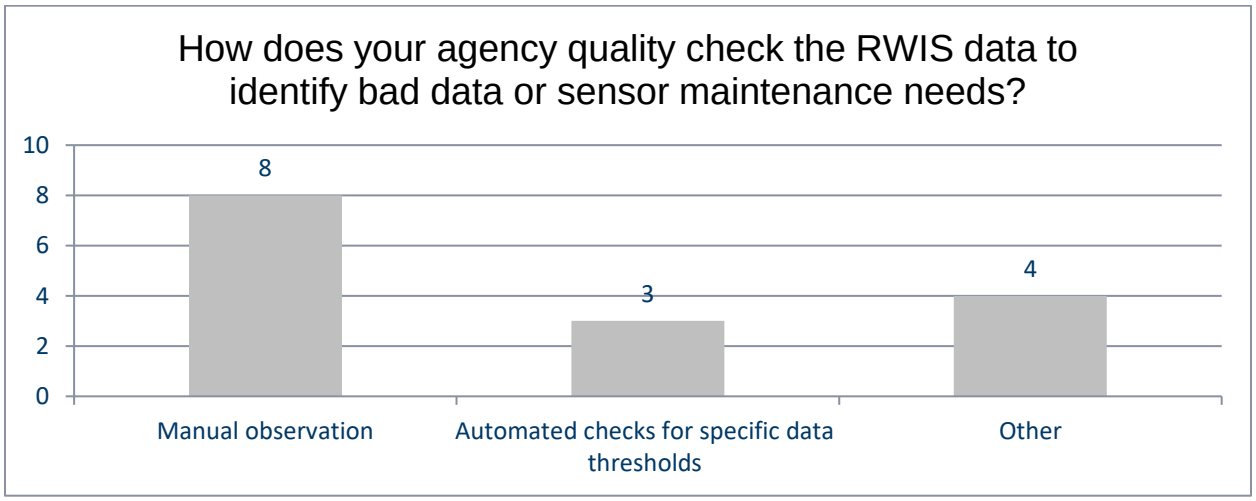

Figure 21. Survey Responses on Quality Checking RWIS Data

Additional explanations provided by respondents included:

- RWIS data is quality checked by RWIS vendor and reported to the DOT on a monthly basis.
- Vendor software sends alerts when issues are found.
- The vendor has an error checker.
- RWIS Coordinator conducts monthly manual checks of data but uses the DOT's "Storm Intensity Index" to quickly identify if participating instruments are having problems. Public, other DOT employees, and Weather Services/RWIS maintenance contractor will also notify the DOT Weather Operations Group/RWIS Coordinator if sensors are not behaving as they should.
- During the calibration required by the EPA, public comments, and comparing nearby weather sites (NOAA MADIS [Meteorological Assimilation Data Ingest System], MesoWest, and NWS).
- We pay for third party polling through the procurement contract. We also do manual observations.
- Most public facing sites have some basic quality checks.

4.19 Challenges with Certain Technologies, Sensors, or Sensor Types

There was a total of 13 responses to a question about whether agencies experience challenges with certain technologies, sensors, or sensor types. Nine agencies responded affirmatively. Results are presented in Figure 22.

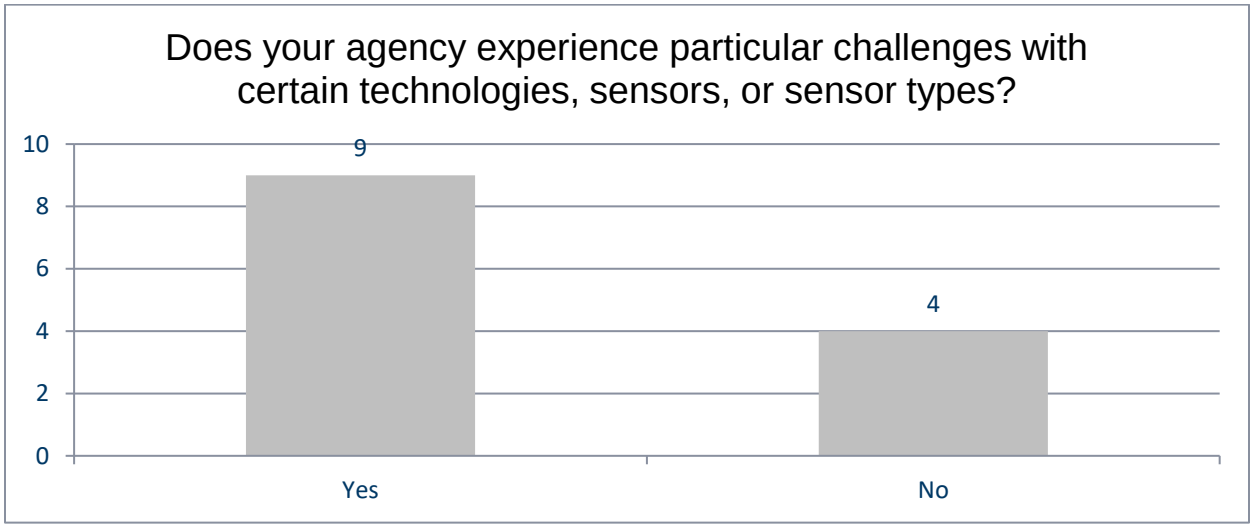

Figure 22. Survey Responses on Experiencing Challenges with RWIS

Additional explanations provided by respondents included:

- In pavement sensors are accurate, but then they get water damaged, or get milled out.
- Dirty sensors are the biggest issue we have.
- Calibration of ultrasonic wind sensors.

