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16. Abstract

In Texas, approximately eight flood-related fatalities occur each year—the majority of these (78.6 percent) involve motorists that are trapped in their vehicles or washed away. In many cases, victims, not wanting to take a lengthy detour, ignored barricades and tried to drive across a flooded street or low-water crossing—literally driving themselves into harm's way. It takes as little as 2 ft of water to float most cars. Several districts in Texas have developed different signing strategies for warning motorists of low-water crossings. As part of this research, the Texas Transportation Institute (TTI) developed guidelines and recommendations for creating signing uniformity for low-water and flood-prone sections of roadways. Signing guidelines were created for the following situations: 1) roadway sections that have several low-water crossings where water flows over the roadway in wet conditions, 2) actual low-water crossings, and 3) temporary road closures due to high water. TTI also developed criteria for when to implement active water-level detection and advance warning systems at low-water crossings and flood-prone roadway sections.

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SIGNING STRATEGIES FOR LOW-WATER AND FLOOD-PRONE HIGHWAY CROSSINGS

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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. The engineer in charge was Kevin N. Balke, P.E. (Texas, #66529).

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CHAPTER 1. INTRODUCTION

According to the Federal Emergency Management Agency (FEMA) (*1*), floods are the top natural disasters in the United States in terms of loss of life and extent of damage. Flooding and flash floods occur in all 50 states. Flooding can cause loss of life and severe damage to properties. As shown in Table 1, approximately half of the flood-related fatalities that occurred in the nation in 2000 through 2006 involved vehicles. In Texas, approximately eight flood-related fatalities occurred each year in that timeframe—the majority of those (78.6 percent) were classified as vehicle-related. In many cases, victims, not wanting to take a lengthy detour, ignored barricades and tried to drive across a flooded street or low-water crossing—literally driving themselves into harm's way.

Table 1. Flood-Related Fatalities in the United States and in Texas.

	National			Texas		
Year	**Total Number of Fatalities**	**Number of Vehicle-Related Fatalities**	**Percentage of Vehicle-Related Fatalities**	**Total Number of Fatalities**	**Number of Vehicle-Related Fatalities**	**Percentage of Vehicle-Related Fatalities**
2006	76	32	42%	8	4	50%
2005*	43	18	42%	3	2	67%
2004	82	45	54%	14	13	93%
2003	86	39	45%	2	2	100%
2002	49	28	57%	14	9	64%
2001	48	24	50%	9	8	89%
2000	38	24	63%	9	8	89%
Average	**60.3**	**30.0**	**49.7%**	**8.4**	**6.6**	**78.6%**

*Excludes flood-related deaths associated with Hurricane Katrina.
Source: National Weather Service (*2*).

The amount of water required to wash away a vehicle depends on a number of variables, including the speed of the current, the design of the vehicle, whether the vehicle is sideways or end-to-end of current, and the type of surface over which the water is flowing (*3*). As a rule of thumb, each foot of water pushes against the broad side of a typical car with approximately 500 ft-lb of force and can displace about 1,500 lb. Therefore, it only takes about 2 ft of water to float most cars and, in some cases, less. For example, where the current is swift, the bottom hard and smooth, and the car's body low to the ground, as little as 1 ft of water with a speed of 6 mph will move most cars.

Part of the reason why some drivers enter flooded roadway sections is that they have trouble judging the speed and depth of the water. This is especially true if the water is muddy or if visibility is low (such as during a heavy rain or at night).

Static Warning Signs

The *Texas Manual on Uniform Traffic Control Devices* (TxMUTCD) provides a series of signs that can be used at low-water crossings and flood-prone areas (see Figure 1) (*4*). The first sign, WATER CROSSING (W8-13T), is intended to be used at crossings where water is continuously present. A typical application for this sign would be at a low-water crossing; it is not intended to be used on roadway sections that experience periodic flooding. The WATER OVER ROAD sign (W8-14) is intended to be used at locations that occasionally experience flooding. The TxMUTCD indicates that this sign should normally be posted only when water is actually over the roadway and implies that the sign is temporary in nature and would only be used during flooding events. This would require that the sign be manually placed at the point of the flooding, although in some cases, fold-out signs have been used at known flood-prone locations. The WATCH FOR WATER ON ROAD sign (WB8-15) is a permanent sign that can be placed at locations that occasionally flood. This sign could also be potentially used as an advance sign at the beginning of a roadway segment that is prone to flooding. The problem is that because the wording is so similar between all of these signs, drivers may not truly understand the different circumstances and situations for which these signs are intended.

 W8-13T	The WATER CROSSING (W 8-13T) sign should be used to warn of a dip or ford where the roadway is normally underwater. It should not be used where water only occasionally and temporarily crosses the roadway due to heavy local rains or flash floods.
 W8-14	The WATER OVER ROAD (W8-14) sign should be displayed to warn of a temporary condition when a low area may flood or fill with water. The sign is normally posted only when water is actually over the roadway.
 W8-15	The WATCH FOR WATER ON ROAD (W8-15) sign should be displayed at all times to warn of locations where wet-weather conditions normally result in a temporary condition of ponding or flowing water on the roadway.

Figure 1. Warning Signs Related to Roadway Flooding Contained in TxMUTCD (*4*).

Recently, the Federal Highway Administration completed a synthesis of non-standard signs that have been used in practice and made recommendations for standardizing the most likely candidate sign messages and symbols for potential future additions to the national MUTCD (*5*). One of the situations that the FHWA investigated was for roadway flooding. The synthesis found that 30 states and the U.S. Forest Service used a wide variety of sign legends to warn travelers of possible flooding or actual flooding conditions. Messages used to warn of possible flooding include the following:

- FLASH FLOOD AREA.
- FLOOD AREA.
- ROAD MAY BE FLOODED.
- SUBJECT TO FLOODING.
- ROAD SUBJECT TO FLOODING.
- ROAD FLOODS.
- WATCH FOR WATER ON ROAD.
- WATCH FOR WATER.
- ROAD FLOODS DURING HIGH TIDE.
- HIGH TIDE MAY COVER ROADWAY.
- IMPASSABLE DURING HIGH WATER.

The synthesis also found the following signs were used to warn of actual flooding conditions:

- ROAD (OR STREET) FLOODED.
- WATER OVER ROAD.
- WATER OVER ROADWAY.
- WATER ON ROAD.
- WATER ON PAVEMENT.
- HIGH WATER.
- FLOOD WATER.
- RUNNING WATER.

The synthesis also found that at least five states (including Texas) and the U.S. Forest Service use a sign that functions as a water depth gauge. These signs are frequently posted at points where intermittent roadway flooding frequently occurs and can be a valuable guide to road users when trying to determine whether to proceed across a water crossing.

As a result of the findings from this synthesis, the Federal Highway Administration added a new section to the national MUTCD specifically related to weather conditions (*6*). This new section (numbered and titled Section 2C.35 Weather Condition Signs) contains options and standard statements regarding the use of three proposed new signs to warn travelers of potential adverse weather conditions:

- WATCH FOR FOG.

- GUSTY WINDS AREA.
- ROAD MAY FLOOD.

Figure 2 shows the wording for the signs related to roadway flooding in the new section on weather condition signs (*7*), while Figure 3 shows these proposed signs to be used in conjunction with areas subject to roadway flooding (*8*). The proposed wording stops short, however, of providing solid guidance on what constitutes "frequent flooding" and how far in advance of a flood zone the signs should be installed. These signs are still in the review and approval process.

Section 2C.35 Weather Condition Signs (W8-18, W8-19, W8-21, and W8-22)

Option:

The ROAD MAY FLOOD (W8-18) sign may be used to warn road users that a section of roadway is subject to frequent flooding. A Depth Gauge (W8-19) sign may also be installed within a roadway section that frequently floods.

Standard:

If used, the Depth Gauge sign shall be in addition to the ROAD MAY FLOOD sign, and shall indicated the depth of the water at the deepest point on the roadway.

Option:

The GUSTY WINDS AREA (W8-21) sign (see Figure 2C-6) may be used to warn road users that wind gusts frequently occur along a section of highway that are strong enough to impact the stability of trucks, recreational vehicles, and other vehicles with high centers of gravity. A NEXT XX MILES (W7-3a) supplemental plaque may be mounted below the W8-21 sign to inform road users of the length of roadway that frequently experiences strong wind gusts.

The FOG AREA (W8-22) sign (see Figure 2C-6) may be used to warn road users that foggy conditions frequently reduce visibility along a section of highway. A NEXT XX MILES (W7-3a) supplemental plaque may be mounted below the W8-22 sign to inform

Figure 2. Language in National MUTCD Text Related to Weather Condition Signing.

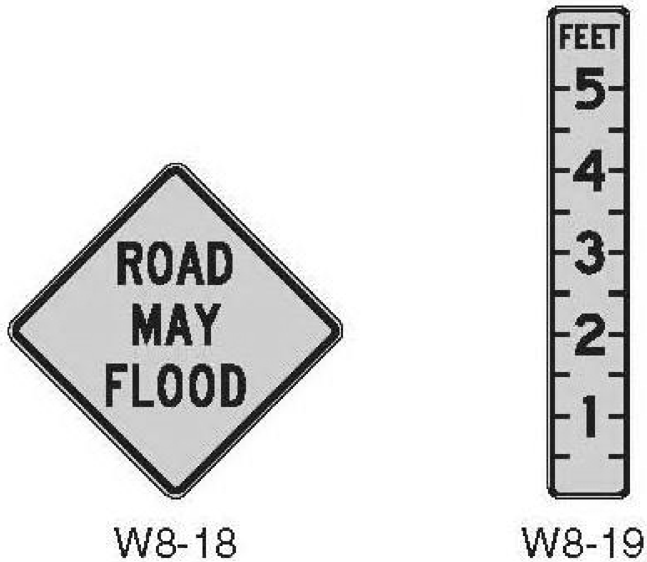


Figure 3. Road Flooding Conditions Warning Signs in National MUTCD.

Automated Flooding Warning Systems

The National Weather Service (NWS) is the federal agency authorized to issue public watch/warning alerts for possible or impending flooding. In the mid-1970s, the NWS developed the ALERT system, which stands for Automated Local Evaluation in Real-Time. ALERT combines radio-based communications protocols, data formats, and sensing techniques for collecting and using rainfall and other environmental parameters to monitor weather conditions and issues weather advisories in real time (*9*).

A typical ALERT detection station consists of a 10-ft standpipe tower, an ALERT data transmitter, a tipping bucket rain gauge, an omni-directional antenna, and a series of other meteorological/ hydrological sensors. The sensors are placed in or beside rivers and reservoirs throughout a designated area. When an environmental event reaches a trigger threshold (for example, receiving 1 mm of rainfall or recording a change in stream depth of 1 mm), the monitoring station transmits the information back to a central processor. The data from the sensors are then fed into computerized flood forecasting models to identify when and where flooding may occur in a region.

As shown in Figure 4, the NWS and the United States Geological Survey (USGS) operate approximately 470 stream-flow monitoring stations in the state of Texas (*10*). These monitoring stations form the backbone of the NWS flood warning system. Using information from these stations as well as rainfall and watershed forecast models, the NWS predicts river and stream levels and issues flash-flood and river-flood warning and watch alerts. This system is intended to provide flood warning alerts on a county-wide basis.

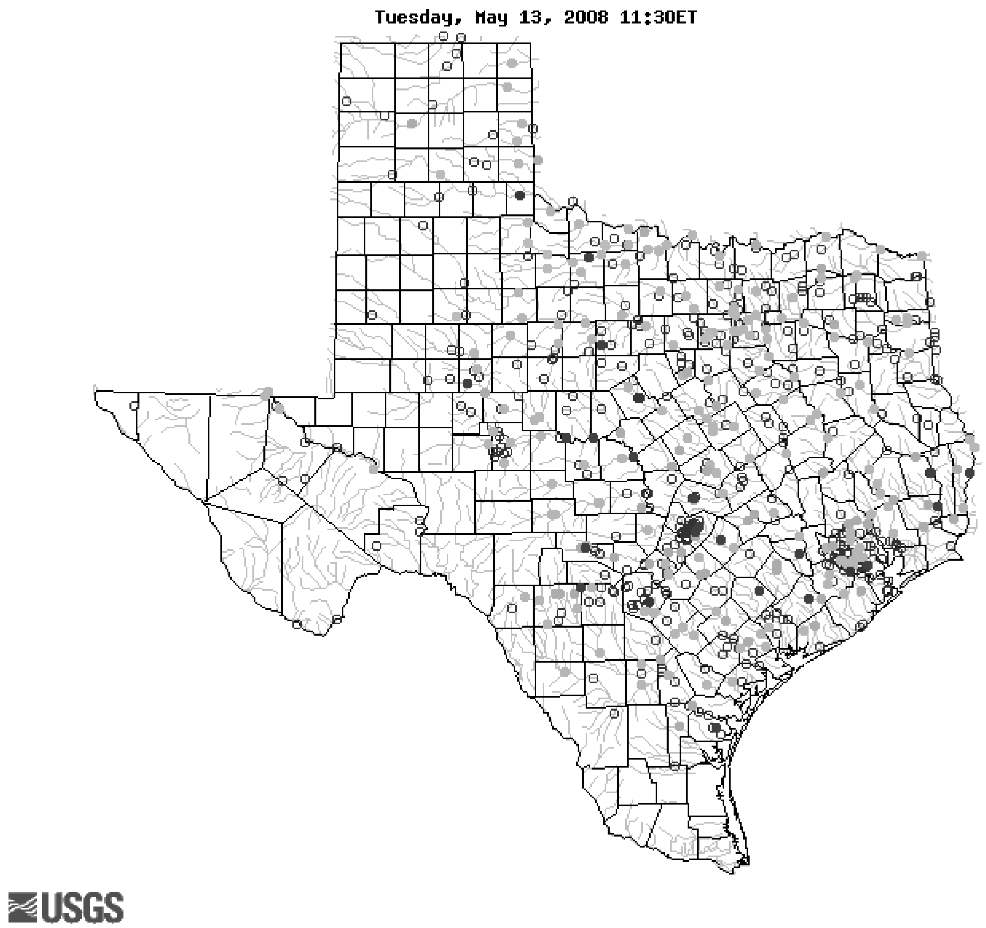


Figure 4. USGS River Monitoring Station in Texas.

Many communities have augmented this system with a series of stream gauges and remote weather monitoring stations that they use to predict flooding locally. These stations allow the local disaster and emergency service office to provide more refined prediction and monitoring of flood-prone areas. In many cases, these stations are located at low-water crossings or flood-prone points on the transportation system and can be used to assist local responders in identifying localized flooding problems.

More recently, many public entities have been integrating advance warning systems with their flood warning and stream-flow management systems. These systems provide motorists with real-time information about flooding conditions at the roadside. At the time a flooding warning notification is issued through the ALERT system, the system can simultaneously activate flashing beacons and remote-controlled gate arms when predetermined flood conditions occur. Figure 5 shows some typical applications of advance warning systems installed at flood-prone areas.

Figure 5. Example of an Advance Flood Warning System Produced by High Sierra Electronics (*11*).

However, little guidance exists about when a particular crossing would require this level of treatment. In evaluating the need for localized flood warnings, the USGS suggests agencies consider several factors: 1) the hydrologic characteristics of the watershed, 2) the frequency of flooding, 3) the potential loss of life and property when flooding does occur, and 4) the amount of warning time that can be provided. Each watershed has a unique set of hydrologic characteristics (topology, stream slope, soil type, amount of channel debris, etc.) that dictates its response to rainfall. These characteristics can be used to determine the extent and magnitude of the flooding threat at a crossing. History can also be a good indicator of the need for more advanced types of warnings at water crossings—the rarer the flooding event, the more difficult it is to maintain local awareness that flooding may occur. Therefore, a more sophisticated advance warning system may be needed at a particular crossing. The potential loss of life and exposure should also be considered—crossings that experience higher traffic volumes are more likely to have a higher potential for loss of life and property than low-volume crossings. Finally, the amount of warning time is another critical factor in assessing the need for localized warning systems. Agencies are more likely to be able to get the equipment and personnel out to the site to manually erect a closure if they have longer warning times. Therefore, crossings that flood more quickly may be in higher need of more automated systems.

Research Objectives

The specific objectives of this research were as follows:

- Develop typical signing layouts for providing static warning signs and devices associated with low-water crossings and flood-prone roadways. These typical layouts will identify the signs and devices that should be installed for the following situations:
    - Roadway sections that have several low-water crossings where water routinely flows over the roadway during wet-weather events.
    - Actual low-water crossings.
    - Temporary closures of roadways during high-water events.
- Develop "warranting" guidelines for identifying and prioritizing when and where an active warning and detection system may be required at low-water crossing locations.

Organization of Report

The results of this research effort are contained in seven chapters in this report. Chapter 2 contains the results of the state of the practice survey conducted as part of this research. Chapter 3 contains the results of an assessment of various automated flood detection and active warning systems. As part of this research, the research team also conducted focus group interviews to gain insight into the factors considered by drivers when trying to decide whether to proceed through a flooded crossing. The results of the focus group interviews are presented in Chapter 4. Using the results of the focus group interviews, the research team identified several different static and active warning systems. These candidate treatments were tested in a serious of driver comprehension studies, the results of which are contained in Chapter 5. Chapter 6 provides a framework for conducting a risk assessment of flood-prone crossings, while Chapter 7 contains the conclusions and recommendations associated with the research. Chapter 7 also provides the recommended signing layouts that were developed as part of this research effort.

CHAPTER 2. FLOOD WARNING SIGNS AND AUTOMATED FLOOD-DETECTION/WARNING SYSTEMS: STATE OF THE PRACTICE

As part of the activities of Research Project 0-6262, the Texas Transportation Institute (TTI) research team conducted an assessment of the state of the practice related to the design, placement, and use of flood warning sign treatments and automated flood detection/warning systems. As part of this assessment, TTI conducted a survey of TxDOT districts and other jurisdictions. The purpose of this survey was twofold:

- To learn about the signs and related traffic controls that TxDOT and other states and cities use to warn motorists about low-water crossings and flooded roadways, as well as their experience with the effectiveness of those signs and traffic controls.
- To identify potential locations on TxDOT roadways subject to flooding conditions where various treatments have been deployed.

The information gained was used as a background for the focus groups of this research project.

Besides Texas, several other states have included signs addressing water hazards into state MUTCDs and other supplemental sign standards. Some local jurisdictions have adopted the "Turn Around, Don't Drown" signs developed by the NWS, and others have incorporated that wording into other warning sign designs.

