DEPARTMENT OF TRANSPORTATION

Model Systems Engineering Document

ITS Application: Flood Warning

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Contents

Acronyms

ARC-IT	• National Architecture Reference for Cooperative and Intelligent Transportation
ATMS	• Advanced Traffic Management Software
BSM	• Basic Safety Message
CARS	• Condition Acquisition Reporting System
CAV	• Connected and Automated Vehicle
DNR	• Department of Natural Resources
DMS	• Dynamic Message Signs
FAT	• Factory Acceptance Test
IRIS	• Intelligent Roadway Information System
ITS	• Intelligent Transportation System
LAN	• Local Area Network
MnDOT	• Minnesota Department of Transportation
NWS	• National Weather Service
RSU	• Roadside Unit
RTMC	• Regional Transportation Management Center
SEA	• Systems Engineering Analysis
VPN	• Virtual Private Network
WAN	• Wide Area Network

Purpose and Description of Application

Document Purpose

This document is intended to support the Systems Engineering Analysis (SEA) activities for the Minnesota Department of Transportation (MnDOT) and other local transportation agencies within Minnesota as they consider, plan, develop, design, implement, and operate flood warning systems. The content of this document will be a systems engineering analysis resource to support project compliance as set forth in 23 CFR Section 940 (Rule 940). This document can be used in conjunction with the Minnesota Statewide Regional Intelligent Transportation System (ITS) Architecture and related systems engineering resources to complete an ITS Systems Engineering project-specific checklist as part of the initial analysis of applications considered for implementation. To access the available checklists for ITS-related deployments, visit the MnDOT Systems Engineering web page at: https://www.dot.state.mn.us/its/systemsengineering.html.

In situations where projects are not consistent with this systems engineering document, the contents of this document may be used as a base to support the development of project specific systems engineering documents, including a concept of operations, functional requirements, and test plans specific to the project.

Description of Application – Flood Warning

Transportation agencies sometimes deploy local flood warning systems at roadway sections that are prone to a high frequency of recurring flooding conditions, to detect the condition and activate advanced warning signs to alert drivers. As operations of Connected and Automated Vehicles (CAVs) expand, several data exchanges between CAV management systems and CAVs are anticipated, some of which will utilize flood warning and related road weather data. Flood warning functions may be completed locally by field devices or in conjunction with a supporting operator using Advanced Traffic Management Software (ATMS), if a communications connection to the ATMS is available.

Flood Warning Environment/Components

Table 1 presents the environment/components included in flood warning systems and describes the function of each.

Table 1: Flood Warning Environment/Components

Environment/Component	Function
1. Field Devices for High Water Detection	Sensing equipment located locally to areas prone to flooding to detect rising water.
2. Field Device for Processing and/or Communications	In local flood warning systems, this is the connection between the high-water detectors and the warning signs. In situations where connectivity to ATMS is warranted, this also processes local flood detection and sends it to the ATMS. In situations where operators use the ATMS to enter flood data, this component would receive flood notices and activate the warning signs.

Environment/Component	Function
3. Warning Signs	Visual indicators to local travelers that flooding is occurring. These could be static signs with flashing lights activated when flooding or dynamic signs with flooding messages posted when appropriate.
4. Supporting Communications	The communications infrastructure to allow data communications among flood/high water detection devices, warning signs, and the ATMS. (See details in the *Model System Engineering Document, ITS Application: Communications* document.) Note that communications to the ATMS is optional and that there are situations where flood warning systems exist as stand-alone systems.
5. On-line Flood Resources	A set of potential external data sources to indicate flood risks. Typically, this would include sensors operated by external agencies (e.g. Minnesota Department of Natural Resources (DNR) or the National Weather Service (NWS)) monitoring rivers that impact one or more roads that could trigger entry into the ATMS or activation of warning signs.
6. Advanced Traffic Management Software (ATMS)	The software that is used by traffic operations personnel to monitor traffic and control infrastructure systems. Examples of relations to flood warning systems are that the ATMS may enable operators to activate flood warning systems remotely or be alerted when flood warning systems activate through local detection field devices.
7. CAV Infrastructure Systems	The systems deployed by the DOTs to communicate with on-board units within CAVs. Flood warning systems (or the ATMS) may communicate flood warnings with CAV Infrastructure Systems.
8. CAVs	The vehicles and on-board applications that communicate with CAV Infrastructure Systems and other CAVs. As noted in this document, situations may exist where CAVs may receive flood warning notices and alert drivers. CAVs may also be a source of flood information.

The primary flood warning components and related systems are illustrated in Figure 1.

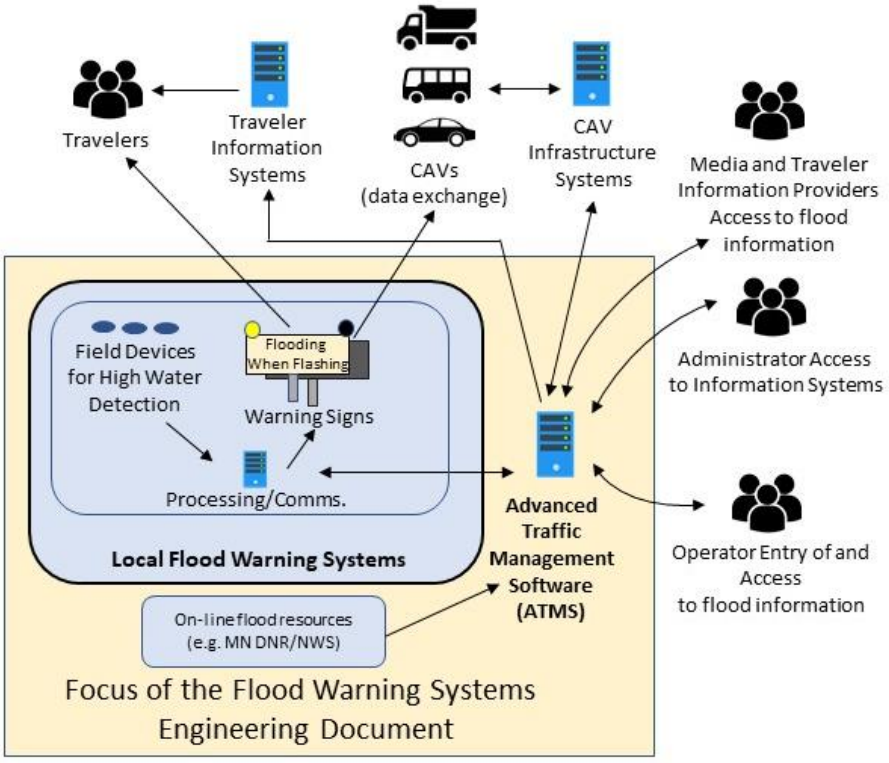

Figure 1: Illustration of Primary Flood Warning Components and Related Systems/Users

As noted above, flood warning system functions rely on field devices for high water detection. However, the provision of a connection from the local flood warning system to the ATMS is a local decision to be addressed during the design process. This decision is expected to be based on a variety of factors that would determine whether local conditions warrant operator influence on the flood warning system. These factors include the location of the roadway within the larger transportation network, potential flooding impact both to the roadway and number of travelers, and availability and cost to provide communications.

Examples of Communications Technologies Supporting Flood Warning

The flood warning application relies upon a number of communications technologies (detailed in a separate document - *Model System Engineering Document, ITS Application: Communications*) to transfer the flood warning information from field devices to eventual end users. The following table summarizes examples of communications technologies used today.

