

Concept of Operations

prepared for

Minnesota Department of Transportation (MnDOT)

for

Rural Intersection Conflict Warning Systems II Deployment

December 22, 2014



Table of Contents

- 1. Introduction and Concept Overview1**
- 2. Needs.....2**
 - 2.1 Needs by Stakeholder Groups..... 2
 - 2.2 High-Level Requirements 4
- 3. Operational Scenarios.....9**
 - 3.1 Driver Perspective 9
 - 3.2 Transportation Agency Perspective 10
 - 3.3 Law Enforcement Perspective 12
- 4. System Components12**
- 5. Operational Concept.....13**

Acknowledgements

These concepts of operations were originally developed by MnDOT for the statewide Rural Intersection Conflict Warning System (RICWS) project in October 2012. Carver County asked SRF Consulting Group to revise this document to incorporate lessons learned from the RICWS project to enable the installation of additional Intersection Conflict Warning Systems (ICWS) on T.H. 212 in Carver County. MnDOT participated in the development of this project and the associated systems engineering documents. These concepts were then reviewed by SRF Consulting Group for use on MnDOT’s second deployment Rural Intersections Conflict Warning Systems II (RICWS II).

1. Introduction and Concept Overview

The primary goal of an Intersection Conflict Warning System (ICWS) is to reduce crashes at stop-controlled intersections. This Concept of Operations documents the needs of stakeholder groups, describes operational scenarios, outlines systems components and presents an operational concept for ICWS that provide both either major or minor road alerts or a combination of both major and minor road alerts. ICWS typically consist of static signing, detection and dynamic elements as illustrated in Figure 1.

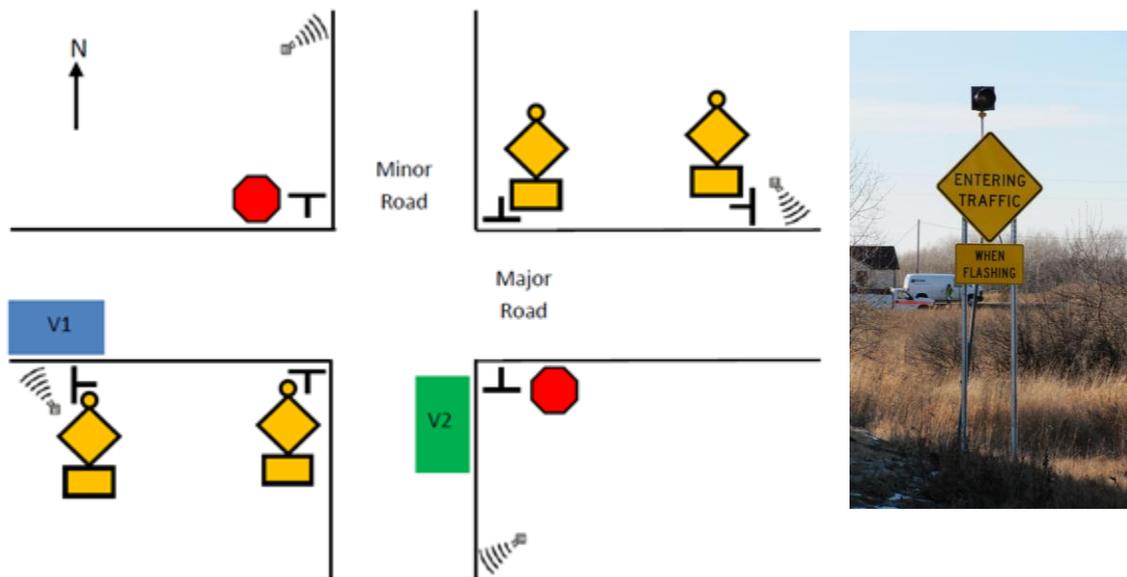


Figure 1 Intersection Conflict Warning System Concept

Stop-controlled intersections consist of a major road intersecting a minor road. The major road typically carries higher traffic volumes and the intersection approach is uncontrolled but may have advance warning signs. In comparison, the minor road usually carries lower traffic volumes and the approach is controlled by a stop sign. Crashes at these intersections continue to represent a significant share of transportation fatalities and injuries throughout rural Minnesota.