- Grip sensors have been a bit of challenge. If a vehicle is driving by when the grip sensor is a taking a measurement, the measurement is not accurate.
- Already addressed our challenges with High Sierra IceSights. We have also had some issues with our precipitation reporting in addition to the precipitation date and time reporting.
- Precipitation sensors are the trickiest to maintain. Road condition is also prone to issues.
- We have had a number of issues with temperature/humidity sensors offered to us. Also, needed to come up with standards for non-invasive instrumentation infrastructure installation and needed to come up with custom programming for solar controllers when charging lithium batteries.
- Communications are a problem.

4.20 Accuracy Issues with Sensors

There was a total of 13 responses to a question about whether agencies experience recurring accuracy issues with certain sensors or sensor types. Results were pretty evenly divided and are presented in Figure 23.

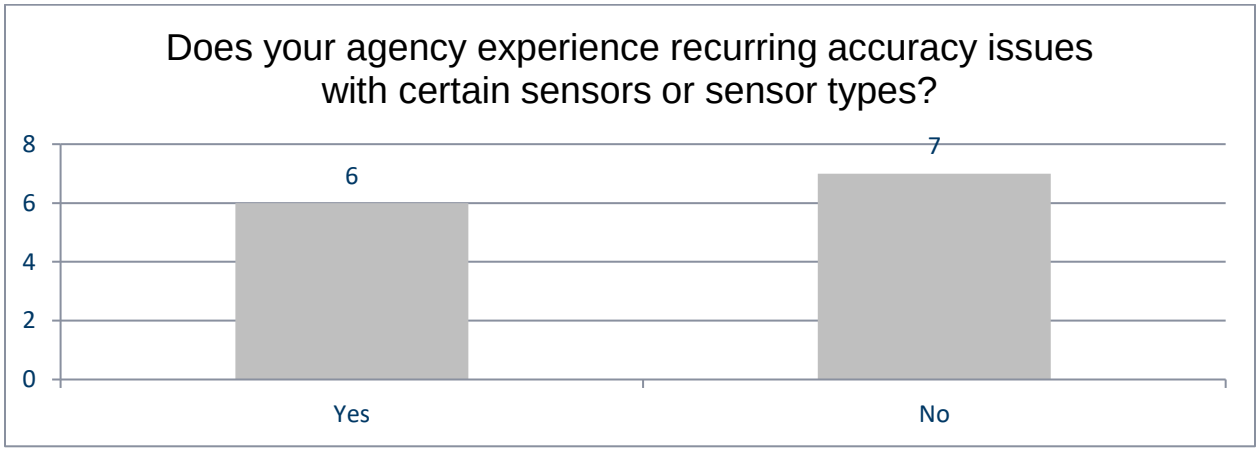

Figure 23. Survey Responses on Experiencing RWIS Accuracy Issues

Additional explanations provided by respondents included:

- Nothing typical, if that were the case, the attached SPs would address it. Had issues with tower structures, but SP was revised.
- Wind gauges when the bearings go bad report drastically different readings than reality.
- Grip sensors have been a bit of challenge. If a vehicle is driving by when the grip sensor is a taking a measurement, the measurement is not accurate.
- We have had some issues with our precipitation reporting in addition to the precipitation date and time reporting.
- Precipitation sensors are the trickiest to maintain. Road condition is also prone to issues.
- Temperature/humidity sensors tend to have more accuracy issues than expected.

4.21 Addressing Accuracy Issues

There was a total of 7 responses to a question about how agencies address identified RWIS accuracy issues. Respondents were able to select more than one choice. Results are presented in Figure 24.