Methodology

A fillable survey document designed to solicit specific information about the types of flood warning signs and automated systems used by agencies was developed. A copy of the survey can be found in Appendix A. After obtaining approval by Texas A&M University's Institutional Research Board, the survey was sent to each of the 25 TxDOT districts, and approximately 40 non-TxDOT jurisdictions, both within and outside of the state. Eight TxDOT districts and 13 non-TxDOT jurisdictions responded to the survey. Another six non-TxDOT jurisdictions partially completed the survey instrument via telephone interviews. The research team used web searches to obtain additional information, such as state MUTCD supplements/signing standards and flood warning system descriptions and specifications.

Survey Findings

TxDOT districts, other state departments of transportation (DOTs), and local jurisdictions were asked about signs (if any) used to warn motorists of on-road water hazards, other traffic controls or enforcement employed, and their experiences with the effectiveness of the warnings. Jurisdictions using automated flood warning systems were also asked questions about any signs, signals, or barriers connected with automated systems that were used as low-water and flood-prone crossings. Additional information was obtained via online searches.

Low-Water Crossing and Flood-Prone Locations

The research team asked survey respondents to identify the number and location of their low-water and flood-prone sites. For the purposes of the survey, a low-water crossing was defined as a location where water regularly or normally flows over the roadway and, unless the water is unusually high, can be traversed by a vehicle in spite of the presence of water on the roadway. A flood-prone location was defined as a site along a roadway where water does not normally flow over the roadway but that can become covered with water under certain conditions (e.g., a heavy rainstorm). Figure 6 and 7 are the examples that the research team used to distinguish between the two types of sites.

Figure 6. Example of Flood-Prone Site.

Figure 7. Example of Low-Water Crossing Site

All eight of the TxDOT districts responding to the survey indicated that both low-water and flood-prone sites exist within their district. Five districts indicated that they have roadways in their district where there are multiple flood-prone sites on the same roadway. Table 2 summarizes the approximate number and type of location by each of the survey respondents.

Table 2. Number of Low-Water Crossing and Flood-Prone Sites by Responding TxDOT District.

TxDOT District	Total Number of Locations	
	Low-Water Crossings	Flood-Prone Locations
Abilene	100	50
Lubbock	1	20
Paris	24	150
San Angelo	7	310
Waco	2	2
Wichita Falls	-	12
Yoakum	-	50

Signs Used at Low-Water Crossings

Six TxDOT districts and four of the other surveyed agencies described signs used at low-water crossings; state MUTCD supplements and signing manuals provided additional examples of messages used to alert drivers to sites where water usually or often covers a road. Signs used by one or more TxDOT districts at low-water crossings include the following:

- WATCH FOR WATER ON ROAD (MUTCD W8-15).
- WATER CROSSING (MUTCD W8-13T).
- WATER ON ROAD (MUTCD W8-14).
- Flood Gauge (D26).

Table 3 lists the messages and sign designs being used for low-water crossings on roadways in jurisdictions other than TxDOT.

Table 3. Signs Used for Low-Water Crossings.

Message	Sign Type	Location
WATCH FOR WATER ON ROAD	Warning—yellow diamond	Phoenix, Arizona area
WATCH FOR WATER OVER ROAD	Warning—orange diamond	Austin, Texas
DO NOT ENTER WHEN FLOODED	Regulatory—white rectangle	Nebraska
FORD	Warning—yellow diamond	Australia
LOW-WATER CROSSING AHEAD	Warning—yellow diamond	Nebraska
ROAD CLOSED WHEN LIGHTS ARE FLASHING	Warning—yellow diamond	Austin, Texas
ROAD MAY FLOOD DURING HEAVY RAIN	Warning—yellow diamond	Tennessee
ROAD FLOODED	Warning—yellow diamond	New York
WATER ON HIGHWAY MAY EXIST	Warning—yellow diamond	Colorado
WATER OVER ROADWAY	Warning—yellow diamond	Alaska

Signs Used at Flood-Prone Locations

Six of the responding TxDOT districts listed signs that are used at flood-prone sites:

- WATCH FOR WATER ON ROAD (MUTCD W8-15); one district adds plaque reading NEXT X MILES for roads with multiple flooding sites.
- ROAD CLOSED X MILES AHEAD—HIGH WATER (folding sign).
- WARNING—STREAM CROSSING SUBJECT TO FLOODING NEXT X MILES.
- Flood Gauge (D26).

Table 4 lists messages and sign types used by other surveyed agencies as well as those listed in state MUTCD supplements. Additional non-MUTCD sign messages for road locations that are occasionally covered with water include the following:

- FLOOD AREA.
- ROAD MAY BE FLOODED.
- ROAD FLOODS.
- WATCH FOR WATER ON ROAD.
- WATCH FOR WATER.
- ROAD FLOODS DURING HIGH TIDE.
- HIGH TIDE MAY COVER ROADWAY.
- IMPASSABLE DURING HIGH WATER.
- CAUTION: THIS ROAD SUBJECT TO FLASH FLOOD.

Table 4. Signs Used at Flood-Prone Locations.

Message	Sign Type	Jurisdiction/Agency
DO NOT CROSS WHEN FLOODED	Warning—yellow diamond	Phoenix, Arizona area
FLASH FLOOD AREA	Warning—yellow diamond	Phoenix, Arizona area
FLOODWAY	Warning—yellow diamond	Queensland, Australia
HIGH WATER	Warning—yellow diamond	Ohio
ROAD MAY FLOOD DURING HEAVY RAIN	Warning—yellow diamond	Tennessee
ROAD SUBJECT TO FLOODING	Warning—yellow diamond	North Carolina and Minnesota
ROAD SUBJECT TO FLOODING, INDICATORS SHOW DEPTH	White rectangle	Queensland, Australia
ROADWAY SUBJECT TO FLOODING	Warning—yellow diamond	Pennsylvania
SUBJECT TO FLOODING	Warning—yellow diamond	California
WATCH FOR WATER OVER ROAD	Warning—orange diamond	Austin, Texas

Signs Used during Flood Events

Five of the surveyed TxDOT districts listed signs that are displayed during flooding events. Signs used by one or more of the surveyed districts for flooding events include the following:

- WATER OVER ROAD (MUTCD W8-14, FOLDING).
- ROAD CLOSED X MILES AHEAD—WATER OVER ROAD.
- ROAD CLOSED (MUTCD R11-2).
- ROAD CLOSED TO THRU TRAFFIC (MUTCD R11-4).
- WATCH FOR WATER ON ROAD (MUTCD W8-15).
- Type III Barricades (MUTCD CW20-3D).
- ROAD CLOSED/HIGH WATER (roll-up sign on barricade).
- FLOODING AHEAD/USE ALTERNATE ROUTE (posted on dynamic message signs).
- HIGH WATER/ROAD CLOSED/X MILES AHEAD (posted on dynamic message signs).
- HIGH WATER/ROAD CLOSED/TO THRU TRAFFIC" (posted on dynamic message signs).

Table 5 lists the sign messages used by the other interviewed agencies and those listed in state MUTCD supplements to warn of current flooding events, as well as any additional devices used in conjunction with the signs. Additional non-MUTCD messages used for actual flooding conditions/events include the following:

- ROAD (OR STREET) FLOODED.
- WATER ON PAVEMENT.
- FLOOD WATER.
- RUNNING WATER.

Reasons for Choosing Signs

Nearly all the responding TxDOT districts cited the inclusion of particular signs in the federal or Texas MUTCD as the primary reason for selecting them. Two districts mentioned the effectiveness of their selected signs in practice. One district also included a sign's ready availability and low cost as a reason for selecting it; another commented on a particular sign's regular use by the district over the past 20 years.

Table 5. Signs and Traffic Control Devices (TCDs) Used during Flood Events.

Message	Sign Type	Additional TCDs	Jurisdiction/Agency
CAUTION—WATER ON ROAD	Dynamic Message Sign (DMS)		Colorado
DETOUR	Orange rectangle		Ohio
DO NOT CROSS WHEN FLASHING	Warning—yellow diamond	Flashing lights	Phoenix, Arizona area
FLOODED	Warning—yellow diamond	Type II barricades	California
		Type II and III barricades	California
		Type I lighted barricade	Palo Alto, California
FLOODED—USE CAUTION; FLOODED—FOLLOW DETOUR	DMS	Type II barricades	California
FLOODED—RT. LANE CLOSED	DMS	Type II barricades	California
HIGH WATER ON ROAD	Warning—yellow diamond	Type I barricade	Brownsville, Texas
HIGH WATER	Warning—yellow diamond		Tennessee
			Ohio
			Indiana
	Yellow or orange diamond		North Carolina
POSSIBLE FLOODING WHEN FLASHING	Yellow and white rectangle	Flashers activated on sign	Colorado
PROCEED WITH CAUTION WHEN FLASHING	Warning—yellow diamond	Flashing lights	Phoenix, Arizona area
ROAD CLOSED	Warning—yellow/orange diamond		Michigan
		Type III barricade	North Carolina
		Type II or III barricades	Utah
	Regulatory—white rectangle		New York
ROAD CLOSED AHEAD	Warning—orange diamond		Ohio
ROAD CLOSED AHEAD DUE TO FLOODING	DMS	Type II and III barricades	California

Table 5. Signs and Traffic Control Devices (TCDs) Used during Flood Events (Continued).

Message	Sign Type	Additional TCDs	Jurisdiction/Agency
[ROAD NAME] CLOSED AT [JUNCTION] DUE TO FLOODING	DMS	Type II or III barricades	Utah
ROAD CLOSED WHEN LIGHTS ARE FLASHING	Warning	Flashing lights Type III barricade	Austin, Texas
ROADWAY FLOODED XX MILES AHEAD—USE CAUTION	DMS	Flashers activated on Highway Advisory Radio signs	California
SHOULDER CLOSED DUE TO FLOODS		Barricade (type not specified)	California
STANDING WATER POSSIBLE—USE CAUTION	DMS		Utah
TURN AROUND—DON'T DROWN			Several cities in Texas and in other states
TURN TO XXXX AM	DMS	Flashers activated on Highway Advisory Radio signs	California
WATER ON HIGHWAY MAY EXIST	Warning—yellow diamond	Flashers activated on sign	Colorado
WATER ON ROAD	Warning—yellow diamond		Delaware
WATER OVER ROAD	Warning—yellow diamond		Tennessee
WATER OVER ROADWAY	Warning—yellow diamond		Alaska

Responses to this question were provided by 11 of the surveyed agencies. Many provided more than one reason. The most common reason given for selecting a particular sign was its inclusion in the federal MUTCD, a state MUTCD, or other state signing standard. Low cost, availability, and effectiveness were other reasons cited by several agencies as selection criteria. The signs used in conjunction with one state's automated flood warning system were designed for that purpose, as the state DOT found nothing in the MUTCD that suited the purpose. The representative from a local agency commented that the older, permanent sign designs used in the county were selected decades earlier, so the criteria for selecting them is unknown.

Table 6 summarizes the reasons stated by the survey respondents for selecting and using different signing treatments.

Table 6. Stated Reasons for Selecting Signing Treatment.

Sign Selection Reason	Mentioned By
Listed in federal MUTCD, state MUTCD, or other signing standard	Austin, Texas California Ohio Palo Alto, California North Carolina Utah
Inexpensive and/or readily available	Austin, Texas Brownsville, Texas Tennessee Utah
Found effective in practice	Brownsville, Texas Palo Alto, California Tennessee Utah
Other	Austin, Texas Phoenix, Arizona area Colorado

Criteria for Placing Signs and Barricades

The stated criteria for placing signs and barricades in response to flood events varied in precision—in some jurisdictions, signs or barricades are placed if the designated responder decides that a road may become hazardous, while in others a certain threshold level of water on or near the road is the deciding factor.

In the responding TxDOT districts, the maintenance supervisor, area engineer, or traffic engineer was cited as being the individual who makes the decision to place a temporary sign/barricade. Criteria for placing these signs/barricades varied somewhat from district to district. The most common stated criterion was flooding or imminent flooding of the roadway, and water at a depth or expected depth that is impassable or could endanger traffic (usually no exact depth was specified; this was a judgment call). Other stated criteria included the following:

- Water is 8 to 10 inches over road and rising.
- Road is prone to flooding or already flooded.
- Water is encroaching on pavement or encroachment is imminent.

Austin, Texas: The decision to activate flashers is tied to remote sensing units (float switch and pressure transducers) in the creek channel. The placement of temporary barricades is made based on recommendations made by the Flood Warning software and observed field conditions; the official criterion is water 6 or more inches deep over the roadway. Additionally, any first responder in the field or the Emergency Operations Center duty officer can make the decision to barricade a road.

Brownsville, Texas: The city traffic director makes the decision to place temporary signs and barricades and to display flip-down signs. The traffic director's decision is based on weather reports and knowledge of which roads in the city are most prone to flooding.

Palo Alto, California: Any qualified city staff member on site at the time of a flooding incident can make the decision to place a sign/barricade, if he/she believes that there is a possible risk of injury or property damage due to water over the roadway.

Phoenix, Arizona area: Any appropriate transportation professional can display signs to warn of a flood event. Sites chosen for automated warning beacons are selected based on criteria including the anticipated road crew response time to the site, frequency and severity of roadway flooding, motorist visibility of the site and surroundings, and locations where the county determines that the devices will enhance public safety. Any roadway that has reached a critical threshold, generally 6 or more inches of water, may have a strong current and is therefore closed. Roadways that have not reached that critical threshold may also be subject to closure, based on the decision of a responding crew's supervisor. Factors such as continuing rain, debris, current rates, road damage, and stuck vehicles among others are taken into consideration.

California: Different DOT districts throughout the state have slightly different procedures and criteria, partly dependent on their particular topographies and traffic volumes. Four different districts' approaches are summarized below:

- The District Maintenance and/or Traffic Management Office decides when to activate flashing lights on Highway Advisory Radio signs and/or to display DMS messages. Either or both of these are activated for any situation, including flooding, that impacts traffic flow. District Maintenance or the California highway patrol can make the decision to place a barricade on a state highway; barricades are generally placed at the highway exit prior to the flooded area.
- District maintenance crews are usually the first to respond to a flooded roadway site and place warning signs (or display DMS messages). The maintenance crews will also barricade roads if necessary; local law enforcement usually directs traffic around the flooded areas until California Department of Transportation (Caltrans) can set up a barricade.
- District field and maintenance crews make the decision to display flood warning signs if water is running across the roadway. If a maintenance crew supervisor feels that a road is unsafe for vehicles to travel, he/she has the authority to barricade the road.
- The maintenance foreman makes the decision to activate flashing beacons on flood warning signs, if water is overtopping the roadway.

North Carolina: The division traffic engineer, county maintenance engineer, district engineer, or road maintenance supervisor makes the decision to place warning signs at flooded locations on state roads. Barricades are placed across roadways if floodwater is present on the road's shoulders.

Ohio: The approaches used in two different areas of the state are as follows:

- The district traffic engineer makes the decision to place signs at flooded locations and/or display hinged signs. Temporary signs for flood events are placed in flooded locations as reported by maintenance and sign crews; hinged "High Water" signs are considered for locations that flood more than once per year. County managers make the decision to place barricades across flooded roads in their counties. Criteria considered regarding the decision to place a barricade include the depth of water on the roadway (the threshold is 1 to 3 inches across all lanes), the surrounding terrain, traffic volumes, and the history of how long a particular roadway site takes to drain.
- County managers make the decision to place warning signs. The decision is made based on the amount of water in the travel lane and the length of time it is expected to be there. Sometimes local police will make the decision to direct traffic around a flooded area.

Tennessee: Regional DOT maintenance staff decides on a case-by-case basis whether to place warning signs, display warnings on DMSs, and/or barricade roads.

Utah: Local DOT maintenance crews and/or law enforcement decide whether to post signs and barricades. The criterion for the decision is that a road is impassable due to standing water.

Effectiveness of Signs in Practice

Representatives from five of the eight responding TxDOT districts felt that the warning signs they use are effective. Three district representatives were not sure of the effectiveness of at least one of their signing treatments, and one of those did not feel that the signing treatments for flood-prone sites are effective, though he or she thought that the signs and traffic controls added for flood events are effective in communicating the dangers to drivers.

Nine of the interviewed representatives from other agencies felt that the flood warning signs in their jurisdictions are effective. One representative responded "not sure," as there is no way to measure the effectiveness of the signs; another was unsure of the effectiveness of the signs used for low-water crossings but felt the signs used for flood events are effective. The representatives from two local agencies felt that their flood warning signs are not effective, as people tend to ignore them; one commented that cameras at many of the city's flood-prone sites show drivers frequently ignoring the signs and even driving around the barriers; law enforcement presence at flooded sites is the only sure deterrent. An automated warning system is being piloted in one local jurisdiction to supplement/replace the older permanent signs; its effectiveness in deterring drivers from dangerous water crossings is yet to be determined.

Suggestions from the surveyed agencies for new or improved signs included the following:

- A symbol version of the “High Water” sign.
- Permanent signs that provide effective enough warnings that temporary signs and barricades would not be needed.
- Flashing beacons on warning signs that are activated by the rise in the water, without the need for a staff person to activate them in person.
- Increased visibility of the sign during the actual flood event.

CHAPTER 3. ASSESSMENT OF AUTOMATED FLOOD-DETECTION AND WARNING SYSTEMS

As part of the overall research on this topic, the research team conducted an assessment of the different types of high-water detection and warning systems currently available on the market in the United States. This chapter presents an overview of the typical system components and a discussion of their advantages and disadvantages. As part of this effort, survey respondents were asked to provide information on their use of automated systems and included in-depth questions pertaining to system components and capabilities, system effectiveness, and system maintenance.

Any weather event that produces significant volumes of water may cause a flood condition. In some cases, the propensity to create flood conditions is increased through weather and soil conditions, or debris build-up in the stream or waterway. Floodwaters can quickly build up and inundate not only large tracts of land but also the roadways. Because these conditions may be difficult to judge for safe travel, especially at night or during inclement weather, automated stations have been developed that measure current conditions and trigger an appropriate response. The purpose of an automated warning system is to get information to either those directly affected by the flooding conditions (the traveler) or support personnel who can activate warning devices.

As mentioned previously, in order to standardize the systems that are used for floodwater detection, the NWS developed the ALERT system in the mid-1970s. ALERT combines radio-based communications protocols, data formats, and sensing techniques for collecting and using rainfall and other environmental parameters to monitor weather conditions and issues weather advisories in real time.

Today, the NWS maintains a nationwide system of flood monitoring stations, with more than 470 in Texas alone. Using information from these stations as well as rainfall and watershed forecast models, the NWS predicts river and stream levels and issues flash-flood and river-flood warning and watch alerts. This system is intended to provide flood warning alerts on a county-wide basis.

Many communities have augmented the NWS devices with monitoring stations that they use to predict flooding locally. These stations allow the local disaster and emergency service office to provide more refined prediction and monitoring of flood-prone areas. In many cases, these stations are located at low-water crossing or flood-prone points on the transportation system and can be used to assist local responders in identifying localized flooding problems.