Transportation agencies have utilized a variety of safety countermeasures including intersection lighting, enhanced signing and geometric improvements to address intersection crashes. Recently, though, agencies have turned to Intelligent Transportation Systems as another tool for improving safety at intersections. Over the past several years, a variety of major and minor road oriented Intersection Conflict Warning Systems have been developed and tested in many states across the country. Through its leadership role in the [ENTERPRISE](#) transportation pooled fund project, [Developing Consistency in ITS Safety Solutions - Intersection Warning Systems](#), MnDOT is aware of over a dozen different systems that have been deployed at over 120 intersections throughout the United States. Deployment sites in North Carolina and Missouri have seen over 30% reductions in total crashes (based on simple before and after studies).

2. Needs

This section presents needs according to stakeholder groups and it also begins to translate those needs into high-level requirements that will be further detailed in the corresponding System Requirements document.

2.1 Needs by Stakeholder Groups

The deployment and operation of intersection conflict warning systems will be driven by the needs of the stakeholder groups who will interact with them. Such needs have been identified for two primary groups – drivers and transportation agencies.

- **Drivers** of the major and minor roads at stop-controlled intersections equipped with ICWS.
- **Transportation Agencies** at the state, county and local level that will operate, maintain and own the ICWS. Future needs of transportation agencies, not included in these concepts, will include communication with connected vehicles.
- **Law enforcement** who may observe operation of ICWS.

Table 1 lists stakeholder needs in three broad categories – Driver Alerts, Traffic Control, and Assessment and Evaluation. These needs will drive what the system must do and they will further drive the system requirements for how the intersection conflict warning system must perform.

Table 1 Stakeholder Needs for ICWS

Number	Stakeholder Needs	Drivers	Transportation Agencies	Law Enforcement
1	Driver Alerts			
1.1	Major road drivers approaching an intersection equipped with ICWS need an alert to indicate when vehicles are approaching or at stop signs on the minor road.	X		
1.2	Major road drivers need ICWS alerts to be visible at a distance that allows drivers to take corrective action as needed	X		
1.3	Minor road drivers approaching or stopped at stop signs before entering the major road need an alert to indicate when vehicles are approaching the intersection on the major road.	X		
1.4	Minor road drivers need ICWS alerts to be visible while they are stopped at the stop sign to support their decision about when it is	X		

Number	Stakeholder Needs	Drivers	Transportation Agencies	Law Enforcement
	safe to enter or cross the major road.			
1.5	Drivers, transportation agencies, and law enforcement need alerts to be dynamic and not become nearly continuous so as to lose impact.	X	X	X
1.6	Drivers, transportation agencies and law enforcement need ICWS alerts to be easily understood.	X	X	X
1.7	Drivers, transportation agencies and law enforcement need ICWS alerts and signage to be consistent throughout Minnesota, to the extent possible.	X	X	X
1.8	Drivers who are distracted need ICWS alerts to be of a nature that will capture their attention.	X		
2	Traffic Control			
2.1	Transportation agencies and law enforcement need ICWS alerts to provide supplemental warning that does not contradict or override the regulatory signs at the intersection.		X	X
2.2	Drivers and transportation agencies need ICWS to be operational whenever vehicles approach the intersection.	X	X	X
2.3	Drivers, transportation agencies and law enforcement need an ICWS malfunction to be readily and easily differentiated from an ICWS that is inactive due to lack of conflicting traffic.	X	X	X
2.4	Drivers and transportation agencies need ICWS not to obstruct view of intersection, other vehicles or regulatory signs.	X	X	X
2.5	Drivers and transportation agencies need ICWS components to be crashworthy in the event they are hit by vehicles.	X	X	X
2.6	Transportation agencies need a maintenance process that can be followed to repair or replace ICWS components in context with priorities for repairing all other traffic control devices.		X	
2.7	Transportation agencies need operational and maintenance training for ICWS.		X	
2.8	Transportation agencies need ICWS to be cost effective.		X	
2.9	Transportation agencies need to be able to maintain ICWS with minimal impact on traffic.		X	

Number	Stakeholder Needs	Drivers	Transportation Agencies	Law Enforcement
3	Assessment and Evaluation			
3.1	Transportation agencies need to understand ICWS safety impacts on total crash reduction, target (right angle) crash reduction and reduction in crash severity.		X	
3.2	Transportation agencies need ICWS design, construction, operation and maintenance documentation.		X	
3.3	Transportation agencies need ICWS to provide information regarding system status.		X	
3.4	Transportation agencies need to be able to remotely command and control the ICWS system.		X	

2.2 High-Level Requirements

To create a system that will address the stakeholder needs presented in Section 2.1, those needs must be translated into requirements for what the ICWS must do. Although detailed system requirements will be presented in a separate document, high-level requirements are presented in the following table to map their origin back to stakeholder needs. These high level requirements will serve as the basis for further detail in the final system requirements or in project contract documents.