Table 2: Example of Current Communications Supporting Flood Warning Applications

Flood Warning Application Communications	Communications Technologies Supporting Flood Warning Applications
Flood detectors to warning signs	• **Short-range wireline or wireless communications** – Ethernet or serial connections using fiber or copper mediums or WiFi, microwave, or FM radio, depending on local conditions, to support two-way communications over short distances between the flood detectors and warning signs. • **Commercial wireless communications** – Services provided by third party providers over commercial networks, such as cellular and WiFi, allow wireless communications of flood data from flood detectors to warning signs. • **Virtual Private Network (VPN) over public internet** – Secure and encrypted communications over less secure networks and the public internet allow communication of flood data from detectors to warning signs in locations where agency owned communications are not practical.
Flood warning field systems to ATMS	• **Long-range communications** – Ethernet connections using fiber or copper mediums to communicate flood-related information from flood warning field systems to the ATMS. • **DOT operated Local Area Network (LAN) or Wide Area Network (WAN)** – Private communications network that allows a connection between flood warning field systems and the ATMS with standard security concerns. • **Commercial wireless communications** – Services provided by third party providers over commercial networks, such as cellular, allow wireless communications of flood information from flood warning field systems to the ATMS. • **VPN over public internet** – Secure and encrypted communications over less secure networks and the public internet allow communication of flood data from field systems to the ATMS in locations where agency owned communications are not practical.
3rd party flood notifications to ATMS	• **Public internet** – Public internet allows the ATMS to access information from non-agency websites (e.g. to access flood information from the National Weather Service).
Flood warning field systems to CAVs	• **Short-range, wireless, low latency communications** – Extremely low latency communications from flood warning field systems to CAVs that are able to support credentials-based security protocols within a line of sight range of generally 300 meters or less.
ATMS to CAVs (flood warnings)	• **Public internet** – Use of the public internet allows information (e.g. flood warning information) to be shared with CAVs. • **Commercial wireless communications** – Services provided by third party providers over commercial networks, such as cellular, allow wireless communications of flood warning information from the ATMS to CAVs.

Stakeholders and Typical Conditions

Stakeholders

Table 3 identifies the stakeholder groups that interface with one or more aspects of flood warning deployment and operations. While these stakeholders are presented for flood warning systems, it should be noted that in most cases the same stakeholders would be present for any weather-related local warning system that is deployed, such as a high wind warning system or a low visibility warning system. Note that additional stakeholders may exist for these other weather-related local warning system deployments, e.g. truckers for a high wind warning system.

Table 3: Flood Warning Stakeholders/Users

Stakeholder	Description
Travelers	Vehicle drivers and passengers operating traditional vehicles and CAVs.
Operators	Operators responsible for performing freeway or arterial operations and entry of traveler information and alerts. Where a communications connection is warranted and available, operators may enter flood warnings (not detected by field devices) or may view flood warnings detected by field devices and communicated to the Advanced Traffic Management Software.
Administrators	A combination of operators and technical staff responsible for configuring, updating, verifying agency owned flood detection field equipment or the ATMS capable of supporting flood warnings.
Technicians and Installers	Technical staff responsible for installing, maintaining, and troubleshooting field equipment that detects flooding, processes and communicates the notices, and the signs that display flood alerts to travelers.
External Partners	MnDOT road maintenance staff, law enforcement, and National Weather Service staff all assist in monitoring flood-prone areas and may identify or benefit from understanding road segments at risk for flooding. These external partners also inform other stakeholders, recommend or help implement road closures when needed, and assist in the return to normal operations.
CAV Infrastructure Systems and CAVs	External systems that include both CAV infrastructure systems (systems operated by MnDOT) and CAVs (vehicles and on-board units in the vehicles) that support connected and automated vehicle operations. CAVs may receive flood warning notices and alert drivers. CAVs may also be a source of flood information.

Typical and Local Conditions

Flood warning systems are installed at roadway locations that are prone to a high frequency of recurring flooding. Installation locations can include mainline roadway sections or freeway ramps. Deployments of flood warning systems are considered at locations where:

- Flooding conditions recur frequently;
- Flood water levels tend to rise quickly; and
- There is a lack of adequate surveillance to monitor conditions at all times.

Stakeholder Needs

Table 4 identifies a series of problems or challenges and the related needs for each stakeholder identified above. Note that some needs are listed as optional needs (i.e. "may need…") depending on whether the local flood warning system has a connection to the ATMS.

Table 4: Challenges/Needs

Problem/Challenge	Needs (As a Result of the Problem/Challenge)
Travelers Needs	
- Travelers en-route to their destination are unaware of situations when high water levels may block their travel routes or create hazards.	***Need 1: Real-time, En-route, Local Flooding Notification*** Travelers need to view information in advance of locations where flooding is impacting the road, ideally prior to a decision point that allows them to avoid the flooded area.
- Without advanced notice, travelers will not be able to adjust trip plans to avoid flooded areas.	***Need 2: Advance Flooding Information*** Travelers need a mechanism for planning their trip that informs them which portions of roads are currently impacted by flooding, or may be in the near future.
Operators Needs	
- Flooding can occur at any time and in any weather condition.	***Need 3: Automated Activation of Local Flood Warning Displays*** In locations prone to high water or flooding that impacts travel on the roadways, operators need the presence of high water to be detected and local warnings displayed to travelers without requiring or waiting for operator involvement.
- Field equipment may not always detect high water or operators may wish to warn drivers in anticipation of rising waters.	***Need 4: Operator Interaction with Flood Warning Displays*** When local conditions warrant operator influence, operators need a mechanism to interact with local flood warning systems to either activate the warning displays or receive notices that they are active.
- Flood warning signage deployed in the field could be automatically activated based on external sources of flood data that indicate possible flooding conditions.	***Need 5: Activation Using External Flood Data Sources*** If local field devices for high water detection are not deployed or require additional detection, operators need a mechanism for external flood data sources to be incorporated to trigger flood warning alerts.
- Operators could benefit from field device data and information sources like current and historical flood reports to help predict and detect possible flooding conditions, in order to modify or refine operational procedures and practices.	***Need 6: Usable Access to Current and Historical Flood Data and Reports*** When a connection to the ATMS is deployed, operators need a mechanism for current and historical data and information from field devices for high water detection and flood reports to be available to help them predict and understand the likelihood and impact to the select road segment when flooding occurs.

Problem/Challenge	Needs (As a Result of the Problem/Challenge)
Administrators Needs	
- It is important to identify issues with devices as early as possible, to implement repairs or replacements in order to minimize disruption in flood warning.	***Need 7: Flood System Assessment Tools*** Administrators need tools to query and understand the operational status of flood warning field equipment. Depending on whether or not the flood warning field equipment has a connection to the ATMS, these tools may be used in the field or remotely.
- Centralized flood information management requires configuration of local flood warning systems.	***Need 8: Local Flood Warning System Configuration*** When a connection to the ATMS is deployed, administrators need to be able to configure the local systems associated with flood warning (e.g. establish their location and roads impacted into the ATMS to be able to process flooding alerts received and assign them properly to roads).
Technicians and Installers Needs	
- Proper use of field equipment to detect and disseminate flood warnings require communications, power, and installation at the deployment sites.	***Need 9: Field Device Supporting infrastructure*** Technicians and installers need power, communications, and support structures to be available at locations where field equipment is used to detect high water and located above any anticipated high-water mark. Note: power may be locally generated (e.g. solar, wind); local communications may not be able to provide a connection to the ATMS.
- Equipment deployed in the field must not harm technicians, installers, or anyone in vicinity of the equipment.	***Need 10: Safety Standards*** Technicians and installers need the field devices to adhere to appropriate safety standards, specifications, and protocols.
- Devices that are not compatible with existing equipment or systems may not be able to be installed or could require significant staff effort during installation.	***Need 11: Equipment Consistency*** Technicians and installers need consistency and compatibility in the local flood warning equipment to achieve efficiencies in procurement, maintenance, and training.
External Partners Needs	
- External partners may be unaware about water levels that are impacting portions of the roadway.	***Need 12: External Partner Access to Flood Notices*** External partners need a mechanism to receive notices about when potential flooding is detected (or be alerted when detection occurs) in order to make informed decisions about flood forecasts, deploying additional traffic control devices, or executing or assisting with lane closures.