In addition to notifying officials, many systems have been integrating advance warning capabilities to provide motorists with real-time information about flooding conditions at the roadside. As an example, at the time a flooding condition is detected, the system can activate warning devices such as flashing beacons and/or remote-controlled gate arms to block the roadway.

Typical System Components

The typical system components for an automated flood or high-water system include the following:

- Sensor.
- Processor/Electronics package.
- Warning devices.
- Communications.
- Housing and power equipment.

Due to the fact that there are a wide variety of mechanisms in use, a short summary of each of the major components is presented below.

Sensors

There are five major types of sensors typically used in an automated system. These include:

- Pressure Transducer—a sensor that outputs a change in signal as a function of the water pressure (height) in a tube or enclosure.
- Ultrasonic—a sensor type that uses the change in the transmission characteristics of sound waves (through water or air) to produce an electronic signal.
- Bubbler Gauge—a sensor setup in which the change in hydrostatic pressure of water above an air outlet is measured.
- Shaft Encoder—a device that monitors changes in water levels by converting the rotation of a shaft to electronic signals.
- Tipping Bucket—a sensor that measures the rainfall amount.

In most cases, the sensor that is ultimately deployed depends on several characteristics, including local site conditions. There are advantages and disadvantages to each type of system, including cost and the local environment. Sensors such as bubbler systems can be used in turbulent flow situations or where significant debris could accumulate. Air bubblers can also use a differential system using more than one measuring location to see a difference in the fluid level over a distance. Shaft encoders and pressure transducers often require a large vertical housing assembly. Tipping buckets do not measure stream levels directly but do so in combination with other sensors or interpretation of the rainfall amount.

Processor/Equipment Package

The brain of any installation is really the processor or equipment package that interprets the readings from whatever sensor system is installed and initiates actions based on those results. A wide variety of capabilities are present in commercial products, including the ability to process information from more than one sensor site, data logging, and local automated response if communication is lost. Once again, the specific capabilities are typically chosen based upon site conditions, site needs, and integration with existing systems.

Communications

When discussing communications for floodwater stations, two aspects are typically involved. The first aspect is the actual devices used to communicate, such as cellular modem, radio frequency, phone lines, spread-spectrum radio, or more. Some locations may rely on permanent in-ground transmission capabilities, such as fiber, but that is likely to be along areas with significant infrastructure and industry, and not in remote locations.

The other aspect of communications for automated flood detection is the specific protocol used to transmit the data. As stated earlier, the ALERT protocol was developed by the National Weather Service as a means of standardizing the information transmission related to hydrological events. Practically all devices on the market utilize the ALERT protocol to collect and send information. If a proprietary protocol is used to communicate with sensors and equipment, all systems should be able to send information in standard ALERT protocol format to external agencies, such as the NWS.

Protocols

The ALERT protocol has been successful for several reasons, including the following.

- It is a one-way transmission, eliminating the reception end at the sensor site.
- It can be event driven, sending information only when an event is taking place.
- It can be a timed system sending status messages, for trend and update monitoring.
- It is an extremely low bandwidth system, utilizing very short messages that can typically be sent in 0.5 seconds of airtime at 300 baud.
- It is a standard, low-cost, widely implemented and supported technology.

Some commercial vendors sell products that utilize two frequencies, one for the ALERT protocol and one for a proprietary protocol that incorporates fixes for many of the problems identified above, such as retransmission.

As with many systems, however, the success of ALERT has highlighted the need for potential changes in the future. Several challenges currently exist with the protocol, including the following.

- There is no timing coordination between multiple sensors, so independent sites may transmit at the same time, leading to lost data.

- Error detection is not included in the protocol, so typical communications problems, such as noise and interference, may lead to errors in the values, which translates to incorrect readings.
- The unique addressing (identification) aspects of the protocol are becoming outstripped as the number of automated stations deployed increases.
- The data resolution of the protocol is limited, leading to interpretation needs at the receiving station to resolve the actual information.

As time progresses, it is likely that the ALERT protocol will change. The next generation ALERT-2 protocol has been proposed with significant additions. More information can be found at http://www.alert-2.com/. Additions have been proposed that would allow the messages to include items such as global positioning system (GPS) location and two-stage sensor measurements (which would remove calibration needs), as well as error detection, retransmission, and a longer addressing range for more unique station identification. These changes, however, will be implemented and adapted at the level of the NWS and implemented by vendors. While they may provide additional capabilities to automated stations in the future, changes in the protocol do not appear to be an imminent concern that would warrant forestalling any sites.

Warning Devices

Automated stations can be paired with virtually any active warning device, including gates, barrier arms, or flashing lights. Significant installations of these types of systems exist across the state, including locations such as Dallas, Fort Worth, Austin, Galveston, San Antonio, Del Rio, and Houston, and other locations such as Fort Hood.

A wide range of capabilities is present at these locations, including some with local automated control, allowing the on-site processor package to determine when activation of warning devices is required, without direction by a central computer. Some Dallas locations utilize changeable messages on the signs, displaying HIGH WATER WHEN FLASHING when the systems are not activated and the lights are off. The message changes to DO NOT ENTER HIGH WATER when the system is activated and is accompanied by flashing lights.

At some deployments, the activation of local sensors triggers alert lists to be activated. These may include website updates, emails, or paging. The Fort Hood system utilizes email and paging to protect soldiers training in remote field areas near high-water locations. The military command structure and on-site training coordinators are notified at the time of activation of local warning devices.

Housing/Power Equipment

A necessary part of any installation is the housing for the sensors and/or local processors. Standpipes are a common housing for pressure transducers or tipping gauges and are typically a

10-ft-tall metal enclosure. Other types of sensors may require piping or tubing to water locations, requiring the use of conduit. A typical installation may also include a National Electrical Manufacturers Association (NEMA) rated outdoor enclosure to house the electronics and communications. This enclosure will typically be mounted on a pole that may also serve as the support pole for solar panels and backup batteries, which is a common mechanism for powering remote sites.

Results of QuestionNaire

As detailed in the previous chapter, an assessment of the state of the practice related to the design, placement, and use of flood warning sign treatments and automated flood detection/warning systems was conducted as part of the project. The assessment was conducted for both TxDOT districts and other jurisdictions.

Section 4 of the assessment focused on determining the types of flood detection and/or warning systems installed, as well as their capabilities. Overall, Section 4 asked questions pertaining to:

- System description.
- Effectiveness.
- Testing and maintenance.
- Installation criteria.

Unfortunately, the results of the assessment were limited by a poor response rate. Overall, only seven locations reported back with information pertaining to their installations, which included two TxDOT districts, two other in-state locations, and three out-of-state locations. The answers reported are factual but, due to the low response rate, may not be indicative of standard practices or results.

System Description

Table 7 contains the questions asked in the section of the assessment pertaining to system description. Of the respondents, the majority (70 percent) indicated the development of systems in-house, using commercial components, as opposed to the purchase and installation of a full turnkey commercial system.

Table 7. Assessment Questions Related to System Description.

System Description	System 1	System 2
4.1 Is this a commercial system, or a system developed in-house? (Choose one)	Commercial In-house	Commercial In-house
4.2 If a commercial system, name the company or vendor.		
4.3 If a commercial system, name the make and model.		
4.4 Does the system include roadway water sensors?	YES NO	YES NO
4.5 Does the system include other flood warning sensors (rainfall, tide, stream level, or similar)?	YES NO	YES NO
4.6 When flooding conditions are detected, how does the system respond? (Check all that apply)		
• Notifies DOT staff and/or other safety/emergency management personnel.		
• Activates signs, flashers, or other signals along the roadway.		
• Activates gates/barriers.		
• Sends information to public websites and/or other public information channels (TV, radio).		
• Other (please specify):		
4.7 What communications infrastructure does the system use? (Check all that apply)		
• Dial-up		
• Wireline (Coax. Fiber, etc.)		
• Radio		
• Microwave		
• Cellular		
• Other (please specify):		

Answers pertaining to sensor types were approximately a 50 percent split on roadway water sensors vs. other types of sensors. Some implementations indicated the use of multiple sensor types.

In terms of response mechanisms, all responses indicated an agency notification. Approximately 70 percent indicated that the system would activate signs or flashers, with one system activating gates. Approximately 50 percent of the systems incorporated a public notification beyond the site itself.

The majority of the respondents indicated the use of a wireless communications system, such as radio frequency or cellular. This is entirely consistent with the short burst transmission needs of the ALERT protocol and the deployment of equipment at remote locations.

System Effectiveness
The assessment asked respondents to tell the researchers if they were satisfied with the performance of the systems in place. The following questions were posed:

- Are you satisfied with the performance of the automated flood warning system(s) used in your jurisdiction?
- How do you evaluate system performance?
- Have you had any "false positive" incidents (i.e., an alert or activation of the system when there is no flooding/high water present)?

An interesting response is that the TxDOT responses generally indicated dissatisfaction with the systems, while out-of-state responses indicated satisfaction. Additionally, in-state responses from non-TxDOT locations indicated satisfaction with the systems, as does the literature that can be obtained in a web review.

TxDOT responses indicated problems with reliability, such as the water-level sensors getting clogged and hung up at a high-water reading. It is possible that these sites would experience better performance and reliability with a different type of sensor. Overall, this response is not thought to be indicative of the true performance or effectiveness of automated systems, given the pervasiveness of their installations across the state.

Testing and Maintenance
The assessment also asked questions pertaining to the testing and maintenance of the systems. The following questions were posed:

- Do you perform regular testing of the system(s)?
- If yes, what is the frequency of testing?
- If yes to 4.12, how is the system tested?
- Are there system components that need to be tested more frequently than the system as a whole? If yes, what are they?
- Are there components of the system that need to be regularly calibrated? If yes, what are they?
- Are there components of the system that need to be regularly replaced? If yes, what are they?

An interesting dynamic in the response is the TxDOT district responses indicated a far longer timeframe between maintenance and testing cycles than other installations. TxDOT reported annual cycles, while other deployments reported cycles ranging from one to three to six months for on-site inspections and automated "heartbeat" testing of the system responsiveness by the central computer every 10 minutes, with follow-up on-site visits if communications are lost. Additionally, respondents that were not TxDOT districts provided information pertaining to the calibration needs of the sensors or other components and regular cleanings or replacement of components.

While the response rates do not allow definitive conclusions to be drawn, the disparity in the maintenance and testing timeframes and procedures would appear to have a positive correlation with the satisfaction levels expressed in the operation of the deployments.

Criteria

Section 4 of the assessment concluded with asking respondents for the criteria they used for installing these types of systems. The specific questions posed were:

- What criteria do you use to decide if a location needs an automated warning system for flood detection or high water?
- Do you have a formal process for determining this need and/or evaluating these criteria?
- If yes, may we obtain a copy of it?

As with other areas of the assessment, a wide variety of answers was received from the pool of respondents. Some respondents indicated a very analytical process using hydraulic models, while other responses indicated "where flooding is severe." Additional considerations included items such as crew response time to get to the location, the motorist's visibility of the wash, and whether it is determined the installation of the device will enhance public safety. No TxDOT districts responded with installation criteria, which may indicate an important missing element in the use of the installations within the department.

Summary of Findings

While the response rate for the assessment was low, a number of apparent trends can be identified. First is the fact that TxDOT responses indicated dissatisfaction with the performance of automated flood warning systems. This is in contrast to deployments elsewhere in state and out of state that indicate satisfaction, a result more consistent with the several hundred installations across the state and several thousand across the country.

An indication as to why this disparity occurs may be identifiable in the responses reported for maintenance and testing. Although based on few responses, TxDOT districts indicated a lower level of testing and maintenance activities than other deployments. TxDOT districts also did not provide any installation criteria, which could indicate a lack of developed procedures or an understanding of where these systems will work best.

Adding to the results from the assessment is the fact that these systems can take many different forms in actual deployments, varying in the type of sensor in use, the type of communications, the type of activation, and even the data provided by the site to a central location. A thorough understanding of the pros and cons of each of these aspects may be necessary to provide relevant installation criteria.

CHAPTER 4. FOCUS GROUP INTERVIEWS ON WARNING TREATMENTS AT FLOOD-PRONE AND LOW-WATER GRADE CROSSINGS

The purpose of Task 4 was to collect opinions from Texas drivers regarding the hazards of water over roads (passable and impassible), the kind of information they feel is useful or necessary to navigate flood-prone roads, and the most effective ways to present that information.

Methodology

Eight focus groups were conducted in four Texas cities: two each in College Station, Odessa, San Angelo, and San Antonio. A total of 74 drivers participated. A summary of the demographics of the groups is shown in Table 8. The College Station and San Antonio focus groups were held in conference rooms at the College Station and San Antonio TTI offices, respectively; the Odessa and San Angelo focus groups were held at conference rooms rented in local hotels. Focus group discussions ranged from 1.5 to 2 hours.

Table 8. Focus Group Demographics.

Group	Number of Participants by Age Group and Gender					
	18–25 Years		26–54 Years		55+ Years	
	Male	Female	Male	Female	Male	Female
College Station #1	2	0	1	3	1	2
College Station #2	0	1	3	0	1	3
Odessa #1	1	2	0	3	2	2
Odessa #2	0	1	1	2	1	2
San Angelo #1	1	0	2	0	1	6
San Angelo #2	5	1	0	0	0	4
San Antonio #1	3	1	1	4	0	1
San Antonio #2	0	2	3	4	0	1
Total	12	8	11	16	6	21

After conducting three of the eight focus groups, researchers decided to add an additional question in order to get a base definition of what participants felt the term “flooding” actually indicated (passable or not passable roadway) to them. At this point, five of the eight groups (47 participants) were asked “What do you think when you hear the word ‘flooded’?” Answers to this question varied in detail, but participants generally defined “flooded” as a particular depth of water and/or in terms of the hazard it poses. Water depths that participants considered “flooding” ranged from 3 to 4 inches over the pavement surface (especially if the water is moving) to “over two feet” or “anything high enough to affect your vehicle.” Many of the participants described flooding as a danger: "fast moving water," "cars being washed off the roads," "danger." Some included details such as "lots of rain" and "fields flooding."

At least 11 people (23 percent of those who discussed this question) stated that they would automatically consider a "flooded" road to be impassible.

Driver Responses and Decisions on Flooded Roads

The first part of each focus group began with a discussion about flooded roads and the factors that affect driver decisions about driving on those roads. The following questions were discussed in each focus group:

- What types of flooding concern you most?
- When would it be all right to drive through water that is covering a road?
- What information do you need to know about a flooded or flood-prone area of road?
- Where do you seek that information?

Responses regarding the causes of roadway flooding generally centered on heavy rains, poor or blocked drainage, and overflowing rivers and/or water tanks. Responses to the questions listed above are summarized below.

What Types of Flooding Concern You Most?

"Flash flooding" and "moving water/water with a current" were the most frequent answers in all groups and were agreed upon by nearly all participants. Other concerns mentioned included deep water, flooded roads at night or under other low-visibility conditions, flooding at or near a bridge, flooded roads in an unfamiliar area, and "long-term" flooding conditions that can wash out sections of roads.

When Would It Be All Right to Drive through Water That's Overflowing a Road?

Six participants (approximately 8 percent) said "never." The majority of participants named and/or agreed on conditions for when they thought it would be safe to attempt to cross water that is over a road:

- If water is "not too deep." This was the most common criterion given. When asked to define "not too deep," some participants defined a safe depth in inches ("three or less," "six to eight") and others by some visual cue ("if I can see the edge line on the road," "if the water is up to hubcaps, you should be concerned," "based on a gauge you can tell if you can make it").
- If the water is not moving. Several participants specified that running water is more dangerous than still water of the same depth.
- If the driver feels his/her own vehicle would be capable of traversing the water ("You know what your own car can handle").

- If other vehicles are crossing—but only if they are the same size or smaller than the driver's own vehicle ("Do not cross if you only see trucks going through").
- Previous experience with flooding and/or familiarity with the road that is flooded. Interestingly, drivers who spoke of having previous experience with flooded roads tended to be less likely to want to risk crossing a flooded area.
- Road characteristics, topography, and signs. A few participants mentioned "Low-Water Crossing" signs as an indication that the water is safe to cross. Others said that guardrails on the side of the road would make a water-covered area safer to cross and might weigh into their decision, or that the overall geography/topography of the area would give them an idea about how dangerous the water might be.

What Information Do You Need to Know about a Flooded or Flood-Prone Area of the Road?

There were relatively few differences in responses here. Most participants agreed that they need to know about the presence and depth of water over the road, and if the road is closed or too dangerous to proceed. Other information deemed necessary by participants included the nature of the flooding (e.g., moving or still water, rapidly rising water) and advance warning of flood sites accompanied by detour information.

Where Do You Seek That Information?

Flood warning signs and/or gauges were mentioned by participants in six of the groups. Television, radio, and "the news" were identified in seven of the groups; a few participants specified Highway Advisory Radio, with the radio station displayed on a DMS sign. The Internet was mentioned in two groups as a good information source but was identified as a poor/unreliable source by some members of another group. Personal experience, calling a friend or the sheriff, topographical maps (to identify low areas), and a telephone hotline were other suggestions. One participant stated that she does not always rely on signs to provide accurate information about flooding but may be more inclined to believe a warning sign if the weather is bad.

FACTORS AFFECTING DRIVERS' DECISION TO PROCEED THROUGH FLOODED CROSSINGS

The participants of each focus group were asked to discuss what information affects a driver's decision process when he or she encounters a flooded road. The two questions ("How would you decide if the water was safe to cross in your vehicle?" and "What are some of the things you would consider?") were presented and discussed together rather than as two separate questions.

The considerations mentioned most frequently were the perceived depth and movement of the water, and whether or not other vehicles were seen crossing the water. Group participants stated that they are less likely to attempt to cross water on a road if it appears to be moving or rising, and/or if it is “too deep.” Definitions of hazardous water depth varied, as did the means of measurement. Some participants said they would look for flood gauges; other visual “gauges” mentioned included the following:

- Half the depth of tire rims.
- Top of tires.
- Tailpipe height.
- Water higher than the curb.
- Too deep to walk through.
- Over the tops of shoes.

Besides the perceived depth of the water, many participants listed additional considerations:

- Road condition and features, including whether the roadway appears to be washed out, the presence of curbing or guardrails, and the presence of debris.
- Driver’s familiarity with the road and surrounding roadway network.
- Size of the flooded area.
- Overall topography of the area.
- Current weather.
- Size and type of car being driven.
- Importance to driver to get to destination on time.

Participants who had experienced flooded roads tended to be more cautious about water on a roadway than those who had not. Six of the participants (8 percent) stated that they simply would not continue on a road that was covered with water of any depth (as opposed to a road that is merely wet).