Table 2 ICWS Stakeholder Needs and Associated High Level Requirements

Number	Stakeholder Needs	Number	High Level Requirements
1 Driver Alerts			
1.1	<p>Major road drivers approaching an intersection equipped with ICWS need an alert to indicate when vehicles are approaching or at the stop signs on the minor road.</p>	1.1.1	ICWS shall detect vehicles approaching or waiting at the stop or yield signs on the minor road.
		1.1.2	ICWS shall display alerts to major road drivers whenever a vehicle is approaching or waiting at the stop or yield sign on the minor road.
		1.1.3	ICWS may display an alert for major road drivers even if no major road vehicles are present.
1.2	<p>Major road drivers need ICWS alerts to be visible at a distance that allows drivers to take corrective action as needed.</p>	1.2.1	ICWS alerts shall be visible to major road drivers at a distance that allows them to take corrective action.
1.3	<p>Minor road drivers approaching or stopped at stop signs before entering the major road need an alert to indicate when vehicles are approaching the intersection on the major road.</p>	1.3.1	ICWS shall detect all vehicles as they approach the intersection on the major road.
		1.3.2	ICWS shall display alerts to minor road drivers whenever vehicles approach the intersection on the major road.
		1.3.3	ICWS may display an alert for minor road drivers even if no minor road vehicles are present.
1.4	<p>Minor road drivers need ICWS alerts to be visible while they are stopped at the stop sign to support their decision about when it is safe to enter or cross the major road.</p>	1.4.1	ICWS shall display alerts at a location visible to minor road drivers waiting at the stop sign.

Number	Stakeholder Needs	Number	High Level Requirements
1.5	Drivers, transportation agencies and law enforcement need ICWS alerts to be dynamic and not become nearly continuous so as to lose impact.	1.5.1	ICWS design shall include dynamic alerts.
1.6	Drivers, transportation agencies and law enforcement need ICWS alerts to be easily understood.	1.6.2	To the extent possible, ICWS shall follow recommended design practices described in “Design and Evaluation Guidance for Intersection Conflict Warning Systems” authored by the ENTERPRISE Transportation Pooled Fund program.
1.7	Drivers, transportation agencies and law enforcement need ICWS alerts and signage to be consistent throughout Minnesota, to the extent possible.	1.7.1	ICWS shall have similar placement, sign combinations and message sets at each deployment site in Minnesota.
1.8	Drivers who are distracted need ICWS alerts to be of a nature that will capture their attention.	1.8.1	ICWS alerts shall be conspicuous.
2 Traffic Control			
2.1	Transportation agencies and law enforcement need ICWS alerts to provide supplemental warning that does not contradict or override the regulatory signs at the intersection.	2.1.1	ICWS shall function as a warning sign as defined in MN MUTCD 2C.1-2C.2.
2.2	Drivers and transportation agencies need ICWS to be operational whenever vehicles approach the intersection.	2.2.1	ICWS shall operate continuously 24x7, 365 days per year , with minimal service interruption.
		2.2.2	ICWS shall not depend on communication with external systems to operate.

Number	Stakeholder Needs	Number	High Level Requirements
2.3	<p>Drivers and transportation agencies and law enforcement need an ICWS malfunction to be readily and easily differentiated from an ICWS that is inactive due to lack of conflicting traffic.</p>	2.3.1	<p>ICWS shall display a visible indication of malfunction.</p>
		2.3.2	<p>ICWS indication of malfunction shall be visibly different than ICWS in any other active or inactive state.</p>
		2.3.3	<p>ICWS indication of malfunction shall be distinguishable without knowledge of ICWS operations.</p>
2.4	<p>Drivers and transportation agencies need ICWS not to obstruct view of intersection, other vehicles or regulatory signs.</p>	2.4.1	<p>ICWS shall not obstruct any drivers' view of the roadway, other vehicles or regulatory signs.</p>
2.5	<p>Drivers and transportation agencies need ICWS components to be crashworthy in the event they are hit by vehicles.</p>	2.5.1	<p>ICWS shall meet MN MUTCD Section 2A.21 Posts and Mountings standard and AASHTO Specification for Structural Supports for Highway Signs, Luminaires and Traffic Signals for crashworthiness.</p>
		2.5.2	<p>ICWS shall consist of materials and be installed as specified in Section 2564 Traffic Signs and Devices and Section 2565 Traffic Control Signals of the MnDOT Standards Specifications for Construction.</p>
2.6	<p>Transportation agencies need a maintenance process that can be followed to repair or replace ICWS components in context with priorities for repairing all other traffic control devices.</p>	2.6.1	<p>ICWS design shall be maintainable and fit within Agency maintenance processes.</p>