Problem/Challenge	Needs (As a Result of the Problem/Challenge)
CAV Infrastructure Systems and CAVs Needs	
- CAVs will benefit from data from nearby vehicles.	***Need 13: Vehicle to Vehicle Data Exchange*** CAVs need real-time, low latency data from other CAVs to exchange data that could describe locations where water is impacting the roadway.
- Vehicle data (e.g. friction sensors, wheel slippage) can offer insight into flooding conditions.	***Need 14: Vehicle to Infrastructure Data Exchange*** DOTs need to benefit from the data broadcast by public and private CAVs to assist in detection of flood conditions whenever possible.
- CAVs will benefit from flood alerts and notices provided by DOT-owned infrastructure, as additional automated driving systems and capabilities are integrated into vehicles.	***Need 15: Vehicle Use of Infrastructure-generated Flood Warnings*** CAVs may need infrastructure-generated flood warnings.

Operational Concepts

The operational concepts below are presented for flood warning systems that may or may not have a communications connection to the ATMS. The provision of a communications connection to the ATMS, while encouraged, is expected to be a local design decision based on factors that would determine whether local conditions warrant operator influence on the flood warning system. These factors include the location of the roadway within the larger transportation network, potential flooding impact both to the roadway and number of travelers, and availability and cost to provide communications.

Travelers' Perspective

Table 5 describes the flood warning operational concepts from the travelers' perspective, and relates each concept to a need, as defined in the previous section.

Table 5: Flood Warning Operational Concepts – Travelers' Perspective

Need (Travelers' Perspective)	Operational Concept
Travelers' Perspective related to ***Need 1: Real-Time, En-route, Local Flooding Notification***	1.1 Travelers driving on selected routes that are prone to flooding may observe static flood warning signs with a message such as "Roadway flooded when flashing" or "Off-ramp flooded when flashing". 1.2 At times when water is detected to be high enough to cause flooding, the flashing beacons will be activated, and drivers alerted to immediate flooding concerns downstream of their position. Ideally, travelers will have an option to divert onto an alternate path to avoid the flooding. 1.3 Travelers may also view messages displayed on Dynamic Message Signs (DMS) describing the flooding conditions immediately downstream.
Travelers' Perspective related to ***Need 2: Advance Flooding Information***	2.1 Prior to departing on their trips, travelers may access traveler information websites (operated by MnDOT or other partners) to view current alerts and notices. While they may not be seeking flooding alerts, travelers may see alerts about flood conditions impacting their routes. 2.2 Travelers en-route to their destination may view notices of flood impacts on DMS upstream of decision points, possibly describing nearby adjacent routes, allowing travelers to avoid impacted routes. 2.3 Travelers accessing local news media broadcasts may view or hear notices of flooding conditions and specifics of the portions of roads impacted. 2.4 Travelers will likely receive more consistent and current notices of flood impacts if the flood warning system has a connection to the ATMS to automate reporting based on real-time flood conditions.

Operators' Perspective

Table 6 describes the flood warning operational concepts from the freeway and arterial operators' perspective, including MnDOT road maintenance staff in situations where a local flood warning system is manually activated and/or does not have a connection to the ATMS. Each concept is related to a need, as defined in the previous section.

Table 6: Flood Warning Operational Concepts – Operators' and Operations Systems Perspective

Need (Operators' Perspective)	Operational Concept
Operators' perspectives related to: ***Need 3 Automated Activation of Local Flood Warning Displays***	3.1 In locations prone to high water and/or flooding, there may be local systems installed to automatically detect high water. 3.2 The detection of high water will be linked to local displays for the travelers upstream of the location (e.g. static signs with flashing beacons or dynamic signs), and the detection of high water will activate these displays. 3.3 As water levels lower, the activations will turn off automatically.
Operators' perspectives related to ***Need 4: Operator Interaction with Flood Warning Displays***	4.1 Local high water/flood detections will also communicate the situation to centralized reporting systems when connections are available, allowing operators to be aware of the conditions. The provision of a communications connection is a local design decision. 4.2 Operators with access to the ATMS (e.g. Intelligent Roadway Information System (IRIS) or condition reporting system (e.g. Condition Acquisition Reporting System (CARS)) will have a mechanism to examine the local flood warning systems configured in the system to view if flood conditions have been detected, when a communications connection to the flood warning system is present. 4.3 In situations where external flood detection sources are used, operators will view these events in the condition reporting system or ATMS and increase their understanding of flood conditions. 4.4 Operators may use cameras, when available, to verify and monitor flood conditions or the current status of the local flood warning signs using cameras deployed in the field, as available. 4.5 Operators may edit or add details to automated flooding reports received into the condition reporting systems before advancing them to traveler information systems such as 511 website and 511 phone. 4.6 When a communications connection from the flood warning system to the ATMS is present, operators need a mechanism to manually activate the flood warning system remotely in

Need (Operators' Perspective)	Operational Concept
	the event flooding conditions are identified that local field devices to detect high water do not. The supporting systems will cause the local warning signs to activate as if the field devices detected the flood conditions. 4.7 Operators, i.e. MnDOT road maintenance staff, need a mechanism to manually activate the flood warning system locally in the field in the event flooding conditions are identified that local field devices to detect high water do not. The supporting systems will cause the local warning signs to activate as if the field devices detected the flood conditions. 4.8 Operators may be informed of flooding conditions impacting stretches of Minnesota roads that do not have local flood warning systems. In these situations, operators will use the ATMS and/or traveler information applications to create events describing the flooding conditions. Event descriptions will include describing the portion of the roadway impacted, a description of the condition, and other supporting information. 4.9 In situations where operators have activated flood warning systems, the flood information will be captured as events in the traveler information application and used to support traveler information dissemination.
Operators' perspectives related to ***Need 5: Activation Using External Flood Data Sources***	5.1 In some locations, external sources of flood data may be used in place of local field devices for high water detection. 5.2 When external flood data is used in place of local field devices for high water detection, external flood data may be used to automatically activate flood warning system signage when high waters pose a flood risk to the roadway. 5.3 When external flood data is used in places of local field devices for high water detection, operators may be required to verify conditions before flood warning system signage is activated. 5.4 In situations where external flood detection sources are available, condition reporting systems or ATMS will ingest the external data and automatically create events that describe the flooding risks and associate them to one or more segments of roads, including those without a flood warning system. 5.5 Operators will view available event notifications and increase their understanding of flood conditions.
Operators' perspectives related to ***Need 6: Usable Access to***	6.1 Operators need to have access to current notifications of flood warnings to take actions to manage the roadway.

Need (Operators' Perspective)	Operational Concept
Current and Historical Flood Data and Reports	6.2 There may be times that operators would benefit from viewing past notifications of flood warnings detected by field devices or external systems to help debrief from incidents/events or to understand the frequency and timing of flooding.

Administrators' Perspective

Table 7 describes the flood warning operational concepts from the administrators' perspective, and relates each concept to a need, as defined in the previous section.

Table 7: Flood Warning Operational Concepts - Administrators' Perspective

Need (Administrators' Perspective)	Operational Concept
Administrators' perspective related to ***Need 7: Flood System Assessment Tools***	7.1 Administrators will be able query and understand the operational status of flood warning field equipment using flood system assessment tools. 7.2 At a minimum, administrators will be able to use these tools at the device location in the field to identify issues in order to implement repairs, as needed. 7.3 If the flood warning system equipment has a communications connection to the ATMS, the flood system assessment tools will remotely provide configurable, automatic notifications to administrators about identified issues with devices as early as possible, to implement repairs or replacements in order to minimize disruption in flood warning capabilities.
Administrators' perspective related to ***Need 8: Local Flood Warning System Configuration***	8.1 Administrators will configure the local flood warning systems once they are installed, if a communications connection to the ATMS is present. Configuration will link the system to the ATMS to establish their location in order to process flooding alerts received and assign them properly to roads. In situations where a communications connection to the ATMS is present and either the flood warning system is modified or upgraded or the ATMS is upgraded, configuration may be required to maintain compatibility. Administrators may perform portions of the flood warning system configuration in the field or remotely when a communications connection to the ATMS is present.