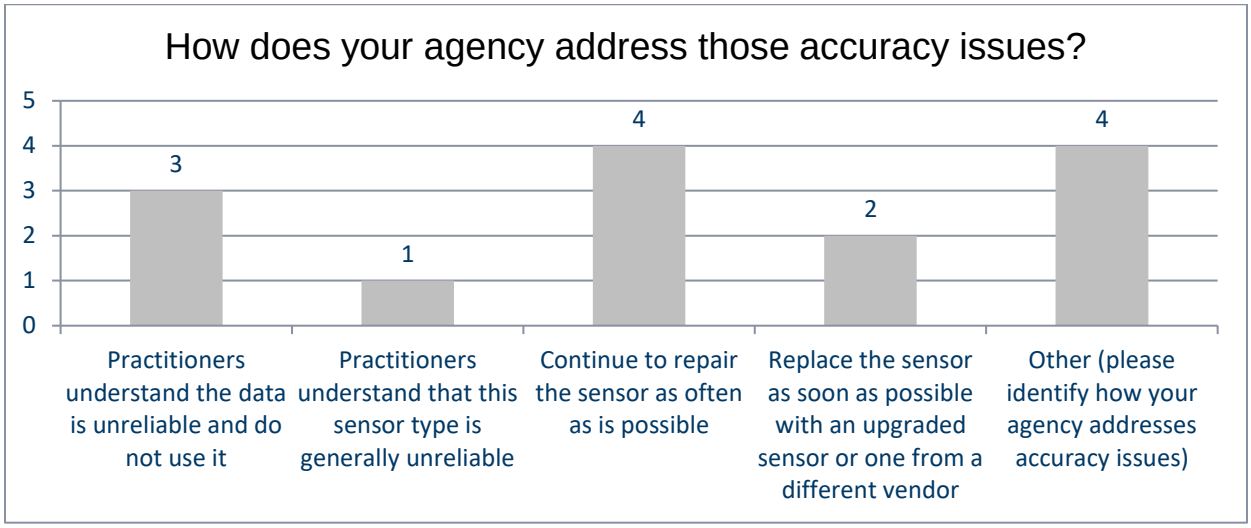

Figure 24. Survey Responses on Addressing RWIS Accuracy Issues

Additional explanations provided by respondents included:

- Using a calibration contract that must be traceable to the National Institute of Standards and Technologies (NIST), a requirement specified by the EPA.
- You have to know the equipment and what data challenges you have and how the sensors react in the storm. You can compare nearby equipment as well.
- We work with our maintenance contractor and our reporting contractor to determine where the issues lie to have them fixed.
- Work with vendors to identify solutions or different instrumentation.

4.22 Estimated Average Cost per Site to Deploy New RWIS

There was a total of 13 responses to a question about the estimated average cost per site to deploy a new RWIS.

- $2,000-$20,000.
- $7,500 – more robust sensor suite installations onto already prepared site (base and pole already set and electric already installed).
- $35,000 in pavement deployment.
- ~$50,000-$60,000 for a robust site, ~$25,000-$40,000 (or less for) for a light site.
- $55,000.

- $72,000.
- For a full brand new site including foundation, 30' folding tower, RPU, Visibility, Air/Humidity, Wind, and pavement sensors it is around $75,000.
- For a 'full' traditional site, probably $90K including parts and labor
- A robust sensor suite would cost $70,000 in equipment. Plus, we install the concrete base with our staff and our technician installs and calibrates the equipment. I would expect that it would cost $100,000 to $120,000 to contract the whole installation.
- Full RWIS $100,000 per site. Mini RWIS $3,000 per year per site with 3-year contract, any issues just ship it back and they send a new unit.
- ~$125,000.
- Approximately $200,000 which includes communication equipment, tower, and foundation.
- n/a.

4.23 Estimated Average Annual Cost Per Site to Maintain RWIS

There was a total of 13 responses to a question about the estimated average annual cost per site to maintain RWIS.

- ~$700-$800 last fiscal year for just preventative and response maintenance. This does not include end-of-life replacement costs.
- $750.
- $1,200
- $2,500.
- $2,592/site annually for maintenance (not including parts that may be needed for repair).
- ~$3000.00 per site. This can vary.
- $3,000.
- $3,900 per site based on 42 full sites: $165,000.
- $5,100 per site per year.
- $5,100.
- We have one full-time position, shop space, vehicle, and a repair budget dedicated to RWIS. I would estimate the maintenance cost to be $6,900 per site.
- Should be spending $2,000-$5,000 per year per site for full RWIS maintenance, typically only repair a handful or a large number all at once.
- $8,000.

4.24 Agency Justification of RWIS Costs

There was a total of 13 responses to a question about how agencies justify the costs to deploy and maintain RWIS. Respondents could select more than one choice. Results are presented in Figure 25.