Figures 11 through 15 are pictures of various low-water crossings and flooded roadways that were shown to participants. They were chosen to provide a range of flooding conditions and roadway characteristics. In order to obtain the participants’ initial driving reaction and reduce any biases that could be caused by the group discussion of the four pictures and two video clips presented, participants were asked to mark an answer on their individual worksheets: “yes” if they would be willing to proceed on the roadway shown, and “no” if they would not. Following the “vote” on each scenario shown, participants discussed their reasons for deciding that proceeding on the road would be safe or unsafe.

Figure 8. Roadway Scenario #1: Low-Volume/Low-Speed Rural Road—Poor Pavement, No Shoulders.

Figure 8 was the first picture shown. This picture shows a rural road with poor pavement, no edgelines, and no shoulder. Still water covers a portion of the road, and a flood gauge is visible on the right. This photograph was meant to illustrate an example of a passable low-water crossing. Of the 74 total participants in the eight groups, 52 (70 percent) said that they would probably drive through the water shown on this road. The most common reason given for considering this crossing "safe" included the apparent shallowness of the water, as evidenced by the visible flood gauge and visible edges of the road. Other reasons voiced by participants included the fact that the water does not appear to be moving rapidly and there are cars parked on the far side of the crossing, which indicated to several participants that others had crossed successfully. One participant said, "It looks normal for water to be there." Some participants commented on the worn road, saying that they would go slowly and cautiously across because of the road's poor condition.

For the remaining 22 participants (30 percent) who said they would not be willing to proceed on the road shown in this picture, the most common reason given was the condition of the road and the concern that it could be washed out or unstable under the water.

Figure 9 shows a water crossing that has been constructed to allow cars to pass through the running water. The roadway is edged with a notched curb to facilitate the flow of water. Forty-four participants (59 percent) said they would proceed on the road shown, while 30 (41 percent) said they would not. Those who said the road looked safe enough to proceed commented (with approximately equal frequencies) that the road's construction looks like it was designed for water to run over it, that the water doesn't look particularly deep or fast moving, and that the wet pavement on either side of the road indicates that other vehicles have passed through. Those who did not think it was safe to proceed were uncertain of the water's depth, concerned about the drop-off from the edge of the road, and concerned that the water running over/through the notched curb could take a vehicle with it.

Figure 9. Roadway Scenario #2: Low-Volume Rural Road—Designed Low-Water Crossing.

Figure 10. Roadway Scenario #3: High-Speed Rural Roadway—Flooded.

Figure 10 shows a flooded rural road. The road has painted edgelines, shoulders, and guardrails along a short stretch (likely a bridge or culvert) and a flood gauge just visible on the right, shaded by trees. The flooded area goes beyond the edges of the road on both sides (and past the area defined by the guardrails), disappearing into the tree line. An approaching car is visible on the far side of the flooded area. This picture was used to illustrate a flooded roadway of uncertain depth, at a site that would not look as though water on the road is a common occurrence. Forty-two participants (57 percent) said that they would continue on the road shown. Their primary reasons for considering the site to be safe enough to cross included the perceived shallowness of the water (noting that the edge and center stripes on the road are partially visible) and the wet tire tracks on the road before and after the flooded area (indicating that other cars have crossed). A few also noticed the flood gauge in the shadows on the right side of the road. The 32 participants (43 percent) who said they would not proceed through the flooded area commented on the uncertain depth of the water, particularly in spots where the road markings are not visible, the area of the road where the water flows past the end of the guardrail, and the spread of the water into the landscape on either side of the road.

Figure 11. Roadway Scenario #4: High-Speed Rural Roadway—Car Traversing Flooded Area.

The first focus group (one of the two in College Station) did not see the picture displayed in Figure 11; it was added after participants in the first group asked about the approaching car seen in Figure 10. Figure 11 is a picture of the same flooded roadway shown in Figure 10, with the car shown at the midpoint of the flooded area moving through the water. Researchers wanted to determine if motorists would be influenced by other vehicles' driving behaviors.

Of the 65 participants in the other seven groups, 47 (72 percent) said that they would continue on this road based on this picture, while 18 (28 percent) said they would not. Twenty of those who saw both Figure 10 and Figure 11 changed their minds about the scenario shown in Figure 10 once they saw the car crossing the flooded area in Figure 11:

- Fourteen who had said they would not cross decided that they would cross after all.
- Six who had been willing to cross the flooded area decided that they would not.

Interestingly, most of those who changed their minds based on the car shown in Figure 11 mentioned the same observation—the depth of the water in relation to the car in the photo. Those who changed from "would not cross" to "would cross" commented that seeing the Figure 11 photograph reassured them that the water was not very deep. Those who changed from "would cross" to "would not cross" commented that the car shown in Figure 11 looked bigger than their own vehicle, and the water looked deeper and more hazardous (again, in relation to the car).

Figure 12. Roadway Scenario #5: Video Clip of Flooded Roadway.

Figure 12 is a screen capture from a video clip that showed water flowing over a roadway. The road shown in the video has a bridge in the foreground with guardrails on both sides of the two-lane, no-shoulder roadway. The flooded area begins midway across the bridge, covers both lanes, and deepens at the far end of the bridge and beyond. The roadway just beyond the bridge is nearly invisible under the water, and it is very difficult to ascertain the depth of the water or the location of the road surface at that point. When the video clip plays, the sound of the moving water can be heard. This video was included as an example of deep, moving water that would be dangerous for a vehicle to cross. The perceived depth and speed of the flowing water was a primary deciding factor for the 73 group participants (99 percent) who stated that they would not proceed through the water on this road. One participant stated that he might try to proceed but would go slowly and try to get a closer look at the water before deciding.

Figure 13. Roadway Scenario #6: Wide Expanse of Shallow but Rapidly Flowing Water across a Rural Roadway.

Figure 13 is screen capture from another video clip that was shown to the focus group participants. The video showed a wide expanse of a shallow but rapidly flowing water across a rural roadway and the surrounding landscape following (but not during) a rainstorm. The video pans to the right to show the right edge of this two-lane roadway, which has painted edgelines and no shoulder. Although the water over the roadway is only a few inches deep, the current and reflection of sunlight off the water's surface make it impossible to see the left edge of the road. The water can be seen "white-capping" as it flows from the right roadway edge onto the adjacent ground and into the trees. The sound of a great deal of rushing water can be clearly heard on the video clip. This slide was included as an example of moving water that is not deep but poses a hazard to a vehicle due to the water's current (the road that was filmed had been closed due to the flooding). All 74 participants stated that they would not attempt to proceed on the road as shown. Although many commented that this water looked shallower than the water in Figure 12, they felt that the breadth of the flooded area and the speed of the water made this flood site too dangerous for a vehicle to cross through it.

Group responses to these four pictures and two video clips reinforced the decision criteria that the groups discussed prior to seeing these slides. Factors that the group participants mentioned when looking at the various sites pictured were as follows, in approximate order of frequency:

- Perceived depth and speed/current of water on the road.
- Presence (or evidence) of other cars proceeding through the water.
- Roadway condition and improvements (e.g., guardrails).
- Topography of the immediate area.
- Size of the flooded area.

Information Preferences for Low-Water Crossings and Flood-Prone Sites

Part 2 of the focus group concentrated on permanent signs that might be used at low-water crossings (locations where water always or usually flows over the road) or flood-prone locations (sites on roadways that are usually dry but can flood under certain conditions, such as heavy rains).

Participants were shown the photographs of the crossing designed to carry water (Figure 9) again and informed that the picture is of a constructed low-water crossing that nearly always has water flowing over it and is designed to be safe for cars to cross under normal conditions (during and after heavy rain, this crossing is closed). The groups were then asked if they thought this type of crossing should be marked with a sign or other information. After the group discussion of this scenario, participants were each asked to write down their preference for information (if any) they would like to see at a site like this and how it should be presented.

Most participants felt that there should be a sign informing drivers that it would be safe under most circumstances to continue to drive on the roadway. Several participants commented that if it were possible for this site to become too deep or dangerous under certain conditions, drivers needed to be warned of that. The following devices were suggested by participants for a site like this one:

- Warning sign identifying/describing the crossing, suggested by 64 participants (86 percent). The most common message suggested (26 participants/35 percent) was "Low-Water Crossing," but that was likely due in part to the use of that term during the discussion of this picture. Other sign messages suggested for this type of scenario are listed below. Most of these messages are intended to provide information and reassurance that water on the road at this site is normal and usually safe to cross in a vehicle. Some also advise caution, including some that recommend a lower vehicle speed.
    - "Low-Water Crossing—Safe for Passage" (or "Unsafe for Passage"; dynamic sign activated by water-level sensors).
    - "Watch for Water on Road."
    - "Stream Crossing."
    - "Low-Standing Water."
    - "Water with Dips."
    - "Dam Ahead."

    - "Water Run-Off—Safe Water Crossing."
    - "Safe to Cross."
    - "Safe Water Crossing."
    - "Slow—Water Crossing."
    - "Caution—Cross at Your Own Risk."
    - "Slow" or "Slow Down."
    - "Be Careful When Raining."
    - "Drive with Caution at __ MPH."
    - "Reduce Speed."
    - "Caution—Water Standing."
    - "Water over Road—Proceed with Caution."
    - "Caution—Proceed with Care."
    - "Low-Water Crossing—Go Slow."
    - "Cross with Caution."
    - "See Gauge before Crossing."
- Flood/depth gauge to provide supplemental information (suggested by 40 participants/54 percent). Variations suggested:
    - Color-coded or marked gauge that specifies dangerous water level.
    - Whole gauge in bold color.
    - Paint on curb/walkway to show high-water level.
- Flashing light activated on a warning sign when the water is too high to cross safely (suggested by 13 participants/18 percent).
- Caution light (no sign specified) when road is covered in water (suggested by 7 participants/9 percent).
- Advance warning/detour information; need a sign where you can still turn around (suggested by 13 participants/18 percent).

Participants were shown the photograph in Figure 8 again and informed that it displays a low-water crossing that has a small amount of water flowing over it most days of the year and that occasionally could be covered with higher levels of water. They were then asked what type(s) of information they thought should be provided at a crossing like this and how they would like to see it presented. Again, responses shown here were collected from individual written answers, supplemented with comments made during the group discussion. Devices suggested by participants for a site like this are listed below:

- Warning sign identifying/describing the crossing (suggested by 53 participants/72 percent). Again, the message suggested most often (by 15 participants/20 percent) was "Low-Water Crossing." As with the previous scenario, the use of this term during the discussion likely influenced this wording. Other suggested messages included the following:
    - "Water on Road."

- “Low Crossing Ahead.”
    - “Flood Prone.”
    - “Standing Water—Careful Crossing.”
    - “Caution.”
    - “Dangerous Water Crossing—Water on Road Most Times—Drive Slowly.”
    - “Road Usually Flooded: Low-Water Crossing.”
    - “Cross with Caution.”
    - “Reduce Speed—Usually Has Water.”
    - “Avoid Edges.”
    - “Danger—Flooded Roads.”
    - “Prepare to Stop” (dynamic sign that activates when water is too deep).
    - “Low-Water Crossing—Bumpy Road.”
    - “Safe to Cross.”
    - “Low-Water Crossing: Safe to Cross.”
- More visible flood gauge (suggested by 39 participants/53 percent); suggestions included:
    - Color-coded gauge to identify safe and dangerous levels.
    - Easier to read than the one shown in the picture; closer to road at lowest point; line in red or fluorescent yellow to show dangerous water level.
- Flashing lights on a warning sign when water is deep (15 participants/20 percent).
- Warning sign far enough ahead to turn around or detour (14 participants/19 percent).
- Gate/barricade when water is deep (9 participants/12 percent).
- Fluorescent paint or guardrail to make road edges more visible (8 participants/11 percent).

Participants were shown Figure 10 again and informed that the photo is of a location that is usually dry but can flood as shown after heavy rains. They were then asked if a site like this should be marked with a permanent sign or other devices to identify it as a flood-prone area. Responses were collected from the group discussion and from individual written answers. Five of the participants (7 percent) did not think a permanent sign is needed here if flooding is an unusual occurrence, suggesting that at most a gauge might be warranted. The majority of participants did feel that some sort of permanent warning device(s) would be useful to drivers. The following devices were suggested as permanent fixtures for this type of flood-prone site:

- Permanent warning sign (suggested by 64 participants/86 percent). A few participants specified sign colors, types, and materials: “yellow diamond,” “reflective paint on signs,” and “flip sign that is red when open.” Terms that were used most often in the suggested sign messages were “flood/flooded/flooding,” “watch for water,” and “caution.” Suggested messages included the following:
    - “Roads May Be Flooded.”
    - “Prone to Flood/Flooding.”
    - “Flooding Water—Use Care.”

- “Flash Flooding Possible.”
- “Possibility of Flooding.”
- “Watch for Water.”
- “Watch for Water on Bridge.”
- “Watch for High Water.”
- “Watch for Water Crossing Road.”
- “Watch for Water after Storm.”
- “Flooding Creek.”
- “Do Not Pass” (when triggered by sensor).
- “Caution—Flooding after Rains.”
- “Use Caution When Water on Road.”
- “Use Caution during Rain Periods.”
- “Road May Flood in Wet Weather.”
- “Caution—Flooding Possible.”
- “Drive Slowly through Water.”
- “Flood-Prone Area.”
- “Flooding Possible with Heavy Rain.”
- “Caution When Raining.”
- “Caution When Crossing.”
- “Proceed with Caution” (triggered by water sensor).

- Gauge (mentioned by 19 participants/26 percent). One participant mentioned color-coding the gauge for this site.
- Flashing lights on the sign when flooded (17 participants/23 percent).
- Advance warning/detour signs (16 participants/22 percent).
- Barricades or gates when dangerously flooded (6 participants/8 percent).
- Warning bumps/grooves on road with speed warning (2 participants).

Signing Ahead of Flood-Prone Area

Figure 14 shows an example of a rural two-lane roadway with shoulders and painted edgelines and a flip-down yellow warning sign on the right side reading HIGH WATER—ROAD CLOSED. The roadway winds out of sight with no water visible; the “high water” mentioned on the sign is presumably farther down the road. The roadway and the sign are pictured on a sunny day, and the portion of the road that is visible is dry. This photo presented one type of sign that is in use to provide advance warning about a flooded roadway that is not passable. Participants were asked what they thought of the sign’s message and the type of sign being used.

Figure 14. An Example of a Sign Treatment in Advance of Flood-Prone Crossing.

Most group participants liked the sign's HIGH WATER—ROAD CLOSED message; some preferred slightly different wording (generally "flooding" instead of "high water"), and some wanted additional information on detours. While group participants liked the positioning of this sign ahead of the actual hazard, many wanted to see it even farther back, specifically at an intersection that would permit them to detour without having to turn around on the road.

Concerns expressed about this sign primarily focused on its visibility (particularly at night or during bad weather) and its timeliness/credibility:

- "Not enough at night. Need orange flashing lights."
- "Sign should be red."
- "Good sign but needs lights to catch your attention."
- "Drivers can get used to this sign and may ignore it on a sunny day—it seems false."
- "I'd continue and check out the water for myself."
- "Don't know if this sign is current; TxDOT may have forgotten to put the sign back up."
- "What if I'm the first one to see the flooding? No one would have flipped the sign yet."
- "It could fall down, or someone could flip it down as a prank."

Many of the suggestions for improving this sign involved adding automated (sensor-triggered) flashing lights—both as a way to draw a driver's attention and as confirmation that the warning is a current one. Another suggestion heard several times was a time/date stamp on the sign to let drivers know when it was activated. Finally, several participants recommended that a ROAD CLOSED sign be reinforced by an actual barricade or gate.

Figure 15 and Figure 16 were used to address two discussion topics: the likelihood of drivers detouring around a flooded area, and the preferred types and locations of advance warnings for one or multiple flooding sites.

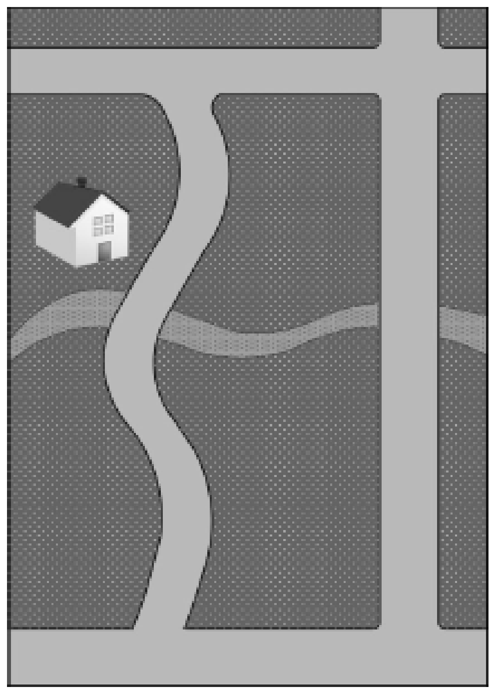


Figure 15. Flood-Prone Area with a Single Stream Crossing.

For Figure 15, participants were given the following scenario: they live in the house shown in the picture and are familiar with the roadways shown. The curved roadway sometimes floods at the stream crossing, while the straight roadway never floods and can serve as an alternate route to the house. Participants were asked the following:

- If you encountered flooding on the curved road on your way home, would you detour around on the straight road?
- Would your willingness to detour depend on distance?
- What information would you want about flood sites on the curved road, and where would you want it?

Answers to the first and second questions varied, partially by city. In San Antonio, nearly all the participants in both groups said they would detour around a flooded site regardless of the distance to be traveled on the detour. This may be in part due to the public outreach effort that the City of San Antonio has promoted to educate local drivers about flooding dangers. In the other three cities, one-third to one-half said they would detour around the flooding in most or all instances. This number increased if they were on an unfamiliar road, if they were driving when it was raining, or if they were driving at night. For some of these drivers, their willingness to detour depended on the length of the detour, though there was no universal "threshold" distance.

Answers to the third question were mostly consistent among participants of all the groups. Information that participants wanted for a road with a flooding site (particularly for a site that would require a driver to turn around and find a detour) included advance warning signs, either at an intersection where the driver could detour or at least in a location where the driver could easily turn around. Additional details and suggestions included:

- Signs should include detour information. Additional signs should identify the alternate route.
- Signs should have time stamps so drivers know they are current.
- Signs should have flashing lights or flags to draw attention; many preferred automated signs to flip-down signs.
- Crews should put up a barricade if the road is too dangerous to continue.

Besides HIGH WATER—ROAD CLOSED, suggested messages included the following:

- POSSIBLE FLOODING.
- POSSIBLE FLOOD (automated).
- FLOOD-PRONE AREA.
- ROAD CLOSED DUE TO FLOODING X MILES AHEAD.
- ROAD CLOSED DURING HEAVY RAIN.
- FLOODED AREAS/ROAD DURING RAIN PERIODS.
- DANGEROUS WATER LEVELS.
- WATER CROSSING" OR "LOW-WATER CROSSING.
- YIELD WHEN RAINING.