Technicians/Installers' Perspective

Table 8 describes the flood warning operational concepts from the perspective of the technicians and installers of road weather field devices, and relates each concept to a need, as defined in the previous section.

Table 8: Flood Warning Operational Concepts - Technicians/Installers' Perspective

Need (Technicians/Installers' Perspective)	Operational Concept
Technicians and Installers' Perspectives related to ***Need 9: Field Device Supporting infrastructure***	9.1 Field devices for high water detection will be deployed at locations where that they are accessible to communications and power, which may be locally generated by solar or wind. 9.2 Field devices for high water detection will be deployed such that communications and power will not be negatively impacted by any anticipated high water levels. 9.3 Field devices for high water detection will be deployed such that technicians and installers can access the devices to perform maintenance. 9.4 Field devices for high water detection will be mounted on appropriate support structures. 9.5 Field devices for high water detection will be calibrated to activate flood warning systems when water levels reach a level that poses a potential risk to the roadway.
Technicians and Installers' Perspectives related to ***Need 10: Safety Standards***	10.1 Technicians and installers need the field devices for high water detection to adhere to appropriate safety standards, specifications, and protocols. Equipment deployed in the field must not harm technicians, installers, or anyone in vicinity of the equipment.
Technicians and Installers' Perspectives related to ***Need 11: Equipment Consistency***	11.1 Legacy field devices for high water detection will continue to be used. 11.2 Procurement of new field devices for high water detection will be consistent with in-place devices to the extent possible, so that installers and technicians will be well-trained to install and repair new devices and can interchange parts. 11.3 New field devices for high water detection will be compatible with existing equipment and systems such as communications (fiber, etc.) and data management systems (e.g. IRIS), even if there are no current plans for a communications connection to the ATMS. 11.4 Consistency and compatibility needs will not prevent or inhibit the testing and eventual production use of new products or services. MnDOT will continue to benefit from advances in technology.

Need (Technicians/Installers' Perspective)	Operational Concept
	11.5 Selection of new equipment or software tools will be done in a way that ensures interoperability and consistency with latest standards and technologies.

External Partners' Perspective

Table 9 describes the flood warning operational concepts from the perspective of external partners, which may include law enforcement personnel and National Weather Service staff. Each operational concept relates to a need, as defined in the previous section.

Table 9: Flood Warning Operational Concepts – External Partners' Perspective

Need (External Partners' Perspective)	Operational Concept
External Partner Perspectives related to ***Need 12: External Partner Access to Flood Notices***	12.1 External partners need a mechanism to understand when local flood warning systems have detected high water or flood conditions, when a communications connection from the flood warning system to the ATMS is present. 12.2 External partners may use this information to help inform flood forecasts, decisions about monitoring conditions, deploying traffic control devices, and issuing road closures. 12.3 There may be times that flooding is occurring and when local field devices to detect high water do not detect flooding conditions. When these situations are identified by external partners, external partners will contact MnDOT to manually activate the flood warning system, either remotely or at the device.

CAV Infrastructure Systems and CAVs' Perspective

Table 10 describes the flood warning operational concepts from the perspective of CAV infrastructure systems and CAVs, and relates each concept to a need, as defined in the previous section.

Table 10: Flood Warning Operational Concepts - CAV Infrastructure Systems and CAVs' Perspective

Need (CAV Infrastructure Systems and CAVs')	Operational Concept
CAV Infrastructure Systems and CAVs' Perspectives related to ***Need 13: Vehicle to Vehicle Data Exchange***	13.1 CAVs (including agency owned CAVs) are expected to broadcast the Basic Safety Message (BSM) continuously as they drive the Minnesota roadways. 13.2 Agency-owned CAVs may receive and process BSM messages from other vehicles and use this information to support such applications as spot weather information warning.

CAV Infrastructure Systems and CAVs' Perspectives related to ***Need 14: Vehicle to Infrastructure Data Exchange***	14.1 MnDOT may locate CAV infrastructure systems on the roadside to receive and process BSM messages at key locations to gather information to help identify flood conditions, such as wheel slippage and friction sensor data. MnDOT will develop data retention policies for CAV related data and regularly review these as the CAV industry matures and the amount of data generated is better understood.
CAV Infrastructure Systems and CAVs' Perspectives related to ***Need 15: Vehicle Use of Infrastructure-generated Flood Warnings***	15.1 MnDOT may locate CAV infrastructure systems to broadcast road weather-related data in flood prone areas, such as flood-related advisory or alert messages, road closure information, and/or alternate routes, that will be received by CAVs. CAV infrastructure systems may receive road weather data or derived values from MnDOT data management systems, for use by CAVs. CAVs may ingest this road weather data or derived values from the CAV infrastructure systems to support automated driving system features.

Operational Scenarios/Roles and Responsibilities

Roles and Responsibilities

The Operational Concept section defined interactions of the primary stakeholders with the flood warning systems. The table below provides a high-level summary of the roles and responsibilities of the stakeholder groups.

Table 11: Operation and Maintenance Roles and Responsibilities

User Group	Role/Responsibility
Operators	• Monitor the status of flood warning systems, through notifications from external partners or field staff, or by viewing the status in the ATMS (if connected to ATMS). • View nearby cameras to assess local roadway conditions (e.g. flooding or high water) in the vicinity of flood warning systems. • View and monitor external flood detection sources, as available in the CARS or ATMS system (if connected to CARS or ATMS). • Add or edit flooding events in CARS (if connected to CARS). • Activate and de-activate flood warning systems as needed, locally in the field and remotely via the ATMS (if connected to ATMS).
Administrators	• Configure new flood warning systems to ATMS (if connected to ATMS). • Query the operational status of flood warning system equipment using flood system assessment tools, to identify operational issues. • Receive automatic notifications about operational issues (if connected to ATMS). • Notify technicians and installers of operational issues, to initiate repairs as needed.
Technicians/Installers	• Prepare needed designs for flood warning system supporting infrastructure and support structures. • Install flood warning systems (including needed traffic control). • Troubleshoot technical issues with the flood warning systems in the field and ATMS software (if connected to ATMS) and make repairs. • Perform routine maintenance in accordance with MnDOT ITS field device guidance. • Participate in configuring flood warning systems with the ATMS (if connected to ATMS).
External Partners	• Monitor flood-prone roadways to identify road segments that are at risk for flooding. • View flood warning systems and conditions in the field to determine related actions, such as road closures or additional advanced signage needs. • View flood warning systems in the field and communicate any known operational issues with the systems. • Contact MnDOT to request activation of flood warning systems, as needed.

User Group	Role/Responsibility
Travelers	• View messages on flood warning signs (and DMS, as deployed) to make decisions about diverting away from roadways that may be experiencing flooding conditions and/or high water.

Operational Scenarios

Scenarios are intended to describe how users will interact with the flood warning systems and specifically to provide a temporal description of the sequence of events. The following scenarios briefly describe how users will be impacted and how they are expected to respond.

- Scenario A: Identifying Flood-Prone Location and Deploying a Flood Warning System
- Scenario B: Local Activation of Flood Warning System
- Scenario C: Flood Warning System Monitoring and Control by ATMS
- Scenario D: Viewing Road Flooding Information on Traveler Information Mechanisms
- Scenario E: Maintenance and Repair of a Flood Warning System

Scenario A: Identifying Flood-Prone Location and Deploying a Flood Warning System

MnDOT District 7 field staff and local law enforcement identify a section of highway that floods nearly every spring. They determine that the location would benefit from a flood warning system and work with Regional Transportation Management Center (RTMC) operators to determine it will be connected to ATMS. During deployment, installers work with the administrators and operators to configure the system into the ATMS such that it can be recognized and controlled by operators using the ATMS. The flood warning system is not near a local power connection, so it is powered using a combination of battery and solar power.