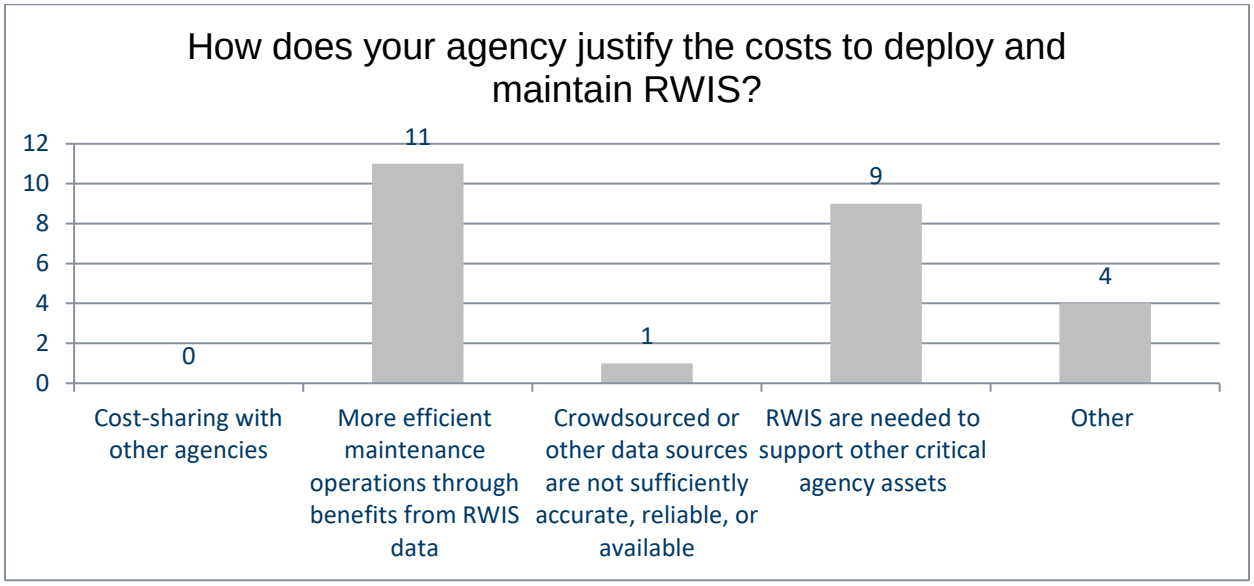

Figure 25. Survey Responses on Justification of RWIS Costs

Additional explanations provided by respondents included:

- From current Maintenance contract: $2,219/year.
- Public safety.
- Safety, "Pea Soup fog," wind advisories, winter operations, traveler information, and automated DMS to name a few.
- A "Snow and Ice Performance Measure" helps supervisors and district engineers more reliably allocate resources and has in turn justified more funding for more RWIS in locations where RWIS do not exist.
- Locations are strategically decided.

4.25 Use of Mobile RWIS or Portable RWIS to Supplement Permanent RWIS

There was a total of 15 responses to a question about how agencies justify the costs to deploy and maintain RWIS. Results are presented in Figure 26.

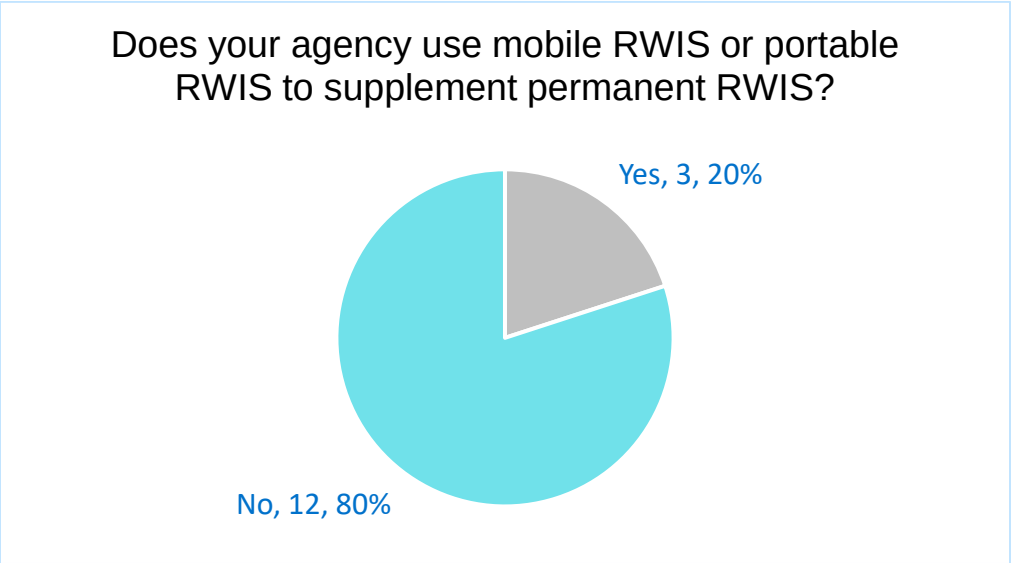

Figure 26. Survey Responses on Agency Use of Mobile RWIS or Portable RWIS

4.26 Use of Third-Party Data Sources to Supplement Permanent RWIS

Out of 15 responses received, respondents were almost evenly divided about whether their agency uses third-party data sources to supplement permanent RWIS (7 agencies) or not (8 agencies), as depicted in Figure 27.