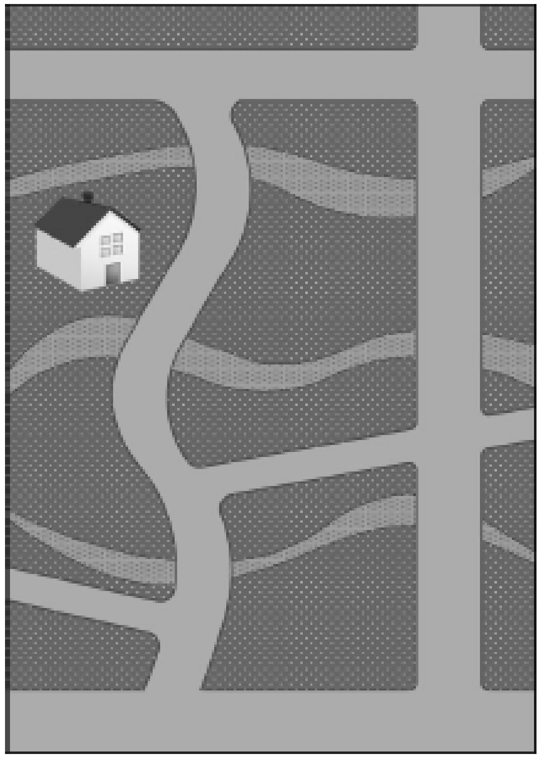


Figure 16. Flood-Prone Area with Multiple Stream Crossings.

Figure 16 presented a similar situation with multiple potential flooding sites (again, along the curved road, with the straight road designated the non-flooding detour road). Participants were asked what additional information, if any, they would want provided for a road with multiple flooding sites. Suggestions for roads with multiple flooding sites included the following:

- Warning sign to indicate how far ahead the flooding begins.
- Flood gauge at each crossing/low spot.
- Sign saying NO THRU TRAFFIC.
- Sign specifying each road closure location so residents along that road know if they can reach their homes.

Information and Device Preferences for Flood Events and Road Closures

The final segment of the discussion focused on signs and devices that might be posted or activated during actual flooding events, specifically for water levels that would be considered hazardous enough to warn or prohibit drivers from continuing on a road. Participants were told that they would see several examples of signs and devices and were asked to discuss both the messages and the formats they thought would be most effective in preventing drivers from entering a dangerous flood site.

Participants made the following comments about the temporary sign with a WATER OVER ROAD message shown in Figure 17:

- Not bad as a "caution" sign.
- Gives message that flooding is a current event/problem.
- Sign might blow over or be tampered with.
- Looks like a construction sign; might not get noticed.
- WATER OVER ROAD message is too general.
- Sign should be placed in center of road for maximum driver visibility.
- Sign is too close to the water; should be farther back to allow drivers to turn around.

Figure 17. Example of Use of Temporary Sign to Alert Drivers to Flooded Roadway Conditions.

Participants were shown an example of a single Type III barricade, placed several yards ahead of a visible flooded area on a two-lane road, to see if drivers would view its presence as sufficient warning to turn around. Almost none of the focus group participants thought a single barricade provided any message to drivers beyond "continue with caution." This scenario is shown in Figure 18. The comments received were very consistent:

- Barricade needs to cover the entire road, with no option to go around.
- Needs a sign saying ROAD CLOSED.
- Needs a sign explaining why the road is closed.
- Barricade should close the road farther back (where you can turn around or detour).

Figure 18. Example of Use of Temporary Barricade to Alert Drivers to Flooded Roadway Conditions.

Participates were shown a close-up of the flip-down sign next to a roadway (see Figure 19) and asked to discuss its potential use as an alternative signing treatment. Discussion of this sign echoed the comments received earlier for this advance warning sign. Most participants considered the message (HIGH WATER—ROAD CLOSED) to be clear and unambiguous but worried that the standard yellow warning sign would be easy to miss, especially in rain. As before, many participants expressed the concern that potential time lags (for TxDOT crews to flip down the sign at the onset of flooding and to fold the sign back up after the flooding threat has passed) could reduce the credibility of the sign. Automatically activated flashing lights and/or a date stamp on the sign were the most frequent suggestions received for addressing this concern. As before, several participants recommended adding a barricade or other physical obstacle to close the road.

Figure 19. Example of Flip-Down Warning Sign to Alert Drivers to Flooded Roadway Conditions.

Participants were shown an example of the two phases of a portable dynamic message sign (PDMS) used to provide detour information to drivers around a flooded roadway (see Figure 20). Most participants liked the PDMS for its visibility; some commented that a CMS is most effective for this type of situation if the sign is NOT in use all the time for non-urgent messages. Participants also liked the messages displayed, though some recommended adding additional information (perhaps on subsequent signs) that would provide more information about the detour and the distances involved for drivers who are unfamiliar with the area. Participants said they preferred that a sign like this be positioned from one to three exits prior to the detour, depending on the road's traffic volume.

Figure 20. Example of Use of Portable Dynamic Message Sign to Alert Drivers to Flooded Roadway Conditions.

Each focus group was also shown the photo in Figure 21, which displays a sign equipped with flashing lights and the message DO NOT CROSS WHEN FLASHING placed a short distance ahead of a flooded section of a two-lane roadway. All of the discussion groups liked this sign, which was not surprising since many of the participants had suggested this type of device earlier in the discussions. When asked what color the flashing lights should be, nearly all participants said that red lights would tell a driver to stop and not continue on the road, while yellow lights would mean "continue with caution." Most participants wanted a sign like this to be automatically activated by a sensor in order to avoid the delay that might result from someone needing to travel out to the sign to activate it. Other comments received regarding this sign included the following:

- Is more believable than a flip sign.
- Should add barricades or gate if the road is closed.
- If applicable, add information to the sign about fines/penalties for passing the sign when it is flashing.

Figure 21. Example of Flooded Roadway with Permanent Active Warning Sign.

Participants were also shown a slide of a crossing that uses an automated railroad-style gate that lowers when sensors are triggered by high-water levels (see Figure 22). A sign on the gate's support post displays the message LOW-WATER XING GATE, and a supplementary sign provides a phone number to call to report gate malfunctions. The majority liked this device; however, in four groups, some concern was raised about the gate looking too much like a railroad crossing and possibly confusing drivers.

The gate as shown extends across the right-hand lane of the road, with a matching gate (not visible in this photo but explained to the groups when the question arose) blocking the right lane of the road for cars traveling the opposite direction. Most participants thought the gate should extend all the way across the road to deter drivers from crossing. Other suggestions and comments received included the following:

- Warning sign should come down with gate to be more visible.
- Sign is good for areas with poor lighting.
- Sign is too big and busy, a lot to look at (2 participants).
- Lights/sign are enough; gate is unnecessary (3 participants).
- Only use this device where there is a risk of being washed away.

Figure 22. Example of Flood-Prone Crossing with Automated Gate.

Other User Comments

To sum up the discussion of flood event/road closure signing, participants were asked to provide suggestions for the messages and devices they would consider to be the most effective for warning drivers of a current flood hazard. Nearly all participants recommended signs with red flashing lights that activate during a flood event; the few that did not specify flashing lights suggested CMS signs or signs that display a date/time stamp to indicate when they were posted/activated. Most participants liked the "Road Closed" message or a similar message that lets drivers know the road is impassible. Forty-two participants (57 percent) would want to see a gate or barricade completely blocking the road. There were mixed opinions about the nature of the barricade—most preferred the railroad-style gate they had seen in the photo, but some pointed out that its similarity to a railroad gate could confuse drivers and thus suggested a different type or color of barricade or gate. Finally, eight participants specified that a permanent barricade/gate should only be used at particularly dangerous locations, feeling that it would be "overkill" for most flood-prone sites.

Several suggestions were received for sign colors, including red, yellow, red and yellow, and "bright green with red lights." The common theme to the color suggestions was for a sign that would be highly visible and attention getting, particularly at night or during bad weather.

Conclusions and Recommendations

The objectives of the focus groups were to learn about factors that influence driver decisions to cross (or not cross) water covering a road, to determine the types of information that drivers find necessary or helpful to make safe decisions about flooded roadways, and to develop ideas for signing and other devices that could be tested in the second year of this project.

When drivers were asked to define a "flooded" road, there was no clear consensus on what that meant.

- Depths that drivers considered hazardous varied from 3 inches to over 2 ft.
- Less than 25 percent of drivers in the groups said that they considered a "flooded" road to be automatically impassable.

About 90 percent of drivers in the focus groups said that they would be likely, depending on their own set of criteria, to proceed through water covering a road. The most common criteria mentioned are listed below:

- Depth of the water (still with a range of definitions of "too deep").
- Water movement (visibly moving/rising water considered more dangerous).
- Other vehicles crossing the water.
- Road condition and features.
- Driver's familiarity with the road or area.
- Vehicle type.

Drivers in the focus groups showed the most concern about moving water; when watching the two videos that were shown of flooded roadways with flowing/moving water, the participants voted overwhelmingly that the sites shown were too dangerous to cross in a vehicle. Water depth was also a significant factor for the group participants when viewing the example pictures and videos, but there was more variation in the depths group members would accept.

Several general trends emerged from the focus groups regarding flood warning sign preferences. The following is a summary of the signs, messages, and devices that were suggested most often during the discussion.

Advance Warnings about Water on the Road

In terms of warning messages in advance of flood-prone and low-water crossing, the following appeared to be common themes derived from the comments of the focus group participants:

- If a flooded road is impassible, drivers want to avoid last-minute turnarounds at the flooded site. Ideally, these warnings should begin as far away of the crossing as practical (e.g., 5 or more miles away from the flooded area). At a minimum, drivers should be

warned at least at the intersection that precedes the site. Additional information requested for advance warnings of an impassible flooding site included:
    - Detour information—road names/numbers, distances, signs to identify alternate routes.
    - A time/date stamp or some other indicator of when it was posted (for instances when the road was closed).
- If water is present on the road but the roadway is safe to cross, drivers should be warned that water is likely water on the road, particularly at night. The warning should also include a speed advisory or a caution to reduce speed along with the notification of the presence of water.
- Finally, drivers should be provided with advance warning signs to include the distance to the flood site, e.g., FLOODING XX MILES AHEAD or WATER CROSSING XX FEET AHEAD."

Information at Low-Water Crossings
The results of the focus group suggest the following be used to provide drivers with information about travel conditions at low-water crossings:

- Signs should be used to let the driver know that water is present on the road ahead and that it is usually safe to cross the crossing with caution. The signs should predominantly convey messages of "caution" or "slow" and "water."
- A flood gauge should be present at each the crossing. The flood gauge should have the following characteristics:
    - Bold colors (easy to see).
    - Color-coded or marked to designate a dangerous/impassible water level.
- Signs should attract attention and let a driver know when water levels are dangerous, e.g., red flashing lights activated when water is too dangerous to cross.
- Markings or railing should be used to identify the edges of the road under the water.

Information at Flood-Prone Sites
The results of the focus group suggest the following be used to provide drivers with information about travel conditions at sections of roadway that are prone to flooding:

- Permanent warning sign should be used to let drivers know that a road/site is prone to flooding under certain circumstances. The most commonly suggested terms to be used on these signs included "flood/flooded/flooding," "watch for water," and "caution."
- Information should be proved when a flooded site is passable and when it is impassable. If a road is impassable due to flooding, drivers want instructions about what they should do, or at least a statement that they should not proceed.
- Signs should attract the attention of drivers, especially when the road is impassable.

Items that were identified as being an issue to be considered in developing treatments included the following:

- The conspicuity of standard yellow warning signs may not sufficient, particularly at night and in bad weather, to convey the appropriate level of warning at these crossings. The participants favored the use of permanent signs with flashing lights that activate when flooding occurs to signify when the crossing is impassible
- A credibility issues exists with using permanent and flip signs at these crossings. The participants are aware of possible time lags both at the onset of a flooding hazard and afterwards.
- The color of the flashing beacons may an effect on driver's decisions on whether or not to proceed through the crossing. The participants indicated that yellow flashing lights signified to "proceed with caution," while red flashing lights implied "road closed" or "do not continue."

Devices for Flood Events

The focus group participants viewed a number of different existing signs and devices commonly used to close roads during flood events. The devices they felt gave the most useful and credible information were DMSs, permanent warning signs with automatically activated flashing lights, and gates or barricades with flashing lights. Other comments included:

- DMSs should provide detour information, including distances.
- Flashing lights should be red if a road is impassable.
- Gates or barricades should extend across an entire road to discourage driving around.

Driver Comprehension Study Issues

Based on the finding from the focus group study, the following issues were identified as needing to be examined in the driver comprehension study:

- Colors to indicate passable and impassable water hazards.
- Colors to indicate advisory vs. regulatory messages.
- Colors to indicate "in effect" vs. "not currently in effect."
- Units/elements of information to be included on changeable message signs.
- Sign messages to indicate passable and impassable water hazards.
- Sign messages to indicate action drivers should take regarding a low-water crossing/flood site, including messages that would not require an active element such as lights.
- Colors, color-coding, and markings for flood gauges.
- Colors of lights.
- Messages for use with barricades.

CHAPTER 5. FLOOD SIGNS—DRIVER COMPREHENSION SURVEYS

The focus groups yielded some basic information regarding how Texas drivers estimate the risks of crossing a water-covered section of roadway and the kinds of information they consider useful for aiding their decisions. Some highlights of the focus group results were as follows:

- Focus group participants indicated that they would decide to continue on a water-covered road or not based on criteria including the depth and speed/movement of water, road condition, and their own familiarity with the road, as well as personal factors such as the type of vehicle they were driving. However, the depth of water considered potentially dangerous varied widely among the participants, and they had difficulty estimating the depth of water seen in photographs of flooded roads.
- Participants wanted positive guidance about whether they should attempt to cross water over a roadway. Flood gauges that are easy to see and read, signs with directive messages, and active elements (e.g., flashing lights, DMS) were among the devices suggested most often.
- Advance warning of a flooded road was considered valuable information, but several participants questioned the reliability of signs stating that the road ahead was closed due to (not yet visible) water, particularly if the sign indicated a flooded road on a sunny day.

Additional suggestions and requests were received from the project panel regarding the types of signs and devices that could assist TxDOT district and area engineers in improving the safety of flood-prone areas in their jurisdictions:

- Static signs and/or devices that would provide positive guidance until TxDOT personnel could arrive to evaluate and close a road if necessary.
- Alternatives to flip-down signs.

In this portion of the study, surveys were designed to test drivers' interpretations of and responses to the messages, colors, and other elements of several flood-related signs and devices that are in use by TxDOT, described by the 2009 MUTCD, or designed/selected by the research team to meet some of the most frequent focus group requests. The surveys were designed to address the following research objectives:

- Driver response to static signs and flood gauges: Which static signs and flood gauge styles are the most effective at influencing driver responses on a flood-prone road?
- Driver response to active signs at a flood-prone site: How effectively do active signs influence driver responses at a flood-prone site? How do drivers respond to active signs that appear to be sending an incorrect message, such as a false alarm or activation failure?
- Driver response to stop bars at a flood-prone site. Does a stop bar increase the effectiveness of a "do not enter," "do not cross," or "road closed" sign message?

- Driver response to static and active signs at the beginning of a flood-prone road: Which signs are the most effective at influencing driver responses at the entrance to a flood-prone road, where flood-prone sites are not yet visible?
- Driver preferences: Which of the passive signs, active signs, and gauges selected for the survey do drivers consider to be the most useful in making decisions about the safety of water-covered roadways?

This chapter provides a description of the questions asked in the survey, their results, and conclusions regarding driver comprehension of different sign types and messages.

Procedure

Participants

Researchers surveyed 200 participants in four Texas cities: San Antonio, San Angelo, Odessa, and College Station. The goal was to survey 50 participants in each city. Recruitment consisted of contacting potential participants in TTI's participant database and distributing flyers containing information about the survey. Participants were paid $20 for their participation, and each session lasted approximately 20–30 minutes.

The gender distribution of the participants is shown in Table 9 with a total of 108 females and 92 males. The participants' age distribution is shown in Table 10.

Table 9. Participant Gender Distribution by City.

Response	College Station	Odessa	San Angelo	San Antonio	Total
Male	32.4%	52.4%	50.0%	43.1%	46%
Female	67.6%	47.6%	50.0%	56.9%	54%
Sample Size	34	63	52	51	200

Table 10. Participant Age Distribution by City.

Age Range	College Station	Odessa	San Angelo	San Antonio	Total
18–29	32.6%	30.2%	38.5%	29.4%	32.5%
30–39	2.9%	20.6%	13.5%	17.6%	15.0%
40–49	8.8%	12.7%	15.4%	23.5%	15.5%
50–59	20.6%	25.4%	28.8%	23.5%	25.0%
60–69	17.6%	9.5%	1.9%	5.8%	8.0%
70–79	17.6%	1.6%	1.9%	0%	4.0%
80+	0%	0%	0%	0%	0.0%
Sample Size	34	63	52	51	200

Survey Presentation

The survey was developed using software called SuperLab™. The software allows a controlled presentation of photographs, text, and video while recording participants' keystroke responses. The software can be programmed to follow a prescribed order of presentation of test items or can create a unique random order for each participant, as was done for this study. For this study, the speed of presentation of photographs, questions, and instruction pages was controlled by the participants through use of a button box connected to the computer (described below). Timed presentation of photographs, response time measurements, and video stimuli was not utilized.

Participants were tested individually in a conference room with four computer workstations present, as shown in Figure 23. Each participant viewed the survey on a 19-inch monitor connected to a laptop computer running the SuperLab™ software. A button box, as shown in Figure 24, was used instead of the keyboard for the subjects to enter their responses. The use of the box helps prevent operator error, especially with older participants who may be unfamiliar and/or uncomfortable using a computer keyboard. With the use of a button box, the survey is limited to multiple choice, with no open-ended answer opportunities.

Figure 23. Survey Workstation Set Up.