Scenario B: Local Activation of Flood Warning System

Flooding occurs in an area adjacent to a state highway that has frequently experienced flood waters that flow over the highway. As flood waters rise, a field device for high water detection located adjacent to the highway detects the water when it reaches a pre-determined elevation. The detection device activates flashing beacons on static warning signs that indicate “Water on Road Ahead,” located upstream of the flood water location in both directions. An approaching motorist sees a warning sign, slows to a stop prior to reaching the flood water flowing over the road, and turns around rather than proceeding through the flood water. The sign’s flashing beacons continue to flash until the detection device detects that the water has receded below the pre-determined elevation, at which time the beacons stop flashing.

Scenario C: Flood Warning System Monitoring and Control by ATMS

Flooding occurs adjacent to a freeway off-ramp, at a location with a history of fast-rising flood waters in the spring. As the flood water level rises, a detection device detects that the water has reached a pre-determined elevation and triggers activation of a warning sign to alert motorists on the freeway that there is water on the exit ramp. Because the flood warning system is connected to the ATMS, operators see that the flood warning system has been activated. At the time of activation, ATMS sends an automated message to external partners (MnDOT road maintenance staff, law enforcement, and NWS staff) to alert them that flooding over the ramp is occurring.

Operators view nearby cameras to assess the extent of water over the ramp and to view the operational status of the warning sign. After a few hours, operators notice that the warning sign is no longer activated but water on the ramp is still at a high level. Operators alert technicians of the issue and use the ATMS to manually re-activate the sign until the water recedes, at which time operators manually de-activate the warning sign.

Scenario D: *Viewing Road Flooding Information on Traveler Information Mechanisms*

During a heavy summer rainstorm, a flood warning system is activated on a segment of MN TH 60, a rural state highway. The flood warning system is connected to the ATMS and CARS, therefore when the system is activated, it sends a notification to CARS, a flooding event is created in CARS, and the event is displayed on MnDOT's 511 website and 511 mobile app. A traveler views the interactive map on the MnDOT 511 website when planning a trip in the vicinity. The traveler selects the warning icon at MN TH60 and views a message saying "MN 60: Flooding between US 61 and McDougall Avenue (Wabasha). Watch for flooding." The traveler views alternate routes to his destination and avoids the flooded roadway location.

Scenario E: Maintenance and Repair of a Flood Warning System

During a flood event near a rural state highway, MnDOT field staff and local law enforcement travel to a location where frequent roadway flooding occurs, to assess the extent of water over the road. A flood warning system is in place at the location; however, it has not been activated. MnDOT field staff manually activate the beacons on the warning sign and contact technicians to inform them of the issue. Because the flood warning system is not connected to ATMS, a technician travels to the scene and uses flood assessment tools to query the field equipment to troubleshoot the issue. They determine that the in-place detection device is faulty, and the technician replaces the device.

System Requirements

System requirements are verifiable details that define what a system will do, but not how the system will do it. Requirements can describe the functional, performance, interface, communications, operational, and maintenance conditions of what a system will do.

Requirements for flood warning systems are listed in the table below first by needs (column 1). These represent the needs of all the stakeholders described in the *Stakeholder Needs and Typical Conditions* section. Based on each need and on the operational concepts presented in the *Operational Concepts* section, one or more system requirements (column 2) are described. Requirements are all numbered to facilitate traceability back to the original needs and further traceability through design and validation.

Table 12: Flood Warning Requirements by Need

Need	System Requirement
Travelers	
1. Travelers need to view information in advance of locations where flooding is impacting the road, ideally prior to a decision point that allows them to avoid the flooded area.	1.1. In locations that experience recurring high water or flooding conditions, flood warning systems shall be considered to advise travelers of periods when high water or flooding impacts the roadway. 1.2. Flood warning systems shall activate visual alerts to drivers when flooding conditions are detected downstream. 1.3. Agencies shall consider locating flood warning systems' visual display to the drivers in advance of a decision point that would allow diversion to an alternate route for travelers to avoid the flooded area. 1.4. Agencies shall consider flood warning systems' visual display visibility to travelers when finalizing location and installation.
2. Travelers need a mechanism for planning their trip that informs them which portions of roads are currently impacted by flooding, or may be in the near future.	2.1. Agencies shall consider deploying mechanisms to enable flood warning systems to communicate flood alerts to the ATMS to enable widespread dissemination using established traveler information system applications.
Operators	
3. In locations prone to high water or flooding that impacts travel on the roadways, operators need the presence of high water to be detected and local warnings displayed to travelers without requiring or waiting for operator involvement.	3.1. The detection of high water shall automatically activate the local displays to alert travelers of flood risk. 3.2. The flood warning activations shall turn off automatically as water levels lower.

Need	System Requirement
4. When local conditions warrant operator influence, operators need a mechanism to interact with local flood warning systems to either activate the warning displays or receive notices that they are active.	4.1. When connections are available, local high water/flood detections shall communicate the flood condition status to centralized reporting systems, allowing operators to be aware of the conditions. Note that the provision of a communications connection is a local design decision. 4.2. When a communications connection to the flood warning system is present, operators with access to the ATMS (e.g. IRIS) or condition reporting system (e.g. CARS) shall have a mechanism to examine the local flood warning systems configured in the system to view if flood conditions have been detected. 4.3. When a communications connection from the flood warning system to the ATMS is present, operators shall be able to manually activate and de-activate the flood warning system remotely. 4.4. Operators, i.e. MnDOT road maintenance staff, shall be able to manually activate and de-activate the flood warning system locally at the device in the field.
5. If local field devices for high water detection are not deployed or require additional detection, operators need a mechanism for external flood data sources to be incorporated to trigger flood warning alerts.	5.1. Agencies shall consider the use of external real-time sources for flood data to be used in place of local field devices for high water detection. 5.2. In situations where external flood detection sources are used, condition reporting systems or ATMS shall ingest the external data and automatically create events that describe the flooding risks and associate them to one or more segments of roads, including those without a flood warning system. 5.3. When external flood data is used in place of local field devices for high water detection, external flood data may be used to automatically activate flood warning system signage when high waters pose a flood risk to the roadway. 5.4. When external flood data is used in places of local field devices for high water detection, operators shall have access to the external flood data to help assess and predict flood impacts to certain areas and specific road segments. 5.5. When external flood data is used in places of local field devices for high water detection, operators may have a mechanism to verify conditions prior to the activation of flood warning system signage.

Need	System Requirement
6. When a connection to the ATMS is deployed, operators need a mechanism for current and historical data and information from field devices for high water detection and flood reports to be available to help them predict and understand the likelihood and impact to the select road segment when flooding occurs.	6.1. When a connection to the ATMS was deployed, operators shall have a mechanism for viewing past notifications of flood warnings detected by field devices or external systems to help debrief from incidents/events or to understand the frequency and timing of flooding.
Administrators	
7. Administrators need tools to query and understand the operational status of flood warning field equipment. Depending on whether or not the flood warning field equipment has a connection to the ATMS, these tools may be used in the field or remotely.	7.1. Administrators shall be able query and understand the operational status of flood warning field equipment using flood system assessment tools. 7.2. At a minimum, administrators shall be able to use these tools at the device location in the field to identify issues in order to implement repairs, as needed. 7.3. When the flood warning system equipment has a communications connection to the ATMS, the flood system assessment tools shall remotely provide configurable, automatic notifications to administrators about identified issues with devices as early as possible, to implement repairs or replacements in order to minimize disruption in flood warning capabilities.
8. When a connection to the ATMS is deployed, administrators need to be able to configure the local systems associated with flood warning (e.g. establish their location and roads impacted into the ATMS to be able to process flooding alerts received and assign them properly to roads).	8.1. When a communications connection to the ATMS is present, the ATMS shall enable administrators to configure the local flood warning systems once they are installed. 8.2. When a communications connection to the ATMS is present, configuration shall link the system to the ATMS to establish the system location in order to process flooding alerts received and assign them properly to roads.