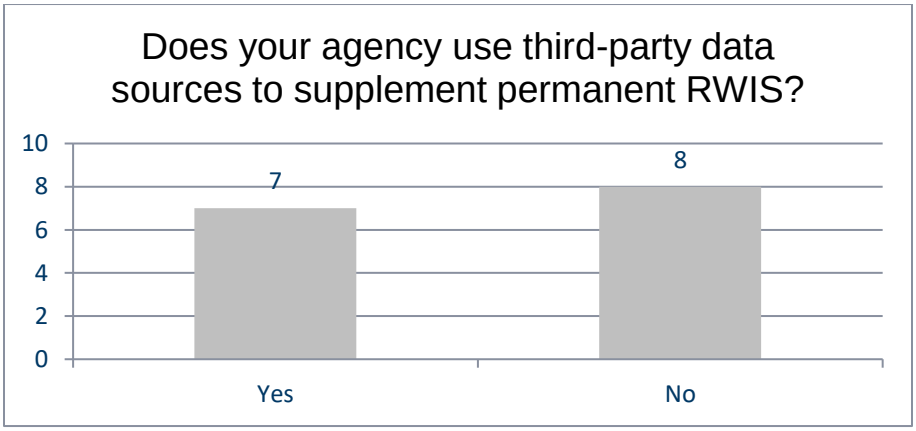

Figure 27. Survey Responses on Agency Use of Third-Party Data Sources

4.27 Additional Information

Additional information provided by respondents included the following items:

- Our RWIS network is robust and has many uses. Our Weather Services Contractor (which also performs our RWIS maintenance) uses them for forecasting efforts and verification, our maintenance staff uses it for standard maintenance purposes and provides good situational awareness for traffic operations and traveler information. Our system is largely customized with different instrumentation and cost effective due to this "combined" Weather Services contract.
- We get a pavement forecast for 5 sites via virtual RWIS. The weather service provider estimates the weather data for the given locations based on nearby information.

Chapter 5: Project Summary and Implementation

This ENTERPRISE Pooled Fund Study project conducted a high-level literature review and a survey of agency practitioners to understand the accuracy, reliability, and cost tradeoffs of deployed RWIS solutions, with an emphasis on RWIS that support ITS solutions. A robust survey was developed with 27 questions to better understand how agencies use RWIS, the types of RWIS deployed, challenges with particular technology or sensor types, RWIS maintenance needs and service life, data reliability and accuracy issues, relative costs to deploy and maintain RWIS, and quality control systems to screen RWIS data and how they function. Survey responses were gathered from 16 state DOTs and a toll authority.

Survey responses were summarized and analyzed to provide insights regarding agency use of RWIS to address roadway conditions during severe weather conditions, the value of RWIS and data provided, reliability and accuracy of RWIS devices, and costs associated with deploying and maintaining RWIS.

5.1 Implementation

The research resulted in findings that ENTERPRISE member agencies can use to help in deploying and managing RWIS. This primarily includes findings in the survey analysis (Chapter 3), as well as the survey responses (Chapter 4) about agency practices that may help to better understand how other agencies deploy, use, and manage RWIS to improve practices. Examples of this include:

- Understanding agency approaches to deploying RWIS, including how agencies collaborate with other stakeholders, the types of sensors agencies deploy, choice of RWIS vendors, associated costs, and how agencies justify the costs to deploy and maintain RWIS.
- Understanding RWIS maintenance and inspection practices, including associated costs, methods to improve RWIS asset conditions, and replacement.
- Understanding RWIS data accuracy and reliability issues, including quality checking data, sensor-specific issues, and how those issues may be addressed.

Transportation agencies can implement the results of this research in several ways. Recommended implementation steps could include the following actions:

1. Distribute the report to agency staff, including operations and maintenance staff and decision makers, at ENTERPRISE agencies.
2. Learn from other agency experiences documented in these research findings, consider modifying agency practices to more strategically deploy RWIS, better leverage RWIS data, and more efficiently manage RWIS to reduce costs.

Overall, the research conducted for this project can support ENTERPRISE member agencies' decisions and practices to more strategically and cost-effectively deploy, use, manage, and maintain RWIS.

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Appendix A: Survey Respondents