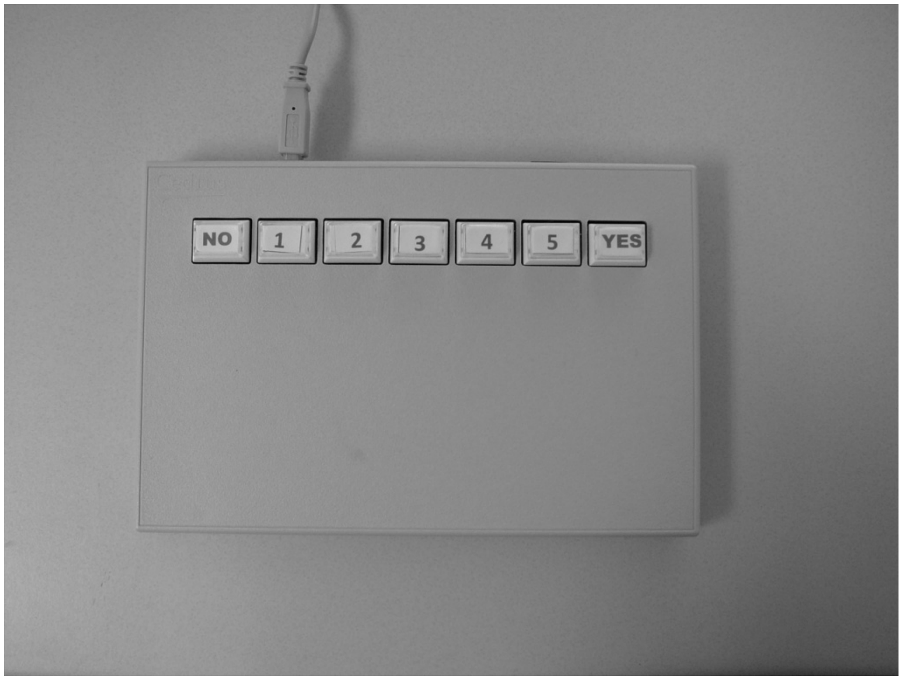


Figure 24. Button Box Used for Participant Response Entry.

Getting Started

The survey began with a brief explanation by the researcher of the button box and the binder, followed by the following instructions displayed on the computer screen:

> *Thank you for participating in this research study conducted by the Texas Transportation Institute. Please turn off all cell phones before beginning. You will not need to use the computer's keyboard for this study. You will only need to use the buttons on the box in front of you.*
> *Press any button when you are ready to begin.*
>
> *Please read each question carefully. When reading each question, please read ALL answer choices before selecting an answer.*
> *Today you will be looking at signs that you may find on rural roadways.*
> *Please let the researcher know if you have any questions at any time.*
> *Press any button to continue.*

The survey began by asking participants to enter information about themselves. Along with providing valuable information, this portion of the survey allowed the participants to become more familiar and comfortable with the button box and the interaction the survey would require.

As the participants completed the survey, the researcher remained present in the survey room to answer any questions and to monitor progress.

Presentation of Survey Questions

As previously stated, the survey questions were designed to test participant responses to and preferences for selected warning signs and flood gauges. Picture "scenarios" created for Objectives 1 through 4 were designed to measure participant responses to the following:

- Objective 1: static warning signs and gauges.
- Objective 2: active warning signs.
- Objective 3: stop bar pavement markings used in conjunction with selected warning signs.
- Objective 4: warning signs (static and active) placed at the entrance to a flood-prone road.
- Objective 5: driver preferences.

Participants saw a similar sequence of slides for each scenario tested (see Figure 25):

1) A slide with the following instructions: *"You are going to see two pictures that were taken in sequence driving down a road. Look at the first picture, then press any button to see the second picture. After the second picture, press any button to see questions about what you saw."*
2) Two pictures that represented two successive points along a road. The first picture displayed one of the two advance warning signs. The second picture displayed a flood-prone site on the road; the roadway in the picture might be dry, have a low level of water over the road (shown as 6 inches deep on the flood gauge), or have a high level of water (shown as 18 inches deep on the gauge). The site would be marked with a flood gauge, either by itself or accompanied by a static or active warning sign and, in Objective 3 scenarios, a stop bar marking. Exceptions to this sequence were the Objective 4 scenarios, which consisted of one picture showing a sign at the entrance to a road.
3) Three or four question slides, each displaying a question and multiple-choice answers:
    a. *Would you continue driving on this road?* (Yes/No)
    b. *From the information shown, how risky do you think it would be to continue on this road?* (1 to 5, with 1 defined as "not at all risky" and 5 defined as "extremely risky")
    c. *If five other drivers saw this scenario, how many of them do you think would continue on this road?* ("0 out of 5" other drivers to "5 out of 5" other drivers)
    d. *Do you think you could get a traffic citation (ticket) for continuing on this road?* (Yes/No)

Question "a" was intended to address the fundamental questions of whether some signs outperform others in deterring drivers from continuing into the water. Questions "b" and "c" were included because of feedback that had been received during the focus group discussions and were intended to assess participant's tolerance for risk related to water on roadways.

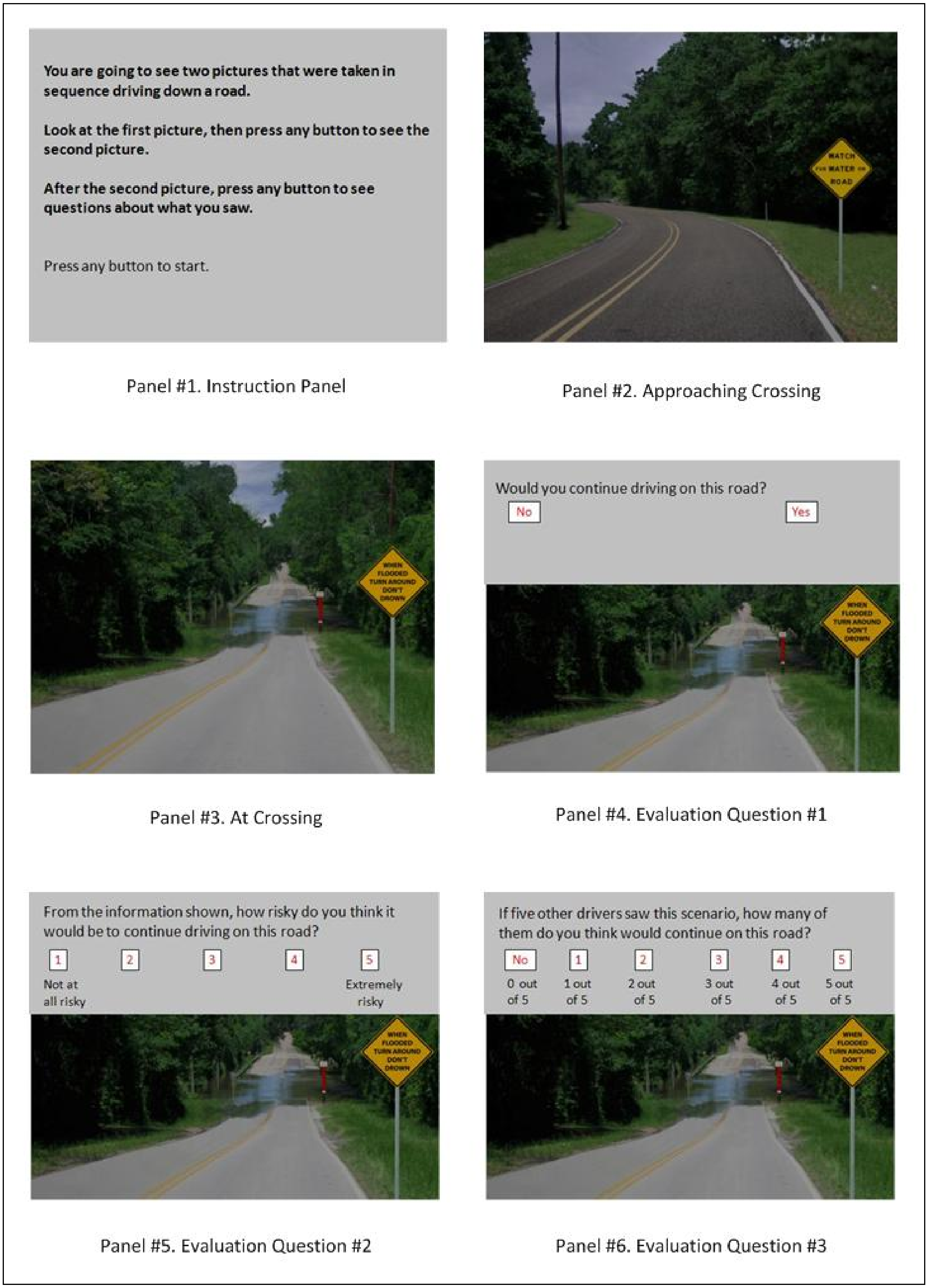


Figure 25. Sequencing of Panels Used in Driver Comprehension Studies.

Question “d” was asked only for the active signs shown in Objective 2 and 3 scenarios, to see if participants thought that flashing beacons or an activated light-emitting diode (LED) message meant that the sign’s message was regulatory rather than advisory.

The scenarios for Objectives 1 through 4 were presented in random order for each participant.

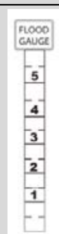
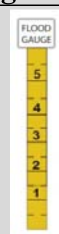
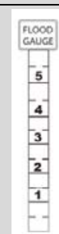
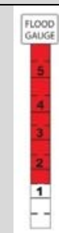
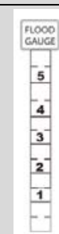
Objective 5 questions asked participants to choose the signs and gauge types they felt provided the best information to drivers about flooded roadways. These questions were the only ones not presented in a random order; they were the final five questions that every participant answered.

Static Signs and Gauges

The first objective of the driver comprehension study focused on participants’ responses to static warning signs and flood gauges. Two advance signs, three gauge types, and two different warning signs at/near the flood-prone site were tested, crossed with three different roadway conditions (dry road at flood site, low water at flood site, high water at flood site) on two roads. The tested combinations of advance sign, road condition, gauge style, and sign at the flood-prone site are indicated with a check-mark in Table 11. This resulted in 32 scenarios, which were labeled 1.1 through 1.32.

Two different sets of roadway pictures were used for Objective 1 scenarios. “Road 1” was used for the 16 scenarios that used the WATCH FOR WATER ON ROAD advance sign (see Figure 26). “Road 2” was used for the 16 scenarios that began with the ROAD MAY FLOOD advance sign (see Figure 27). The two different roads (and “Road 3,” which was used as a background for most of the active signs in Objective 2) provided visual variety and helped to minimize learning effects, particularly since participants saw all the scenarios in random order.

Table 11. Combination of Advance, At-Crossing, and Gauge Treatments Tested for Passive Crossing.

Road Condition at Flood-Prone Site[a]	Advance Warning Sign	Warning Sign Located at Crossing						
		No Sign (Gauge Only)						
		Gauge Colors			Gauge Colors		Gauge Colors	
								
No Water (Dry)		✓	-	-	✓	-	✓	-
		✓	-	-	✓	-	✓	-
Low Water		✓	-	✓	✓	✓	✓	✓
		✓	-	✓	✓	✓	✓	✓
High Water		✓	✓	✓	✓	✓	✓	✓
		✓	✓	✓	✓	✓	✓	✓

"✓" indicates configuration was tested, "-" indicates configuration was not tested

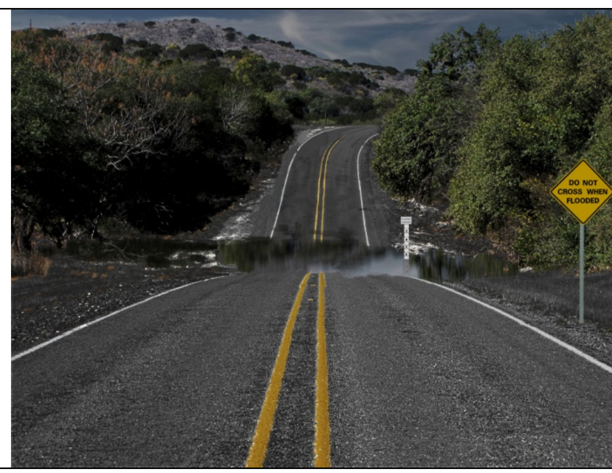
Road 1: Advance Sign Picture
Watch for Water on Road

Road 1: Flood Site Picture
Shown here with white gauge only. Questions varied water level, gauge, sign, as shown in Table 11.

Figure 26. Example Pictures for Scenarios 1.1 through 1.16.

(the pictures shown feature the advance warning sign and the white flood gauge that are the current TxDOT standard treatment for flood-prone sites).

Road 2: Advance Sign Picture
Road May Flood

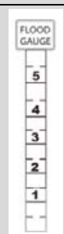
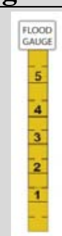
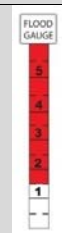
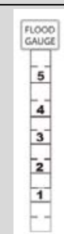
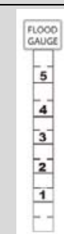


Road 2: Flood Site Picture
Shown here with white gauge plus sign at site. Questions varied water level, gauge, sign, as shown in Table 11.

Figure 27. Example Pictures for Scenarios 1.17 through 1.32.

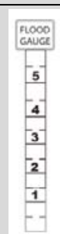
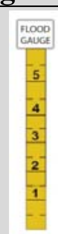
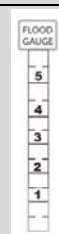
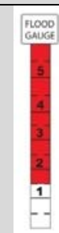
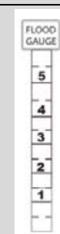
Responses to the three questions asked for each scenario are shown in Table 12 through Table 14. Values in these tables are taken or calculated from the “Total” columns of Results 1.1 to 1.32 in Appendix B.

Table 12. Percentage of Respondents Who Would Not Continue on the Road Shown.

Amount of Water Present at Crossing[a]	Advance Warning Sign	Warning Sign Located at Crossing						
		No Sign (Gauge Only)			WHEN FLOODED TURN AROUND DON'T DROWN		DO NOT CROSS WHEN FLOODED	
		Gauge Colors			Gauge Colors		Gauge Colors	
								
No Water (Dry)	WATCH FOR WATER ON ROAD	7.4%	-[b]	-[b]	15.2%	-[b]	7.6%	-[b]
	ROAD MAY FLOOD	0.0%	-[b]	-[b]	3.0%	-[b]	4.5%	-[b]
Low Water	WATCH FOR WATER ON ROAD	39.4%	-[b]	28.8%	55.9%	35.3%	40.9%	33.3%
	ROAD MAY FLOOD	12.1%	-[b]	4.5%	5.9%	5.9%	7.6%	6.1%
High Water	WATCH FOR WATER ON ROAD	87.9%	93.9%	98.5%	98.5%	97.0%	95.6%	91.2%
	ROAD MAY FLOOD	60.6%	62.1%	63.6%	66.7%	78.8%	73.5%	76.5%

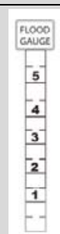
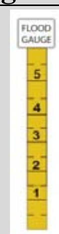
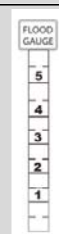
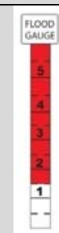
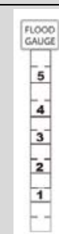
[a] See “Effect of Roadway” section for explanation of results.
[b] This configuration was not tested in this study.

Table 13. Average Risk Score Associated with Driver Continuing on Road Shown.[a]

Amount of Water Present at Crossing[b]	Advance Warning Signs	Warning Sign Located at Crossing						
		No Sign (Gauge Only)			WHEN FLOODED TURN AROUND DON'T DROWN		DO NOT CROSS WHEN FLOODED	
		Gauge Colors			Gauge Colors		Gauge Colors	
								
No Water (Dry)	WATCH FOR WATER ON ROAD	1.5	-[c]	-[c]	1.5	-[c]	1.4	-[c]
	ROAD MAY FLOOD	1.0	-[c]	-[c]	1.3	-[c]	1.2	-[c]
Low Water	WATCH FOR WATER ON ROAD	2.7	-[c]	2.8	3.0	2.7	2.8	2.5
	ROAD MAY FLOOD	1.6	-[c]	1.6	1.9	1.7	1.7	1.7
High Water	WATCH FOR WATER ON ROAD	4.2	4.2	4.4	4.6	4.7	4.5	4.5
	ROAD MAY FLOOD	3.2	3.4	3.6	3.5	3.8	3.4	3.6

[a] Participants could select from risk score ranging from 1 = "Not at all Risky" to 5 = "Extremely Risky."
[b] See "Effect of Roadway" section for explanation of results.
[c] This configuration was not tested in this study.

Table 14. Average Estimated Number of "Other Drivers" Who Would Continue on the Road Shown.[a]

Amount of Water Present at Crossing[b]	Advance Warning Signs	Warning Sign Located at Crossing						
		No Sign (Gauge Only)			WHEN FLOODED TURN AROUND DON'T DROWN		DO NOT CROSS WHEN FLOODED	
		Gauge Colors			Gauge Colors		Gauge Colors	
								
No Water (Dry)	WATCH FOR WATER ON ROAD	4.5	-[c]	-[c]	4.5	-[c]	4.7	-[c]
	ROAD MAY FLOOD	4.9	-[c]	-[c]	4.7	-[c]	4.7	-[c]
Low Water	WATCH FOR WATER ON ROAD	3.3	-[c]	3.7	3.1	3.5	3.3	3.9
	ROAD MAY FLOOD	4.3	-[c]	4.5	4.1	4.4	4.6	4.6
High Water	WATCH FOR WATER ON ROAD	1.7	2.1	2.2	1.5	1.6	1.6	1.5
	ROAD MAY FLOOD	3.0	2.9	2.8	2.6	2.3	2.8	2.4

[a] Participants could select from 0 to 5 out of 5 other drivers would continue on road shown.
[b] See "Effect of Roadway" section for explanation of results.
[c] This configuration was not tested in this study.

The following questions were asked in analyzing participant responses to the combinations of static signs and gauges in 32 scenarios shown in Table 11:

- What is the effect of the water level shown in the pictures?
- Were there differences in responses to the two roads shown?
- Were there differences in responses to the two advance signs (WATCH FOR WATER ON ROAD; ROAD MAY FLOOD)?
- What are the effects of the static signs and gauges at the flood site?
  - Were there differences in responses for different gauge types (for low- and high-water conditions)?
  - Were there differences between the gauge-only, gauge plus WHEN FLOODED TURN AROUND DON'T DROWN sign, and gauge plus DO NOT CROSS sign?

Effect of Water Level

The water levels shown in the pictures were expected to have the following effects on participant responses:

- Percentage of participants saying they would NOT continue on the road was expected to increase from the dry-road condition to the low-water condition to the high-water condition on each of the three roadways.
- Average risk score was expected to increase moving from dry road to low water to high water.
- Average estimated number of "other drivers" expected to continue on the road was expected to decrease moving from dry road to low water to high water.