Need	System Requirement
Technicians and Installers	
9. Technicians and installers need power, communications, and support structures to be available at locations where field equipment is used to detect high water and located above any anticipated high-water mark. Note: power may be locally generated (e.g. solar, wind); local communications may not be able to provide a connection to the ATMS.	9.1. Field devices for high water detection shall be deployed at locations where that they are accessible to communications and power, which may be locally generated by solar or wind. 9.2. Field devices for high water detection shall be deployed such that communications and power will not be negatively impacted by any anticipated high water levels. 9.3. Field devices for high water detection shall be deployed such that technicians and installers can access the devices to perform maintenance. 9.4. Field devices for high water detection shall be mounted on appropriate support structures. 9.5. Field devices for high water detection shall be calibrated to activate flood warning systems when water levels reach a level that poses a potential risk to the roadway.
10. Technicians and installers need the field devices to adhere to appropriate safety standards, specifications, and protocols.	10.1. Field devices for high water detection shall adhere to appropriate safety standards, specifications, and protocols. 10.2. Equipment deployed in the field shall not harm technicians, installers, or anyone in vicinity of the equipment. 10.3. A professional engineer registered in the State of Minnesota shall review and approve all design details of the complete flood warning system field deployment. The detection mechanism, communications, and traveler displays/CAV dissemination components should all be considered in the design.

Need	System Requirement
11. Technicians and installers need consistency and compatibility in the local flood warning equipment to achieve efficiencies in procurement, maintenance, and training.	11.1. Legacy field devices for high water detection shall continue to be used. 11.2. Procurement of new field devices for high water detection shall be consistent with in-place devices to the extent possible, so that installers and technicians will be well-trained to install and repair new devices and can interchange parts. 11.3. New field devices for high water detection shall be compatible with existing equipment and systems such as communications (fiber, etc.) and data management systems (e.g. IRIS) given an available or possible future communications connection to the ATMS. 11.4. Consistency and compatibility needs shall not prevent or inhibit the testing and eventual production use of new products or services. 11.5. Selection of new equipment or software tools shall be done in a way that ensures interoperability and consistency with latest standards and technologies.
External Partners	
12. External partners need a mechanism to receive notices about when potential flooding is detected (or be alerted when detection occurs) in order to make informed decisions about flood forecasts, deploying additional traffic control devices, or executing or assisting with lane closures.	12.1. When a communications connection from the flood warning system to the ATMS is present, external partners shall have a mechanism to understand when local flood warning systems have detected high water or flood conditions. 12.2. External partners shall consider available information and may use this information to help inform flood forecasts, decisions about monitoring conditions, deploying traffic control devices, and issuing road closures.
CAV Infrastructure Systems and CAVs	
13. CAVs need real-time, low latency data from other CAVs to exchange data that could describe locations where water is impacting the roadway.	13.1. Agency-owned CAVs may receive and process BSM messages from other vehicles and use this information to support such applications as spot weather information warning.
14. DOTs need to benefit from the data broadcast by public and private CAVs to assist in detection of	14.1. MnDOT may locate roadside units to receive and process BSM messages at key locations to gather information about vehicle performance to help identify flood conditions, such as wheel slippage and friction sensor data.

Need	System Requirement
flood conditions whenever possible.	14.2. MnDOT shall develop data retention policies for CAV related data and regularly review these as the CAV industry matures and the amount of data generated is better understood.
15. CAVs may need infrastructure-generated flood warnings.	15.1. MnDOT may locate roadside units to broadcast information, such as flood-related advisory or alert messages, road closure information, and/or alternate routes, that will be received by CAVs. 15.2. Roadside units may receive flood warning alerts from the MnDOT data management systems, for use by CAVs. 15.3. CAVs may ingest this flood-related data or derived values from the RSUs, to support automated driving system features.

Relationship to the National ARC-IT and Minnesota ITS Architecture

The Minnesota Statewide Regional ITS Architecture presents a vision for how ITS systems work together, share resources, and share information. The 2018 update to the ITS Architecture represents the latest status of Minnesota, as captured through outreach meetings and input from stakeholders statewide. As such, the Minnesota ITS Architecture was a valuable input to the development of this documents, supporting:

- Identification of stakeholders;
- Definition of needs for flood warning;
- Concepts for the use of flood warning; and
- Overall input to the requirements.

The Minnesota ITS Architecture enabled the Project Team to build upon the content of the architecture and clarify specifics for this document.

In addition to the role of supporting the development of this document, the Minnesota Statewide Regional ITS Architecture and the National Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) will continue to serve as a resource for the agencies that utilize this document as they prepare for deployment. Table 13 below identifies the needs/potential solutions included in the Minnesota ITS Architecture that are addressed through concepts for the use of flood warning systems described in this document, as well as references to service packages and processes as defined in the ARC-IT. Finally, the far right column identifies the flood warning system stakeholder need(s) that were influenced or derived based on each service package.

Table 13: Summary of Local and National ITS and CAV Architecture References Mapped to Flood Warning Needs

MN Statewide Regional ITS Architecture: Need/Potential Solutions	ARC-IT: Service Packages	ARC-IT: Processes	Flood Warning Stakeholder Needs Influenced by each Service Package
• ATMS34 Provide roadway flood warnings	• TM12 Dynamic Roadway Warning	• Control Roadway Warning System	• Need 1: Real-time, En-route, Local Flooding Notification • Need 2: Advance Flooding Information • Need 3: Automated Activation of Local Flood Warning Displays • Need 5: Activation Using External Flood Data Sources • Need 15: Vehicle Use of Infrastructure-Generated Flood Warnings
• ATMS34 Provide roadway flood warnings	• TM12 Dynamic Roadway Warning	• Manage Roadway Warning System	• Need 4: Operator Interaction with Flood Warning Displays • Need 5: Activation Using External Flood Data Sources • Need 8: Local Flood Warning System Configuration • Need 12: External Partner Access to Flood Notices
• ATMS34 Provide roadway flood warnings	• TM12 Dynamic Roadway Warning	• Provide Traffic Operations Personnel Traffic Data Interface	• Need 4: Operator Interaction with Flood Warning Displays • Need 6: Usable Access to Current and Historical Flood Data and Reports • Need 12: External Partner Access to Flood Notices

MN Statewide Regional ITS Architecture: Need/Potential Solutions	ARC-IT: Service Packages	ARC-IT: Processes	Flood Warning Stakeholder Needs Influenced by each Service Package
• ATMS34 Provide roadway flood warnings	• TM12 Dynamic Roadway Warning	• Monitor Roadside Equipment Operation	• Need 4: Operator Interaction with Flood Warning Displays
• ATMS34 Provide roadway flood warnings	• TM12 Dynamic Roadway Warning	• Provide Device Interface to Other Roadway Devices	• Need 2: Advance Flooding Information
• ATMS34 Provide roadway flood warnings	• TM12 Dynamic Roadway Warning	• Collect Traffic Field Equipment Fault Data	• Need 6: Usable Access to Current and Historical Flood Data and Reports
• ATMS34 Provide roadway flood warnings	• MC09 Infrastructure Monitoring	• Collect Vehicle Roadside Safety Data • Process Collected Vehicle Safety Data	• Need 14: Vehicle to Infrastructure Data Exchange
• ATMS34 Provide roadway flood warnings	• MC09 Infrastructure Monitoring	• Collect Infrastructure Sensor Data	• Need 3: Automated Activation of Local Flood Warning Displays • Need 5: Activation Using External Flood Data Sources • Need 14: Vehicle to Infrastructure Data Exchange
• ATMS34 Provide roadway flood warnings	• WX03 Spot Weather Impact Warning	• Collect Vehicle Environmental Data	• Need 13: Vehicle to Vehicle Data Exchange • Need 14: Vehicle to Infrastructure Data Exchange
• ATMS34 Provide roadway flood warnings	• WX03 Spot Weather Impact Warning	• Process In-vehicle Signage Data	• Need 15: Vehicle Use of Infrastructure-Generated Flood Warnings
• ATMS34 Provide roadway flood warnings	• WX03 Spot Weather Impact Warning	• Provide Short Range Traveler Information	• Need 15: Vehicle Use of Infrastructure-Generated Flood Warnings

MN Statewide Regional ITS Architecture: Need/Potential Solutions	ARC-IT: Service Packages	ARC-IT: Processes	Flood Warning Stakeholder Needs Influenced by each Service Package
• ATMS34 Provide roadway flood warnings	• WX03 Spot Weather Impact Warning	• Collect Connected Vehicle Field Equipment Status • Process Environmental Sensor Data	• Need 14: Vehicle to Infrastructure Data Exchange
• ATMS34 Provide roadway flood warnings	• WX03 Spot Weather Impact Warning	• Process Environmental Sensor Data	• Need 1: Real-time, En-route, Local Flooding Notification

Model Test Plan

This section presents a model test plan to support testing and validation activities during the integration and deployment stages of flood warning to confirm that the system is developed, installed, and operating as specified by the system requirements.