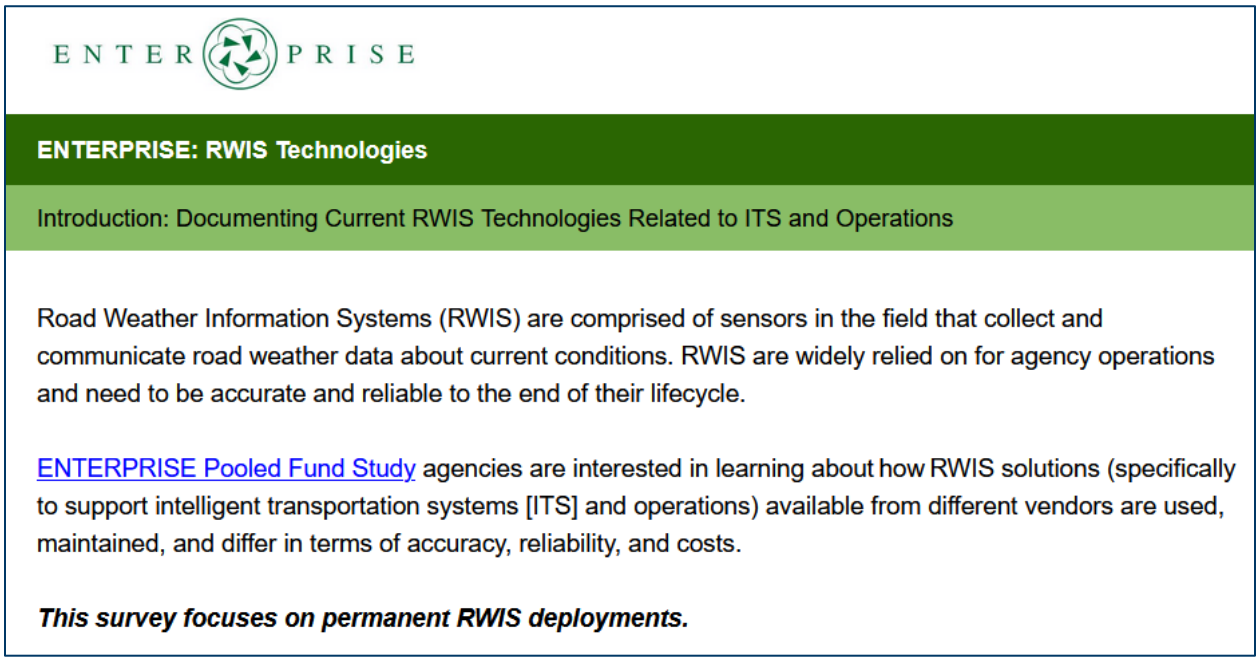
This Appendix lists the respondents to the survey distributed and conducted in August and September 2024. In total, 19 responses were received from 16 state DOTs, including two responses from different DOT Districts in Michigan and California, as well as the Illinois Toll Authority, as shown in Table 2.

Table 2. Survey Respondents

Name	Agency	Email
Isvan Gomez	Alaska DOT & Public Facilities	isvan.gomez@alaska.gov
Kevin Duby	Arizona DOT	kduby@azdot.gov
Michael Mullen	Caltrans	Michael.Mullen@dot.ca.gov
Mohammad Iraki	Caltrans	mohammad.iraki@dot.ca.gov
Kerry Yost	DelDOT Traffic Operations	kerry.yost@delaware.gov
James Landini	Florida DOT	james.landini@dot.state.fl.us
Keith Donovan	Illinois DOT	keith.donovan@illinois.gov
Rob Glaz	Illinois Tollway	rglaz@getipass.com
Tina Greenfield	Iowa DOT	tina.greenfield@iowadot.us
Dale Kirmer	Kansas DOT	Dale.Kirmer@ks.gov
MaryAnn Nickles	Louisiana DOTD TMC	maryann.nickles@la.gov
Dan Mantyk	Maryland SHA	Dmantyk@mdot.maryland.gov
Marlon Spinks	Michigan DOT	spinksm@michigan.gov
Suzette Peplinski	Michigan DOT - Grand Region	peplinskis@michigan.gov
Jay Pierzina	Minnesota DOT	jay.pierzina@state.mn.us
Tara Alston	Ohio DOT	tara.alston@dot.ohio.gov
Jason Norville	Pennsylvania DOT	janorville@pa.gov
Jeff Williams	Utah DOT	JeffWilliams@utah.gov
Mike Adams	Wisconsin DOT	michael.adams@dot.wi.gov

Appendix B: Survey Instrument

Screenshots of the SurveyMonkey web survey that were used for this effort are presented in this Appendix.



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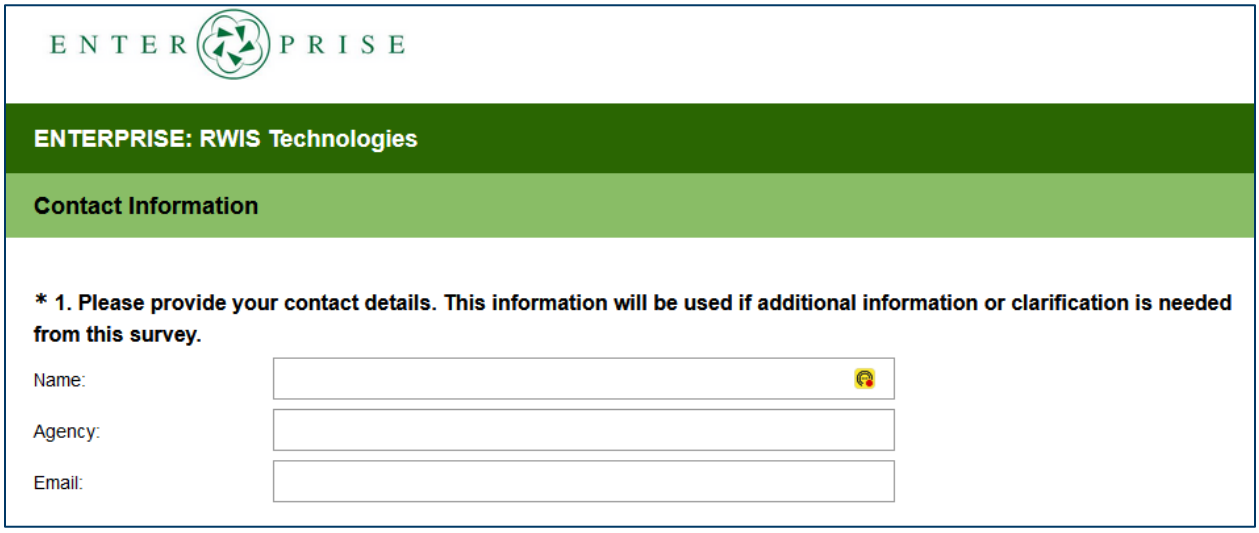
Introduction: Documenting Current RWIS Technologies Related to ITS and Operations