These three effects were in fact seen for both of the roadways used in the static-sign scenarios. Roadway condition (dry vs. low water vs. high water) was found to have a significant effect (X^2=494.8, p = .0001) on the percentage of participants who said they would not continue on the road shown; significant differences over the three roadway conditions were also seen for the estimated risk of continuing and for the estimated number of "other drivers" who would continue. The average of the responses for dry, low-water, and high-water roadway conditions is shown in Table 15. Figure 28 illustrates the percentage of respondents who indicated they would not continue on the road pictured under each roadway condition. Figure 29 illustrates participants' average risk assessment (*increasing* as the water on the pictured roadways increased), and Figure 30 shows their average estimate of the number of other drivers who would continue on the road as shown (*decreasing* as the water on the roadways increased).

Table 15. Average Responses to Questions: Scenarios 1.1 to 1.32.

Question	Dry Road	Low Water over Road	High Water over Road
a. Percentage of participants who would not continue on the road shown	6.3%	22.98%	81.7%
b. Average estimated risk of continuing (1 = low risk, 5 = high risk)	1.4	2.2	4.0
c. Average estimated number of other drivers who would continue on the road shown (from 0 to 5 out of 5)	4.7	3.9	2.2

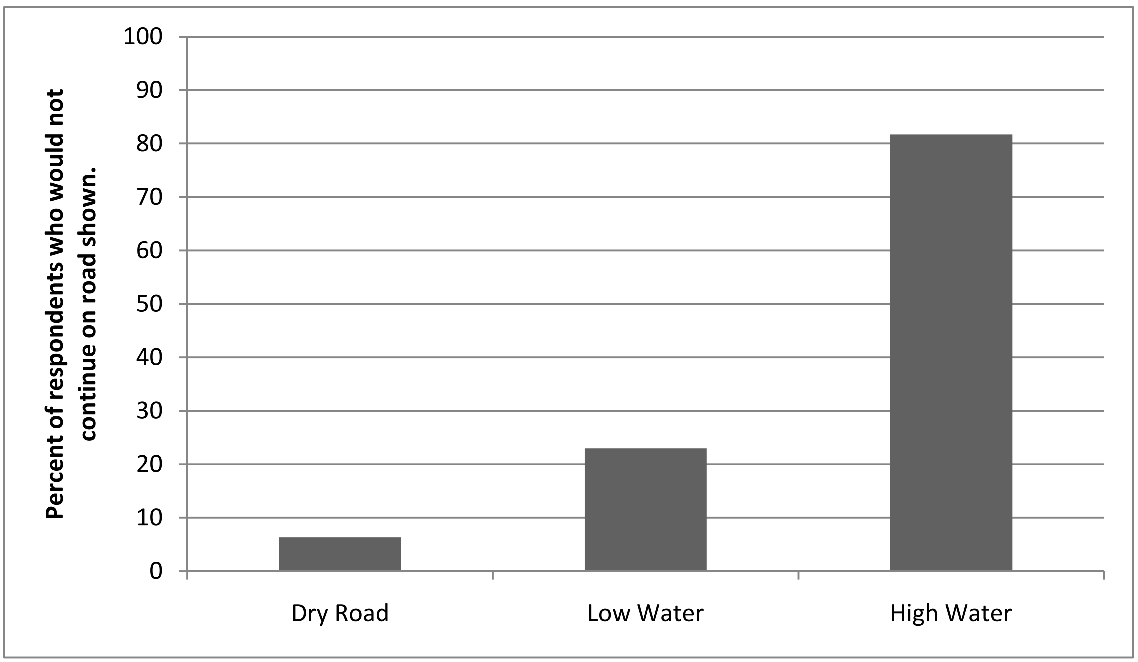


Figure 28. Percent of Respondents Who Would Not Continue on Dry, Low-Water, and High-Water Road Conditions (Scenarios 1.1 to 1.32).

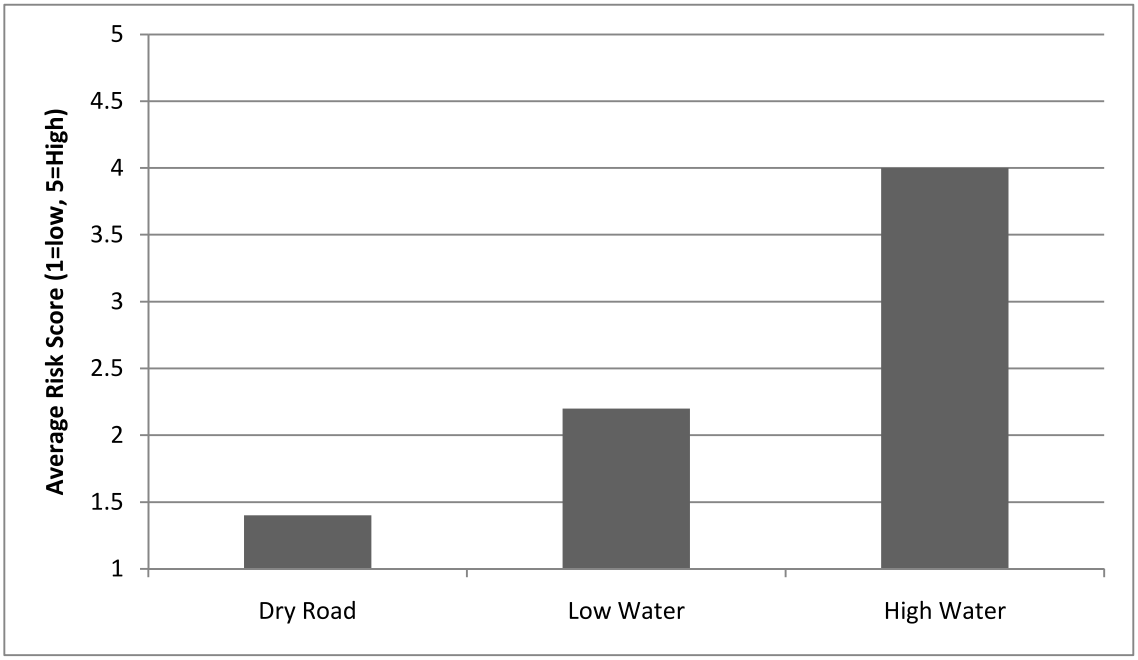


Figure 29. Average of Risk Scores for Dry, Low-Water, and High-Water Road Conditions (Scenarios 1.1 to 1.32).

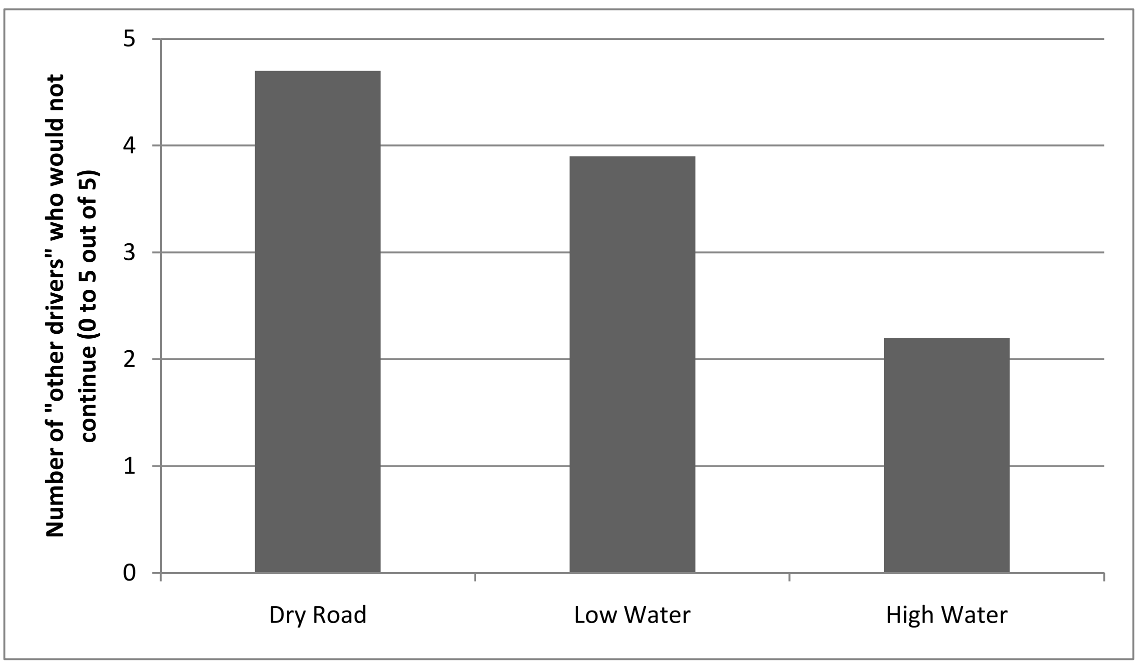


Figure 30. Number of "Other Drivers" Who Would Be Expected to Continue—Average Estimate for Dry, Low-Water, and High-Water Roads (Scenarios 1.1 to 1.32).

Effect of Roadway

The effects of the gauges and signs shown in each of the scenarios must be considered in the context of the roadways on which they were displayed.

As can be seen in Table 12, Table 13, and Table 14, there was a notable difference in participant responses to the scenarios that used the WATCH FOR WATER ON ROAD advance sign vs. the scenarios that used the ROAD MAY FLOOD advance sign. However, as stated previously, the two advance signs were consistently pictured on different roads as shown in Figure 26 and Figure 27—i.e., WATCH FOR WATER ON ROAD was consistently shown on Road 1, and ROAD MAY FLOOD was consistently shown on Road 2. Despite attempts to make the dry, low-water, and high-water conditions appear approximately equal in simulated risk for each road, some comments made by participants indicated that the flooding in the Road 2 pictures (following the ROAD MAY FLOOD slide) did not look as dangerous as the flooding in the Road 1 pictures (following WATCH FOR WATER ON ROAD).

To help distinguish participant responses to the two different advance signs from participant responses to the roadways on which they appeared, a partial follow-up survey was conducted in which 23 participants were shown the two advance signs on both sets of roadways at the high-water level. The results of this follow-up survey supported the hypothesis that participants' responses differed significantly between Roads 1 and 2, regardless of which advance sign was pictured. Responses to the question "would you continue on this road or not?" in this follow-up survey are summarized in Table 16.

Effects of Static Signs and Gauges at the Flood Site

The relative effects of the gauge styles and static signs at the flood-prone site were far less dramatic than the effects of the roadway and water level.

Responses to gauge styles. At low water levels, participants were significantly less likely (X^2 = 7.2, p = .007) to continue on the road when the standard white flood gauge was shown than when the red/white gauge was shown (see Figure 31). This may be because participants paid more attention to the measured depth of water (6 inches) shown on the white gauge and figured that depth into their decision process. The 6-inch-deep water did not reach the red portion of the color-coded gauge, and participants viewing those pictures seemed more likely to interpret the water as being safe to cross.

The difference in participant responses between the two roadways in high-water conditions was significant (X^2 = 19.4, p = .0001); the difference in responses to the two advance signs was not significant.

Table 16. Percentage of Respondents Who Would Not Continue on the Road Shown: Comparison of Advance Signs on Roads 1 and 2.

Scenario	Scenes Depicting Scenario		Advance Warning Signs	Warning Sign Located at Crossing (with White Gauge)	
	Approach to Crossing	Water Level at Crossing			
Road 1				94.4	100.0
				100.0	94.4
Road 2				69.9	69.6
				73.9	69.6

White gauge, low water level | Red/white gauge, low water level

Figure 31. Examples of White and Red/White Gauges at Low Water Levels.

Figure 32 shows the relative percentages of participants who indicated that they would not continue on the roads shown (at low water levels).

At high water levels, when the pictured water level was at 18 inches and reached the red upper portion of the gauge, responses to the gauge styles (white, yellow, and red/white) were not significantly different.

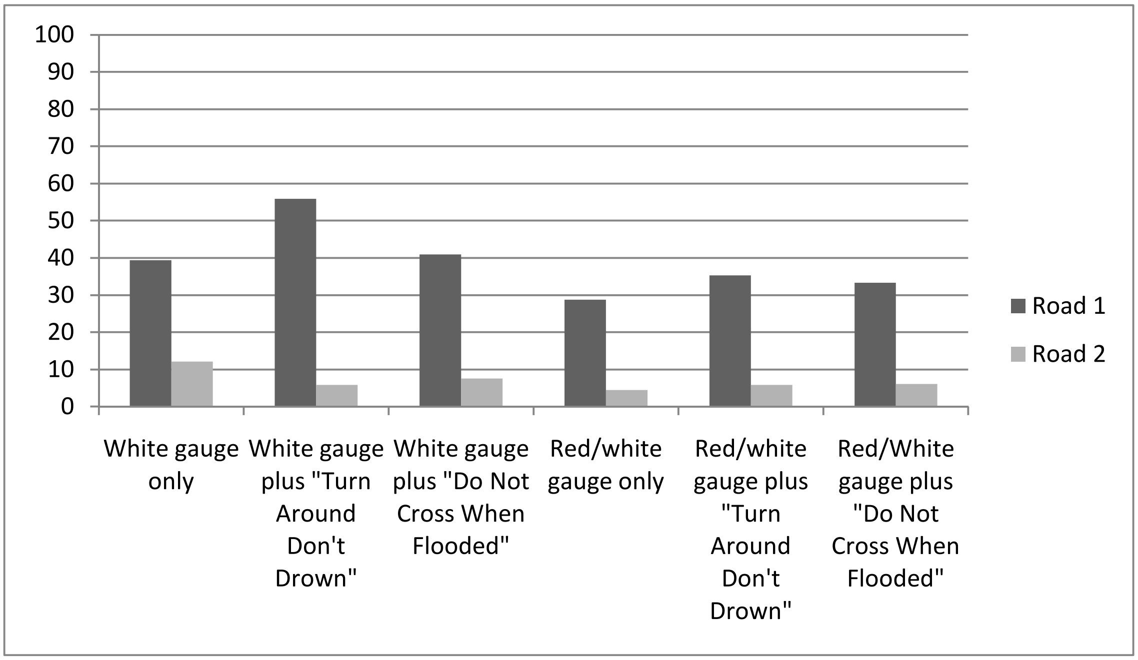


Figure 32. Percent of Participants Who Would Not Continue on the Road Shown: Comparison of White and Red/White Gauges, Low-Water Condition.

Responses to static signs at the flood site. Participant responses to a flood gauge alone, a flood gauge plus the WHEN FLOODED TURN AROUND DON'T DROWN static sign, and a flood gauge plus the DO NOT CROSS WHEN FLOODED sign were compared. The presence of either static sign at the site in addition to the flood gauge did not significantly alter participants' likelihood to continue on the pictured road at either low or high water levels. At high water levels, a significant difference was found in participants' estimate of risk when either static sign was present in addition to a gauge ($X^2 = 11.3$; $p = .01$); participants who viewed either of the two signs in addition to the gauge at the crossing estimated the risk of continuing on the road to be higher than did the participants who viewed a gauge by itself, though the higher risk estimate was not reflected in the decision to continue or not.

Active Warning Signs

The second objective focused on participants' responses to active warning signs at a flood-prone site. The advance sign used for all Objective 2 questions was WATCH FOR WATER ON ROAD and the flood gauge at the site was white. Four different active signs were tested, varying both the water level at the flood-prone site and the active element of each sign. For three of the signs, the active element was a pair of beacons that could be shown flashing red, flashing yellow, or turned off. The fourth sign was an LED sign that displayed the words DO NOT ENTER when on and nothing when off.

The active signs were tested in dry, low-water, and high-water roadway conditions. In some of the scenarios, the signs were shown in "false alarm" (activated warning coupled with a dry or low-water condition) or "failure" mode (non-activated warning coupled with a high-water condition) to test effects on participant response.

The tested combinations of road condition, water level, active sign type and active element condition are shown in Table 17. In all these scenarios, WATCH FOR WATER ON ROAD was used as the advance sign for the active warning sign treatments.

Table 17. Candidate Signing Treatments Tested at Active Crossing Site.

Amount of Water Present at Crossing	 Beacon Color			 Beacon Color			 Beacon Color			 (LED)	
	Off	**Yellow**	**Red**	**Off**	**Yellow**	**Red**	**Off**	**Yellow**	**Red**	**Off**	**On**
No Water (Dry)	-	-	✓	-	-	✓	-	-	✓		✓
Low Water	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
High Water	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

"✓" indicates configuration was tested, "-" indicates configuration was not tested
"Dark" beacon color means that the beacon is not flashing (or is "off")

The 26 scenarios that were created for Objective 2 (labeled 2.1 through 2.26) each consisted of two pictures, as shown in Figure 33. The first picture displayed the advance warning sign WATCH FOR WATER ON ROAD. The second picture displayed a dry, low-water, or high-water site with a white flood gauge and an active warning sign; the water levels were the same as in the Objective 1 scenarios.

Responses to the three questions asked for each scenario are shown in Table 18 through 21. Values in these tables are taken from the "Total" columns for Results 2.1 to 2.26 in Appendix B.

	
Advance Sign picture (Road 3)	Flood Site picture (Road 3) Varied sign, active element, water level, as shown in Table 17.

Figure 33. Example Pictures for Objective 2 (Active Signs).

Table 18. Percentage of Respondents Who Would Not Continue on the Road Shown with Active Signing Treatments.

Amount of Water Present at Crossing										 (LED)	
	Beacon Color			Beacon Color			Beacon Color				
	Off	Yellow	Red	Off	Yellow	Red	Off	Yellow	Red	Off	On
No Water (Dry)	-[a]	-[a]	34.0	-[a]	-[a]	[a]46.9	-[a]	-[a]	[a]54.0	-[a]	74.5 [b]
Low Water	18.0	52.0[b]	56.0 [b]	34.7	69.4[b]	67.3 [b]	26.0	52.0[b]	60.0[b]	21.6	70.6 [b]
High Water	84.0 [c]	96.0	98.0	72.5 [c]	100.0	92.2	86.0 [c]	94.0	92.0	83.7 [c]	98.0

WATCH FOR WATER ON ROAD was used as advanced warning signing ahead of crossing

[a] Configuration not tested

[b] Reflects “False Alarm” condition – active treatment “on” but crossing passable

[c] Reflects “System Failure” condition

Table 19. Risk Score Associated with Driver Continuing on Road Shown with Active Signing Treatments

Amount of Water Present at Crossing										 (LED)	
	Beacon Color			Beacon Color			Beacon Color				
	Off	Yellow	Red	Off	Yellow	Red	Off	Yellow	Red	Off	On
No Water (Dry)	-[a]	-[a]	2.4 [b]	-[a]	-[a]	2.8 [b]	-[a]	-[a]	2.7 [b]		3.3[b]
Low Water	2.4	3.0 [b]	3.1 [b]	2.6	3.4 [b]	3.3 [b]	2.5	3.0 [b]	3.1 [b]	2.2	3.4[b]
High Water	4.0 [c]	4.4	4.5	3.6 [c]	4.2	4.3	4.0 [c]	4.5	4.4	3.9[c]	4.6

Note: Participants asked to assess risk on scale between 1 and 5, where 1 = "Not at all Risky" and 5 = "Extremely Risky."
WATCH FOR WATER ON ROAD was used as advanced warning signing ahead of crossing
[a] Configuration not tested
[b] Reflects "False Alarm" condition – active treatment "on" but crossing passable
[c] Reflects "System Failure" condition

Table 20. Average Estimated Number of "Other Drivers" Who Would Continue on the Road Shown (from 0 to 5 out of 5) with Active Signing Treatments.