Each flood warning deployment will be different, and the testing and validation performed will likely vary depending upon the complexity of the system and the familiarity with the vendor products.

The table below provides a series of testing instructions related to the requirements presented above. The intent is that agencies using this model systems engineering document will incorporate these tests into their overall testing and validation plans, adapting them as needed.

Column 3 in the table below describes 'testing instructions' for each requirement. The flood warning requirements include a range of requirement types and therefore the testing instructions vary. The following bullet list explains the approach to different testing instructions:

- *Advisory requirement – no testing required:* This is noted for requirements that are primarily operational advice (e.g. the locating and use of flood warning) and therefore no formal testing is required;
- *Design:* These test instructions are used to describe testing in the form of design reviews or documentation reviews describing the flood warning. These are typically not physical tests, but rather reviews of processes or documents;
- *Factory Acceptance Test (FAT):* These represent recommendations for FATs to allow the agency deploying the flood warning to verify the quality assurance/quality control and flood warning operational parameters at the site of manufacturing and assembly. This can involve the procuring agency on-site at the vendor factory testing the actual equipment to be delivered or the reports of previous tests of components, software, or features;
- *Field:* These represent recommendations for tests to be conducted in MnDOT offices or the field to test the actual deployment and functionality of the flood warning.

Table 13: Model Test Plan for Flood Warning

System Requirement		Testing Instructions	Type of Result	Comments / Notes
1.1	In locations that experience recurring high water or flooding conditions, flood warning systems shall be considered to advise travelers of periods when high water or flooding impacts the roadway.	Advisory requirement – no testing required	N/A	
1.2	Flood warning systems shall activate visual alerts to drivers when flooding conditions are detected downstream.	Field – Conduct test to confirm all supporting infrastructure is installed and operational (e.g. detection, power, communications) so the system activates visual alerts when high water is detected.	Pass/Fail	
1.3	Agencies shall consider locating flood warning systems' visual display to the drivers in advance of a decision point that would allow diversion to an alternate route for travelers to avoid the flooded area.	Advisory requirement – no testing required	N/A	
1.4	Agencies shall consider flood warning systems' visual display visibility to travelers when finalizing location and installation.	Field – Conduct tests to confirm signs and associated flashing beacons are visible and legible to drivers at posted speeds.	Pass/Fail	
2.1	Agencies shall consider deploying mechanisms to enable flood warning systems to communicate flood alerts to the ATMS to enable widespread dissemination using established traveler information system applications.	Advisory requirement – no testing required	N/A	
3.1	The detection of high water shall automatically activate the local displays to alert travelers of flood risk.	Design – Confirm that the flood warning system display is designed to automatically activate when high water is detected.	Design - Content Review	

System Requirement		Testing Instructions	Type of Result	Comments / Notes
		Field – Conduct test to confirm system will activate when high water is detected.	Field - Pass/Fail	
3.2	The flood warning activations shall turn off automatically as water levels lower.	Design – Confirm that the flood warning system display is designed to automatically turn off when water levels recede. Field – Conduct test to confirm system will turn off when water levels recede.	Design - Content Review Field - Pass/Fail	
4.1	When connections are available, local high water/flood detections shall communicate the flood condition status to centralized reporting systems, allowing operators to be aware of the conditions. Note that the provision of a communications connection is a local design decision.	Design – Confirm that the design allows field devices to communicate flood condition status to central reporting systems, per local design choice. Field – Confirm that central reporting systems receive flood condition status information, if applicable.	Design - Content Review Field - Pass/Fail	
4.2	When a communications connection to the flood warning system is present, operators with access to the ATMS (e.g. IRIS) or condition reporting system (e.g. CARS) shall have a mechanism to examine the local flood warning systems configured in the system to view if flood conditions have been detected.	Field – Confirm that the ATMS or condition reporting system is receiving data communications from flood warning systems describing the activation. Field – Confirm that the ATMS or condition reporting system is receiving data communications from flood warning systems describing the removal/termination of the activation. Field – Confirm that the ATMS or condition reporting system is configured to display when flood conditions have been detected, if applicable.	Pass/Fail	
4.3	When a communications connection from the flood warning system to the ATMS is present, operators shall be	Design – Confirm that design allows the flood warning system display to be manually	Design - Content Review	

	System Requirement	Testing Instructions	Type of Result	Comments / Notes
	able to manually activate and de-activate the flood warning system remotely.	activated remotely using the ATMS, per local design choice. Field – Confirm that the flood warning system display can be manually activated remotely using the ATMS, if applicable. Field – Confirm that the flood warning system display can be manually de-activated remotely using the ATMS, if applicable.	Field - Pass/Fail	
4.4	Operators, i.e. MnDOT road maintenance staff, shall be able to manually activate and de-activate the flood warning system locally at the device in the field.	Design – Confirm that design allows the flood warning system display to be manually activated locally at the device. Field – Confirm that the flood warning system display can be manually activated and de-activated locally at the device.	Design - Content Review Field - Pass/Fail	
5.1	Agencies shall consider the use of external real-time sources for flood data to be used in place of local field devices for high water detection.	Advisory requirement – no testing required	N/A	
5.2	In situations where external flood detections sources are used, condition reporting systems or ATMS shall ingest the external data and automatically create events that describe the flooding risks and associate them to one or more segments of roads, including those without a flood warning system.	Field – Confirm that external flood data is being ingested into the condition reporting system or ATMS and used to create flood-related events for roadways at risk of flooding, if applicable. Field – Confirm that external flood data is being ingested into the condition reporting system or ATMS and used to remove flood-related events created by previous flood data ingests.	Pass/Fail	
5.3	When external flood data is used in place of local field devices for high water detection, external flood data may be used to automatically activate	Design – Confirm that the flood warning system display is designed to automatically activate when high water is detected using external flood data, if applicable.	Design - Content Review	

	System Requirement	Testing Instructions	Type of Result	Comments / Notes
	flood warning system signage when high waters pose a flood risk to the roadway.	Field – Conduct test to confirm system will activate when high water is detected using external flood data, if applicable.	Field - Pass/Fail	
5.4	When external flood data is used in places of local field devices for high water detection, operators shall have access to the external flood data to help assess and predict flood impacts to certain areas and specific road segments.	Field – Confirm that external flood data being used for high water detection is available to operators through the ATMS interface.	Pass/Fail	
5.5	When external flood data is used in places of local field devices for high water detection, operators may have a mechanism to verify conditions prior to the activation of flood warning system signage.	Design – Confirm that the flood warning system display is designed to activate only after operators verify the high water that was detected using external flood data, if applicable. Field – Conduct test to confirm system will only activate after operators verify the high water conditions that were detected using external flood data, if applicable.	Design - Content Review Field - Pass/Fail	
6.1	When a connection to the ATMS was deployed, operators shall have a mechanism for viewing past notifications of flood warnings detected by field devices or external systems to help debrief from incidents/events or to understand the frequency and timing of flooding.	Field – Confirm that flood warning system data is being archived in the ATMS and can be queried by location and notification, if applicable.	Pass/Fail	
7.1	Administrators shall be able query and understand the operational status of flood warning field equipment using flood system assessment tools.	Design – Confirm that the design includes system assessment tools for understanding operational status of the field equipment.	Design - Content Review	