Number	Stakeholder Needs	Number	High Level Requirements
2.7	Transportation agencies need operational and maintenance training for ICWS.	2.7.1	ICWS design shall follow design practices that allow maintenance staff familiar with other statewide ICWS systems to operate and maintain the system.
2.8	Transportation agencies need ICWS to be cost effective .	2.8.1	ICWS shall be scalable and reconfigurable to allow major road only, minor road only or major/minor road alerts.
2.9	Transportation agencies need to be able to maintain ICWS with minimal impact on traffic .	2.9.1	ICWS physical components shall be physically accessible for maintenance with one transportation agency vehicle and a 1-2 person crew in the right of way.
3 Assessment and Evaluation			
3.1	Transportation agencies need to understand ICWS safety impacts on total crash reduction, target (right angle) crash reduction and reduction in crash severity.	3.1.1	Systems engineering documentation shall explain safety considerations for ICWS.
3.2	Transportation agencies need ICWS design, construction, operation and maintenance documentation .	3.2.1	ICWS design shall be compatible with other statewide ICWS systems such that the design, construction, operation and maintenance procedures can be implemented.
3.3	Transportation agencies need ICWS to provide information regarding system status .	3.3.1	ICWS shall collect and retain data about system performance that indicates when and what components have failed or may be operating outside of the Contract requirements.
		3.3.2	ICWS shall have remote communication and monitoring capabilities that allow for determining if the system is operational or in a failure state.

Number	Stakeholder Needs	Number	High Level Requirements
3.4	<p>Transportation agencies need to be able to remotely command and control the ICWS system.</p>	3.4.1	<p>ICWS shall have remote communication capabilities that allow for remote verification, system interrogation, malfunction determination, power cycling, resetting control system components, adjusting timing and other system parameters and determining if an on-site field call is necessary and if so, what work will be needed for this on-site service.</p>

3. Operational Scenarios

Operational scenarios describe what is to be done and who will do it at intersections equipped with ICWS. The following scenarios describe a sequence of events, activities carried out by the each stakeholder group. The scenarios describe how stakeholders are expected to interact with ICWS. Within each scenario, references are also made back to the initial stakeholder needs as a means of verifying that all needs have been anticipated.

3.1 Driver Perspective

- 3.1.1 Major and minor road drivers will see an ICWS alert as they approach the intersection. **(1.1, 1.3)**
- 3.1.2 If a vehicle is approaching, waiting at or entering the intersection from stop signs on the minor road, major road drivers will see an ICWS alert indicating vehicles are present on the minor road. **(1.1)**
- 3.1.3 If a vehicle is not approaching, waiting at or entering the intersection from stop signs on the minor road, the major road driver will see that the ICWS is not activated. **(1.1)**
- 3.1.4 Regardless of the actions taken (e.g. decrease or maintain speed), major road drivers will continue to see the ICWS alert as long as a vehicle is approaching, waiting at or entering the intersection from stop signs on the minor road. **(1.1)**
- 3.1.5 Major road drivers will see an ICWS alert at a distance sufficient to allow them to take corrective action. **(1.2)**

- 3.1.6 If a vehicle is approaching the intersection from any lane on the major road, minor road drivers will see an ICWS alert indicating vehicles are present on the major road. **(1.3)**
- 3.1.7 Minor road drivers will continue to see the ICWS alert as long as a vehicle is approaching the intersection from any lane on the major road. **(1.3)**
- 3.1.8 If a vehicle is not approaching the intersection from either direction on the major road, minor road drivers will see that the ICWS is not activated. **(1.3)**
- 3.1.9 Minor road drivers will see an ICWS alert when they are stopped at the stop sign to support their decision about when it is safe to enter or cross the major road. **(1.4)**
- 3.1.10 Drivers will adhere to all regulatory signs (e.g. stopping at stop signs) and will use the ICWS as additional information to assist the decision-making process. **(1.4)**
- 3.1.11 Drivers will not experience a situation where ICWS alerts are displayed in a nearly continuous manner. **(1.5)**
- 3.1.12 Drivers will easily understand and recognize ICWS alerts as supplemental warning information. **(1.6)**
- 3.1.13 Drivers will see similar placement, sign combinations and message sets in the ICWS alerts they encounter throughout Minnesota. **(1.7)**
- 3.1.14 Drivers will see ICWS alerts that are conspicuous enough to draw their attention, even if they are distracted. **(1.8)**
- 3.1.15 Drivers will see activated ICWS whenever they approach the intersection. **(2.2)**
- 3.1.16 Drivers, including transportation agency officials and law enforcement, will understand when an ICWS is malfunctioning by a visible indication that makes the ICWS appear different than when it is simply inactive from lack of traffic without stopping and watching traffic for a period of time. **(2.3)**
- 3.1.17 Drivers will have an unobstructed view of the intersection, other vehicles, regulatory signs and ICWS. **(2.4)**
- 3.1.18 If a vehicle crashes into an ICWS, damage will be minimized by the crashworthiness of the ICWS. **(2.5)**