Road Weather Information Systems (RWIS) are comprised of sensors in the field that collect and communicate road weather data about current conditions. RWIS are widely relied on for agency operations and need to be accurate and reliable to the end of their lifecycle.

ENTERPRISE Pooled Fund Study agencies are interested in learning about how RWIS solutions (specifically to support intelligent transportation systems [ITS] and operations) available from different vendors are used, maintained, and differ in terms of accuracy, reliability, and costs.

This survey focuses on permanent RWIS deployments.



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Contact Information

*** 1. Please provide your contact details. This information will be used if additional information or clarification is needed from this survey.**

Name:

Agency:

Email:

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RWIS Use

2. How are RWIS used in your state? (Select all that apply)

- [ ] Winter maintenance operations staff decision making (staffing, resources)
- [ ] Construction and maintenance staff decision making
- [ ] Integrated with the agency Advanced Traffic Management System (ATMS)
- [ ] Support Maintenance Decision Support Systems
- [ ] Support Variable Speed Limit deployments
- [ ] Support other ITS devices *
- [ ] Traveler Information
- [ ] Other internal uses by agency staff *
- [ ] Use by external agencies *
- [ ] N/A, my agency does not deploy or use RWIS

*** Please explain your selections above where further information is needed (e.g., what other ITS devices, what other internal uses, what external agencies, if known).**

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RWIS Use

3. With whom and how does your agency collaborate with users of RWIS data to understand their needs, the value of the data, and how it is used? (Select all that apply)

- [ ] National Weather Service (NWS)
- [ ] Environmental agencies
- [ ] Internal or contracted winter maintenance staff
- [ ] Other (please explain)

Please explain how collaboration occurs

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RWIS Deployed

4. How would you characterize your RWIS deployments?

- ○ Most RWIS contain similar sensor suites
- ○ RWIS deployments are generally comprised of different sensors and brands
- ○ Some are "light" deployments with fewer sensors, others are more robust - depending on the location and need
- ○ Other (please explain)

Please explain, as needed

5. My agency deploys new RWIS... (select all that apply)

- ☐ Not at all; other providers, mobile data sources, etc. are used instead
- ☐ Only to replace obsolete/old RWIS at existing locations
- ☐ At new locations that are identified by internal practitioners
- ☐ At new locations based on a developed plan for RWIS coverage
- ☐ At new locations after collaborating with external agency practitioners
- ☐ Other (please explain)

Please explain, as needed

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Sensor Types

6. What sensors are commonly deployed on RWIS by your agency? (Select all that apply)

- [ ] Camera
- [ ] Air temperature
- [ ] Dew point
- [ ] Atmospheric pressure
- [ ] Humidity
- [ ] Visibility distance
- [ ] Wind speed and direction
- [ ] Precipitation type
- [ ] Precipitation rate
- [ ] Air quality
- [ ] Pavement temperature
- [ ] Pavement freezing point
- [ ] Pavement condition (e.g., wet, icy, flooded)
- [ ] Pavement friction
- [ ] Pavement chemical concentration
- [ ] Subsurface conditions (e.g., soil temperature)
- [ ] Water level (stream, river, lake, or tide levels near roads)
- [ ] Other (please specify)

Please explain, as needed

7. What sensors are deployed by your agency but only in limited locations? (Select all that apply)

- [ ] Camera
- [ ] Air temperature
- [ ] Dew point
- [ ] Atmospheric pressure
- [ ] Humidity
- [ ] Visibility distance
- [ ] Wind speed and direction
- [ ] Precipitation type
- [ ] Precipitation rate
- [ ] Air quality
- [ ] Pavement temperature
- [ ] Pavement freezing point
- [ ] Pavement condition (e.g., wet, icy, flooded)
- [ ] Pavement friction
- [ ] Pavement chemical concentration
- [ ] Subsurface conditions (e.g., soil temperature)
- [ ] Water level (stream, river, lake, or tide levels near roads)
- [ ] Other (please specify)

Please explain, as needed

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RWIS Vendor

8. From what vendor(s) does your agency procure RWIS sensors? (Select all that apply)

- [ ] Campbell Scientific
- [ ] High Sierra
- [ ] Lufft
- [ ] Vaisala
- [ ] Other (please specify)

9. What influences the vendor from which your agency procures RWIS? (Select all that apply)

- [ ] Low-cost bid
- [ ] Agency specifications (please share, if available)
- [ ] Agency special provisions (please share, if available)
- [ ] Availability of data as a service or system as a service (e.g., agency installs, vendor maintains) (please explain)
- [ ] Efficiency for maintaining assets (e.g., spare parts, known maintenance steps)
- [ ] Other (please explain)

Please explain, as needed

10. Please upload any agency specifications, special provisions, or other documents for procuring RWIS that you are able to share.