System Requirement		Testing Instructions	Type of Result	Comments / Notes
		Field – Confirm that operators can use the ATMS user interface to check operational status of the field equipment.	Field - Pass/Fail	
7.2	At a minimum, administrators shall be able to use these tools at the device location in the field to identify issues in order to implement repairs, as needed.	Design – Confirm that the design allows for system assessment tools to be used at the field device to identify issues. Field – Confirm that the system assessment tools can be used at the field device and can properly identify issues.	Design - Content Review Field - Pass/Fail	
7.3	When the flood warning system equipment has a communications connection to the ATMS, the flood system assessment tools shall remotely provide configurable, automatic notifications to administrators about identified issues with devices as early as possible, to implement repairs or replacements in order to minimize disruption in flood warning capabilities.	Design – Confirm that the design allows the flood warning system to be configured in the field or remotely, per local design choice. Field – Confirm that the flood warning system can be configured either in the field or remotely, if applicable.	Design- Content Review Field - Pass/Fail	
8.1	When a communications connection to the ATMS is present, the ATMS shall enable administrators to configure the local flood warning systems once they are installed.	Design – Confirm that the design allows the flood warning system to be configured in the field or remotely, per local design choice. Field – Confirm that operators can use the ATMS user interface to configure flood warning systems.	Pass/Fail	
8.2	When a communications connection to the ATMS is present, configuration shall link the system to the ATMS to establish the system location in order to process flooding alerts received and assign them properly to roads.	Field – Confirm that the ATMS has established the flood warning system location in order to receive flood condition status information and make appropriate assignments of resulting road impacts, if applicable.	Pass/Fail	

	System Requirement	Testing Instructions	Type of Result	Comments / Notes
9.1	Field devices for high water detection shall be deployed at locations where that they are accessible to communications and power, which may be locally generated by solar or wind.	Design – Confirm that design considers access to power and communications. Field – Confirm communications and power connections to the field device.	Design -Content Review Field - Pass/Fail	
9.2	Field devices for high water detection shall be deployed such that communications and power will not be negatively impacted by any anticipated high water levels.	Design – Confirm that design of power and communications anticipates and will not be impacted by high water levels. Field – Confirm installation of communications and power has been done in a way to protect the system from high water levels.	Design - Content Review Field - Pass/Fail	
9.3	Field devices for high water detection shall be deployed such that technicians and installers can access the devices to perform maintenance.	Design – Confirm that design places field devices in an accessible location for technicians and installers to perform maintenance. Field – Confirm that the field devices can be accessed by technicians and installers for maintenance activities.	Design - Content Review Field - Pass/Fail	
9.4	Field devices for high water detection shall be mounted on appropriate support structures.	Design – Confirm that local design has been completed and identified the proper mounting structure.	Content Review	
9.5	Field devices for high water detection shall be calibrated to activate flood warning systems when water levels reach a level that poses a potential risk to the roadway.	Field – Verify that device is calibrated to activate the flood warning system for water levels that pose a risk to the roadway.	Pass/Fail	
10.1	Field devices for high water detection shall adhere to appropriate safety standards, specifications, and protocols.	Design – Confirm that safety standards, specifications, and protocols are met.	Design - Content Review	

System Requirement		Testing Instructions	Type of Result	Comments / Notes
		FAT – Confirm that safety standards, specifications, and protocols for the field device are met.	FAT - Pass/Fail	
10.2	Equipment deployed in the field shall not harm technicians, installers, or anyone in vicinity of the equipment.	Design – Confirm that safety standards, specifications, and protocols are met. FAT – Confirm that safety standards, specifications, and protocols for the field device are met.	Design - Content FAT - Review Pass/Fail	
10.3	A professional engineer registered in the State of Minnesota shall review and approve all design details of the complete flood warning system field deployment. The detection mechanism, communications, and traveler displays/ CAV dissemination components should all be considered in the design.	Design – Confirm professional engineer review.	Content Review	
11.1	Legacy field devices for high water detection shall continue to be used.	Advisory requirement – no testing required	N/A	
11.2	Procurement of new field devices for high water detection shall be consistent with in-place devices to the extent possible, so that installers and technicians will be well-trained to install and repair new devices and can interchange parts.	Advisory requirement – no testing required	N/A	
11.3	New field devices for high water detection shall be compatible with existing equipment and systems such as communications (fiber, etc.) and data management systems (e.g. IRIS) given an available or possible future	Design – Confirm that design is compatible with existing equipment and systems for communications and data management, per local design choice.	Design - Content Review	

	System Requirement	Testing Instructions	Type of Result	Comments / Notes
	communications connection to the ATMS.	Field – Confirm that the field devices can communicate and interface with communications and data management systems, if applicable.	Field - Pass/Fail	
11.4	Consistency and compatibility needs shall not prevent or inhibit the testing and eventual production use of new products or services.	Advisory requirement – no testing required	N/A	
11.5	Selection of new equipment or software tools shall be done in a way that ensures interoperability and consistency with latest standards and technologies.	Design – Confirm that design is compatible and interoperable with current standards. FAT – Confirm that equipment conforms with current standards.	Design - Content Review FAT - Pass/Fail	
12.1	When a communications connection from the flood warning system to the ATMS is present, external partners shall have a mechanism to understand when local flood warning systems have detected high water or flood conditions.	Design – Confirm communications connection to ATMS, per local design choice. Field – Confirm the flood warning system provides notification to external partners upon detection of high water or flood conditions, if applicable.	Design - Content Review Field - Pass/Fail	
12.2	External partners shall consider available information and may use this information to help inform flood forecasts, decisions about monitoring conditions, deploying traffic control devices, and issuing road closures.	Advisory requirement – no testing required	N/A	
13.1	Agency-owned CAVs may receive and process BSM messages from other vehicles and use this information to support such applications as spot weather information warning.	Advisory requirement – no testing required	N/A	

System Requirement		Testing Instructions	Type of Result	Comments / Notes
14.1	MnDOT may locate RSUs to receive and process BSM messages at key locations to gather information about vehicle performance to help identify flood conditions, such as wheel slippage and friction sensor data.	Design – Confirm BSM receipt and processing capabilities. Field – Demonstration of RSU capability to receive BSM, process data, and trigger flood warning devices.	Design - Content Review Field - Pass/Fail	
14.2	MnDOT shall develop data retention policies for CAV related data and regularly review these as the CAV industry matures and the amount of data generated is better understood.	Advisory requirement – no testing required	N/A	
15.1	MnDOT may locate RSUs to broadcast information, such as flood-related advisory or alert messages, road closure information, and/or alternate routes, that will be received by CAVs.	Design – Confirm roadside unit communications and processing capabilities. FAT – Demonstration of roadside unit ability to: • Generate a CAV message in a standard format that conveys the flood-related message. • Broadcast the generated CAV messages over industry standard communications, with appropriate message certifications. Field – Confirm with one or more on-board devices that the roadside unit is able to: • Generate a CAV message in a standard format that conveys the flood-related message. • Broadcast the generated CAV message to via one or more standard communications mechanisms.	Design - Content Review FAT - Pass/Fail Field - Pass/Fail	

System Requirement		Testing Instructions	Type of Result	Comments / Notes
15.2	Roadside units may receive flood warning alerts from the MnDOT data management systems, for use by CAVs.	Design – Confirm roadside unit communications and processing capabilities. FAT – Demonstration of roadside unit: • Receiving CAV messages in standard formats. • Processing CAV messages to generate roadside safety messages to broadcast to vehicles. • Broadcast of roadside safety message with flood warning data included. Field – Confirm with one or more on-board devices that the roadside unit is able to: • Receive CAV messages in standard formats. • Process CAV messages to generate roadside safety messages to broadcast to vehicles. • Broadcast of roadside safety message with flood warning data included.	Design - Content Review FAT - Pass/Fail Field - Pass/Fail	
15.3	CAVs may ingest this flood-related data or derived values from the RSUs, to support automated driving system features.	Advisory requirement – no testing required	N/A	