3.2 Transportation Agency Perspective

- 3.2.1 Transportation agencies will not deploy ICWS where traffic volumes cause alerts to be displayed in a nearly continuous manner. **(1.5)**
- 3.2.2 To facilitate driver recognition of ICWS as a warning device, transportation agencies will deploy ICWS consistent with warning standards and guidance in the MN MUTCD. **(1.6)**

- 3.2.3 To support driver understanding of ICWS alerts, transportation agencies will deploy ICWS with similar placement, sign combinations and alerts throughout Minnesota. **(1.7)**
- 3.2.4 Transportation agencies will deploy ICWS consistent with warning standards and guidance in the MN MUTCD to ensure that they do not contradict or override regulatory signs at the intersection. **(2.1)**
- 3.2.5 Transportation agencies will see ICWS operate continuously, all day, every day, year round with minimal service interruptions. **(2.2)**
- 3.2.6 When driving by an ICWS, transportation agencies will clearly see when the ICWS is malfunctioning by a visible indication that makes the ICWS appear different than when it is simply inactive from lack of traffic. **(2.3)**
- 3.2.7 Transportation agencies will see that ICWS does not obstruct the intersection, other vehicles and regulatory signs. **(2.4)**
- 3.2.8 Transportation agencies will see that ICWS are crashworthy in the event of a collision. **(2.5)**
- 3.2.9 Transportation agencies will be able to adjust ICWS alert lag time parameters to accommodate traffic volumes, speeds and intersection configurations when ICWS are installed and over the life of the installation as these parameters change. **(1.1, 1.4)**
- 3.2.10 Transportation agencies will have training, spare parts and technical support available to support ICWS maintenance in context with priorities for repairing all other traffic control devices. **(2.6, 2.7)**
- 3.2.11 Transportation agencies will manage costs through ICWS scalability and reconfiguration options to suit changing needs. **(2.8)**
- 3.2.12 Transportation agencies will maintain ICWS within public right of way and with minimal impacts on traffic. **(2.9)**
- 3.2.13 Transportation agencies will be able to evaluate ICWS safety effectiveness because they are deployed and operated in a consistent manner. **(3.1)**
- 3.2.14 Design, construction, operation and maintenance documentation will allow transportation agencies understand and be able to explain ICWS to the public or in legal inquiries. **(3.2)**
- 3.2.15 Transportation agencies will understand ICWS performance through records of system failure, activation and vehicle detection. **(3.3)**
- 3.2.16 Transportation agencies will be able to receive notification of system failure and malfunction remotely. Upon receipt of this automatic notification, agency personnel will be able to interrogate the system from a remote location, determine cause of system malfunction, make

system adjustments, reset system components, and determine if an on-site field call is necessary and if so, what work will be needed for this on-site service. **(3.3, 3.4)**

3.3 Law Enforcement Perspective

- 3.3.1 Law enforcement will observe that ICWS alerts are not displayed in a nearly continuous manner that impacts driver compliance. (1.5)
- 3.3.2 To observe driver compliance with ICWS as a warning device, law enforcement will observe ICWS operations in a manner consistent with warning sign standards and guidance in the MUTCD. (1.6)
- 3.3.3 To observe driver understanding of ICWS alerts across jurisdictions, law enforcement will observe uniform ICWS placement, sign combinations and alerts throughout their jurisdiction. (1.7)
- 3.3.4 Law enforcement will observe ICWS operating in a manner consistent with warning sign standards and guidance in the MUTCD to ensure that ICWS do not contradict or override regulatory signs at the intersection. (2.1)
- 3.3.5 Law enforcement will observe ICWS operating continuously, all day, every day, year round with minimal service interruptions. (2.2)
- 3.3.6 When driving by an ICWS, law enforcement will clearly see when the ICWS is malfunctioning by a visible indication that makes the ICWS appear different than when it is simply inactive from lack of traffic. Malfunctions will be reported to the transportation agency. (2.3)
- 3.3.7 Law enforcement will observe that ICWS do not obstruct the intersection, other vehicles and regulatory signs. (2.4)
- 3.3.8 Law enforcement will see that ICWS are crashworthy in the event of a collision. (2.5)