Please upload documents that are less than 16MB in pdf, doc/docx, png, jpg/jped, or gif format. If your document will not upload, you may email it directly to Jeremy Schroeder at schroeder@acconsultants.org.

Choose File No file chosen

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Maintenance

11. RWIS maintenance is conducted by:

- ◯ Internal staff
- ◯ Contractors
- ◯ As part of data-as-a-service or system-as-a-service contracts
- ◯ Other

Please explain, as needed

12. What is your agency's typical inspection interval for RWIS assets?

- ◯ None
- ◯ Quarterly
- ◯ Annually
- ◯ Every 2 years or longer
- ◯ Other

Please explain, as needed

13. What is your agency's typical frequency for RWIS preventative maintenance?

- ◯ None
- ◯ Annually
- ◯ Every 2 years
- ◯ Other

Please explain, as needed

14. At what point, or under what circumstances, does your agency attempt to improve RWIS asset condition?

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Maintenance

15. Do you generally find your agency RWIS assets to be reliable for the duration of the anticipated lifecycle? Please explain.

- ◯ Yes
- ◯ No

Please explain, noting what RWIS sensors or components are less reliable.

16. Do you generally find your agency RWIS assets to provide accurate data for the duration of the anticipated lifecycle? Please explain.

- ◯ Yes
- ◯ No

Please explain, noting what RWIS sensors or components are less accurate.

17. Please share whether you find you are routinely able to add time to the RWIS lifecycle, what has proven to be most effective, and how much longer you can typically rely on RWIS beyond their typical lifecycle.

18. When does your agency replace this asset type? Select all that apply.

- ☐ At the end of its useful life
- ☐ In connection with roadway replacement or a new construction project
- ☐ When it fails to meet performance standards (for example, uptime or accuracy)
- ☐ When it has become obsolete
- ☐ When it no longer functions as originally intended
- ☐ When one or more components fail
- ☐ When replacement parts are no longer available
- ☐ Other

Please explain, as needed

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Data QC and Accuracy

19. How does your agency quality check the RWIS data to identify bad data or sensor maintenance needs?

- ◯ Manual observation
- ◯ Automated checks for specific data thresholds (please explain below)
- ◯ Other (please explain below)

Please explain as needed

20. Does your agency experience particular challenges with certain technologies, sensors, or sensor types?

- ◯ Yes
- ◯ No

If yes, please explain and identify the sensor or sensor types.

21. Does your agency experience recurring accuracy issues with certain sensors or sensor types?

- ◯ Yes
- ◯ No

If yes, please identify the sensor or sensor types.

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Data QC and Accuracy

22. How does your agency address those accuracy issues? Select all that apply and explain, as needed.

- [ ] Practitioners understand the data is unreliable and do not use it
- [ ] Practitioners understand that this sensor type is generally unreliable
- [ ] Continue to repair the sensor as often as is possible
- [ ] Replace the sensor as soon as possible with an upgraded sensor or one from a different vendor
- [ ] Other (please identify how your agency addresses accuracy issues)

Please explain, as needed

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Costs

23. Please estimate your agency's average cost per site to deploy a new RWIS and indicate whether this average cost is for a "light" RWIS with fewer sensors or a more robust sensor suite.

24. Please estimate your agency's average annual cost per site to maintain an RWIS.

25. How does your agency justify the costs to deploy and maintain RWIS? (Select all that apply)

- [ ] Cost-sharing with other agencies
- [ ] More efficient maintenance operations through benefits from RWIS data (i.e., benefit-cost analyses)
- [ ] Crowdsourced or other data sources are not sufficiently accurate, reliable, or available
- [ ] RWIS are needed to support other critical agency assets (e.g., VSLs for road weather)
- [ ] Other (please specify)

Please explain, as needed

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Mobile RWIS or Third-Party Data Sources

The following questions are not about permanent RWIS, and we may follow up with you for more information.

26. Does your agency use mobile RWIS or portable RWIS to supplement permanent RWIS?

- ◯ Yes
- ◯ No

27. Does your agency use third-party data sources to supplement permanent RWIS?

- ◯ Yes
- ◯ No

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Additional Information

28. Please share any additional information regarding your agency's RWIS practices that you feel would be beneficial to this project.