4. System Components

Intersection conflict warning system components include all the physical parts of the system that, working together, create the complete system to provide both major and minor road alerts to drivers. Following is an overview of the typical components for ICWS.

- **Detection:** Used to detect vehicle presence and/or speed. Detection may include a range of technologies such as radar or inductive loops
- **Warning:** Dynamically activated based on the detection of a vehicle, these components may consist of static signing, flashing beacons, dynamic message signs or illuminated static sign alerts.

- **System Communication:** This component manages communication used to transmit data among other components (e.g. detection and warning) and send or receive information regarding the operational state of the system. These communications may include cellular, radio or other landline and wireless forms.
- **Data Management:** This component is used to store system performance data and may be accomplished with a variety of on/off-site databases or data storage devices.
- **System Monitoring:** System logical components may be used to operate, detect and report fluctuations in system performance.
- **Power:** Operation of the detection, warning and system communication require power and the most common sources are grid, battery and solar.

5. Operational Concept

Each ICWS deployed will consist of the six components described in Section 4 to address the needs identified in Section 2 and requirements that will be further detailed in the System Requirements documents. Each component will require deployment, operations and maintenance activities to support their function. The transportation agency may be MnDOT or a local transportation agency such as a county. A contractor may be procured to design, develop, install or manage ICWS during an initial startup or warranty period. This section defines what deployment, operations and maintenance activities will be required and the party responsible for each.

Table 3 Activities Required for ICWS Components

Component	Deployment/Operations/Maintenance Required	Responsible Party
Overall ICWS	Conduct overall end-to-end system test of ICWS to verify functionality after initial installation.	Contractor and Transportation Agency
	Observe and participate in overall end-to-end system test, and provide final acceptance of system functionality.	Transportation Agency
	Perform periodic observations of the ICWS to assess system performance.	Transportation Agency
	Perform an on-site observation of ICWS following adverse weather conditions (e.g. damaging winds or heavy snow) to ensure all components remain in functioning.	Transportation Agency
Detection	Install detection equipment and connect to power.	Contractor

Component	Deployment/Operations/Maintenance Required	Responsible Party
	Install and integrate detection with system communication to connect detection to the warning, data management and system monitoring.	Contractor
	If detection is not functioning, follow Contractor-prepared procedures to troubleshoot and restore functionality.	Contractor (before final acceptance) Transportation Agency (after final acceptance)
Warning	Install warning equipment and connect to power and other ICWS components.	Contractor
	Perform individual component tests on warning to validate functionality.	Contractor
	If warning is not functioning, follow Contractor prepared procedures to troubleshoot and restore functionality.	Contractor (before final acceptance) Transportation Agency (after final acceptance)
System Communication	Install and connect system communication equipment with other ICWS components.	Contractor
	Perform individual component tests on system communication to validate functionality.	Contractor
	If system communication is not functioning, follow of procedures to troubleshoot and restore functionality.	Contractor (before final acceptance) Transportation Agency (after final acceptance)
Data Management	Install and connect data management equipment to other ICWS components.	Contractor
	Perform individual component tests on data management to verify functionality.	Contractor
	Periodically download data from storage device following procedures.	Transportation Agency

Component	Deployment/Operations/Maintenance Required	Responsible Party
System Monitoring	Install system monitoring equipment and connect to other ICWS components.	Contractor
	Perform individual component tests on system monitoring to verify functionality.	Contractor
	If system monitoring is not functioning, follow Contractor prepared procedures to troubleshoot and restore functionality.	Contractor (before final acceptance) Transportation Agency (after final acceptance)
Power	If AC power is not at selected site, arrange power installation with termination at a location close enough to the intersection to operate ICWS.	Contractor
	Connect ICWS components to power supply following the rules and procedures of the local power company.	Contractor
	If solar or other auxiliary power is specified, install equipment and connect to other ICWS components.	Contractor
	If commercial AC power supply is not functioning (power outage), contact the power company to report the failure and arrange for restoration.	Transportation Agency