Amount of Water Present at Crossing										 (LED)	
	Beacon Color			Beacon Color			Beacon Color				
	Off	Yellow	Red	Off	Yellow	Red	Off	Yellow	Red	Off	On
No Water (Dry)	-[a]	-[a]	3.8 [b]	-[a]	-[a]	3.2 [b]	-[a]	-[a]	3.5 [b]	-[a]	2.7 [b]
Low Water	3.6	3.1 [b]	3.0 [b]	3.6	2.7 [b]	2.5 [b]	3.7	3.3 [b]	2.9 [b]	4.0	2.6 [b]
High Water	2.2 [c]	1.9	1.7	2.6 [c]	2.0	1.6	2.0 [c]	1.6	1.8	2.2 [c]	1.4

WATCH FOR WATER ON ROAD was used as advanced warning signing ahead of crossing
[a] Configuration not tested
[b] Reflects "False Alarm" condition – active treatment "on" but crossing passable
[c] Reflects "System Failure" condition

Table 21. Percentage of Respondents Who Think Continuing on the Road Shown Could Result in a Traffic Citation with Active Signing Treatments.

Amount of Water Present at Crossing											
	Beacon Color			Beacon Color			Beacon Color				
	Off	Yellow	Red	Off	Yellow	Red	Off	Yellow	Red	Off	On
No Water (Dry)	-[a]	-[a]	42.0[b]	-[a]	-[a]	61.2[b]	-[a]	-[a]	[a]54.0[b]	-[a]	72.5[b]
Low Water	18.0	46.0[b]	58.0[b]	22.4	65.3[b]	69.4[b]	16.0	56.0[b]	72.0[b]	6.5	82.4[b]
High Water	28.0[c]	66.0	66.0	31.4[c]	64.7	74.5	40.0[c]	80.0	86.0	30.6[c]	89.8

WATCH FOR WATER ON ROAD was used as advanced warning signing ahead of crossing

[a] Configuration not tested

[b] Reflects "False Alarm" condition – active treatment "on" but crossing passable

[c] Reflects "System Failure" condition

The following questions were asked in analyzing participant responses to the combinations of static signs and gauges in scenarios 2.1 through 2.26:

- For each of the three roadway conditions, did participants respond differently to active signs that were off vs. active signs that were on?
  - Dry road—active signs on vs. static signs.
  - Low water—active signs on vs. active signs off.
  - High water—active signs on vs. active signs off.
- Did participants respond differently to the four different sign messages?
- Did participants respond differently to yellow vs. red beacons?

Effects of Sign Messages

At high water levels, there were no significant differences among participants' responses to the four active signs, with the exception of the question about the likelihood of getting a traffic citation for continuing past an active sign that was "on" (beacons flashing or LED illuminated). More participants believed that continuing past the DO NOT ENTER LED sign could result in a traffic ticket; this number was significantly higher than for any of the other three signs (X^2 ranged from 7.47 to 9.47 for the three comparisons; p-value ranged from .002 to .006).

At low water levels, HIGH WATER DO NOT ENTER WHEN FLASHING and DO NOT ENTER (LED sign) resulted in more participants deciding not to continue on the road shown compared to the other two signs. The following significant differences were found:

- HIGH WATER DO NOT ENTER WHEN FLASHING vs. ROAD FLOODED WHEN FLASHING and HIGH WATER ROAD CLOSED WHEN FLASHING—difference in number of participants saying they would not continue on the road ($X^2 = 4.2$, $p = .04$).
- DO NOT ENTER (LED) vs. ROAD FLOODED WHEN FLASHING and HIGH WATER ROAD CLOSED WHEN FLASHING—difference in number of participants saying they would not continue on the road ($X^2 = 4.4$, $p = .04$).
- DO NOT ENTER (LED) vs. HIGH WATER DO NOT ENTER WHEN FLASHING, ROAD FLOODED WHEN FLASHING, or HIGH WATER ROAD CLOSED WHEN FLASHING—difference in number of participants saying that continuing on the road could result in a traffic citation ($X^2 >= 3.74$, $p <= .05$).

Effects of Beacon Color

For the three signs with flashing beacons, no significant differences were found in responses based on red vs. yellow beacons, either for participants' likelihood to continue on the road, for their perceptions of risk, or for their predictions of getting a traffic citation for doing so.

Active Signs "Off" Compared to Active Signs "On"

Active signs had a significant effect on participant responses across all four sign messages/types and both beacon colors. The deterrent effect of the active signs was seen for all three road conditions.

At high water levels, most participants (approximately 82 percent) opted not to continue on the road even when the active signs were off. This is an important result because it indicates that even without the added cue from an active sign, the participants used other cues from the roadway and the flood gauge to make their decision about whether to continue on the road. When active signs were on, however, the number of participants saying they would not continue rose significantly to 96 percent ($X^2 = 29.7$, $p = .0001$).

At low water levels, an average of 25 percent of participants opted not to continue on the road when an active sign was off. When signs were on, this percentage rose significantly to 61 percent ($X^2 = 84$, $p = .0001$).

The four active signs were shown only in the "on" state for the dry-road condition. Responses to the static signs on a dry road were used for comparison. An average of 53 percent of participants said that they would not continue on the road when active signs were on, significantly more than the 6 percent who would not continue on the dry road with static signs ($X^2 = 82$, $p = .0001$).

Figure 34 shows the percentages of participants who indicated that they would not continue on the road with the active signs "on" vs. "off" (for the dry-road condition, the comparison is active signs "on" vs. static signs).

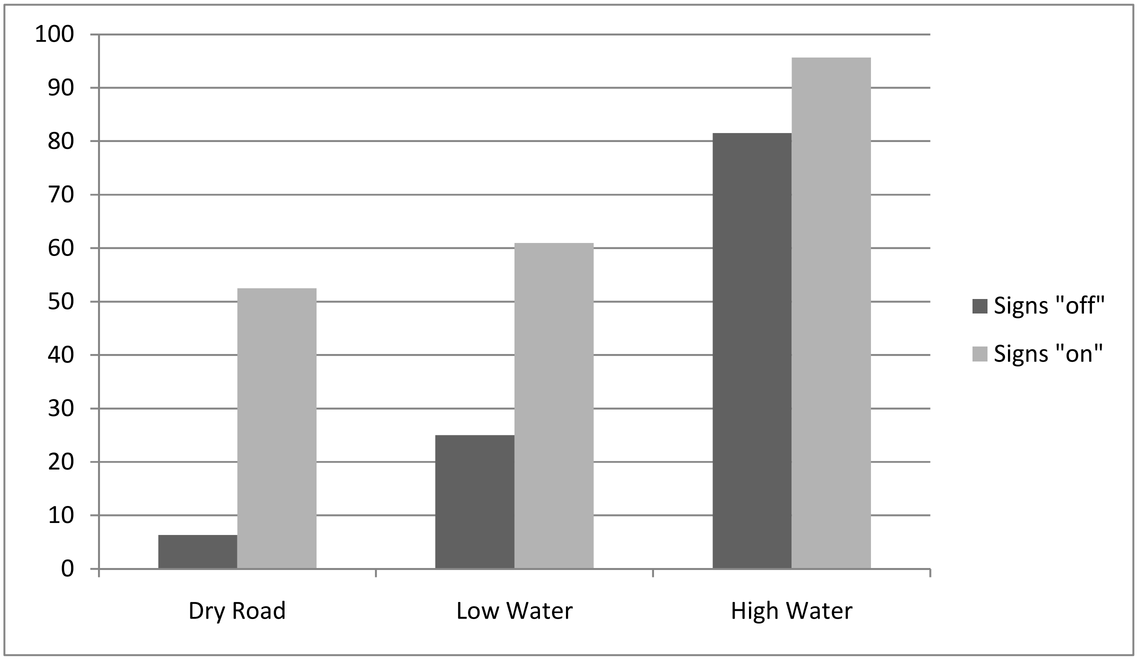


Figure 34. Percent of Participants Who Would Not Continue on the Road with Active Signing Treatments "On" vs. "Off."

Stop Bars at a Flood-Prone Site

For selected signs, a stop bar was added to the pictured road ahead of the flood-prone site to test whether driver responses to the accompanying signs were affected by the presence of this road marking. The four scenarios created for Objective 3 (labeled 3.1 through 3.4) are shown in Table 22. The two-picture sequences were the same as seen in the scenarios for Objective 1 (for the static DO NOT CROSS WHEN FLOODED sign) and Objective 2 (for the three active signs). The stop bar was tested once for each of the four signs shown in Table 22; the advance sign (WATCH FOR WATER ON ROAD) and road condition were held constant, and only one active element condition was shown for each active sign. Figure 35 provides an illustration of how a stop bar might be incorporated into the crossing warning treatments.

Table 22. Signing Treatments Tested with and without Stop Bars Present at Flood-Prone Sites.

Amount of Water Present at Crossing	Advance Warning Signs	 (static sign only)	 With Red Beacons	 With Red Beacons	 (LED)
High Water		✓	✓	✓	✓

Figure 35. Illustration of How a Stop Bar Might Be Used as part of a Flood-Prone Crossing Treatment.

Table 23 compares the percentage of participants who said they would not continue on the road shown, for the scenarios tested with and without a stop bar present. Table 24 compares the average perceived risk (with 1 being low and 5 being high) with and without the stop bar, and Table 25 compares the average estimated number of drivers (out of 5) that participants thought would continue on the road, with and without a stop bar present.

Table 26 compares the percentage of participants who thought it would be possible to get a traffic citation for continuing on the road, with and without the stop bar present. Complete results for Questions 3.1 through 3.4 are shown in Appendix B.

Table 23. Percentage of Respondents Who Would Not Continue on the Road Shown with and without the Addition of Stop Bars to Select Crossing Treatments.

Amount of Water Present at Crossing	Stop Bar Present	 (Static Sign Only)	 (with Red Beacons)	 (with Red Beacons)	 (LED on)
High Water	Without	95.6	92.2	92.0	98.0
	With	92.0	96.1	94.0	98.0

Table 24. Average Risk Score Assessment Associated Continuing on Roadway Shown with and without the Addition of Stop Bars to Select Crossing Treatments.

Amount of Water Present at Crossing	Stop Bar Present	 (Static Sign Only)	 (with Red Beacons)	 (with Red Beacons)	 (LED on)
High Water	Without	4.5	4.3	4.4	4.6
	With	4.4	4.3	4.5	4.6

Table 25. Average Estimated Number of "Other Drivers" Who Would Continue on the Road Shown (from 0 to 5 out of 5) with and without the Addition of Stop Bars to Select Crossing Treatments.

Amount of Water Present at Crossing	Stop Bar Present	 (Static Sign Only)	 (with Red Beacons)	 (with Red Beacons)	 (LED on)
High Water	Without	1.6	1.6	1.8	1.4
	With	1.9	1.6	1.6	1.5

Table 26. Percentage of Respondents Who Think Continuing on the Road Shown Could Result in a Traffic Citation.

Amount of Water Present at Crossing	Stop Bar Present	 (Static Sign Only)	 (with Red Beacons)	 (with Red Beacons)	 (LED on)
High Water	Without	n/a	74.5	86.0	89.8
	With	62.0	70.6	78.0	91.8

These questions were intended to determine whether the presence of a stop bar on the road, coupled with a sign ahead of a flooded site, would make drivers less likely to continue on the road, and/or likely to view continuing on the road as being more risky. Each participant saw one of the four scenarios listed in Table 22 (the WATCH FOR WATER ON ROAD advance sign, high water on the road ahead, and one of the four at-site signs), and saw the same scenario with and without a stop bar.

The results indicate that the presence of a stop bar did not significantly alter participants' perceptions of the roadway or their decisions about whether to proceed. Differences in the answers to all four questions were not significant.

Static and Active Signs at the Beginning of a Flood-Prone Road

One static and two different active signs were shown positioned at the entrance to a roadway to warn of possible flooding conditions farther down the road. These signs were all shown on a dry road, to test participant responses when the flood-prone site(s) could not be seen directly ahead (see Figure 36).

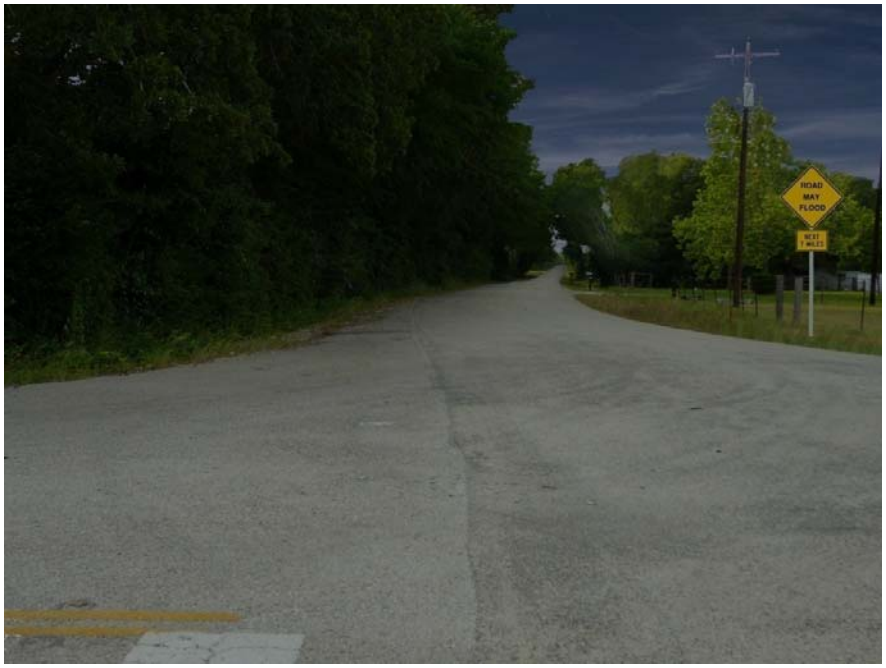


Figure 36. Background Picture Example for Objective 4 Scenarios.

Three different scenarios were created for Objective 4 (labeled 4.1 through 4.3), each using the same background picture (see Figure 34) and one of three different signs:

- HIGH WATER—ROAD CLOSED TO THRU TRAFFIC WHEN FLASHING (active sign; beacons flashing yellow).
- HIGH WATER—ROAD CLOSED USE ALTERNATE ROUTE WHEN FLASHING (active sign; beacons flashing yellow).
- ROAD MAY FLOOD NEXT 7 MILES (static sign).

Instructions were different for these scenarios, which consisted of only one picture rather than two: *“You are going to see a picture that was taken at a roadway intersection. Look at the picture, then press any button to see questions about what you saw.”*

Table 27 lists the scenarios (combinations of signs with roadway conditions) that were tested under Objective 4.

Table 27. Signing Treatments for Intersections in Advance of Flood-Prone Road.

Scenario Name	Candidate Signing Treatment
HIGH WATER—ROAD CLOSED TO THRU TRAFFIC WHEN FLASHING (beacons flashing yellow)	
HIGH WATER—ROAD CLOSED 10 MILES AHEAD LOCAL TRAFFIC ONLY WHEN FLASHING (beacons flashing yellow)	
ROAD MAY FLOOD NEXT 7 MILES (static sign only)	

Table 28 compares the percentage of participants who said they would not continue on the road shown. Table 29 compares the perceived risk (with 1 being low and 5 being high), and Table 30 compares the estimated number of drivers (out of 5) that participants thought would continue on the road. Complete results for Questions 4.1 through 4.3 are shown in Appendix B.

Table 28. Percentage of Participants Who Would Not Continue on the Road Shown with Signing Treatments for Intersections in Advance of Flood-Prone Road.

Sign	Percent
HIGH WATER—ROAD CLOSED TO THRU TRAFFIC WHEN FLASHING (beacons flashing yellow)	79.4
HIGH WATER—ROAD CLOSED 10 MILES AHEAD LOCAL TRAFFIC ONLY WHEN FLASHING (beacons flashing yellow)	78.8
ROAD MAY FLOOD NEXT 7 MILES (static sign only)	3.0

Table 29. Average Risk Score, Where 1 = "Not at all Risky" and 5 = "Extremely Risky."

Sign	Average Risk Score
HIGH WATER—ROAD CLOSED TO THRU TRAFFIC WHEN FLASHING (beacons flashing yellow)	3.8
HIGH WATER—ROAD CLOSED 10 MILES AHEAD LOCAL TRAFFIC ONLY WHEN FLASHING (beacons flashing yellow)	3.9
ROAD MAY FLOOD NEXT 7 MILES (static sign only)	1.8

Table 30. Average Estimated Number of "Other Drivers" Who Would Continue on the Road Shown (from 0 to 5 out of 5) with Signing Treatments for Intersections in Advance of Flood-Prone Road.

Sign	Average Estimated Number of "Other Drivers"
HIGH WATER—ROAD CLOSED TO THRU TRAFFIC WHEN FLASHING (beacons flashing yellow)	2.5
HIGH WATER—ROAD CLOSED 10 MILES AHEAD LOCAL TRAFFIC ONLY WHEN FLASHING (beacons flashing yellow)	2.6
ROAD MAY FLOOD NEXT 7 MILES (static sign only)	4.5

These questions were included to test how drivers respond to signs at the entrance to a roadway that warn about one or more flooded sites on that roadway. The roadway picture used for these questions did not show a visible flooded site; therefore, participants' responses depended entirely on the sign.

One static sign and two active signs were tested. Participants who saw the static sign were most likely to say they would continue on the road (only 3 percent said they would not), regarded continuing as relatively low risk (1.8), and predicted that 4.5 out of 5 other drivers would also continue on the road.

For the two active signs shown with yellow beacons flashing, responses were nearly identical: approximately 79 percent of participants said that they would not continue on the road. The risk of continuing on the road was rated at an average of 3.8 for one active sign and 3.9 for the other, and the estimated numbers of "other drivers" continuing on the road averaged 2.5 and 2.6. The specific message wording for these signs appeared to be far less important than the active component.

Driver Preferences for Signing Treatments

Which of the passive signs, active signs, and gauges selected for the survey do drivers consider to be the most useful in making decisions about the safety of water-covered roadways?

Questions 5.1 through 5.5 asked participants to choose the signs and gauge types they felt provided the best information to drivers about flooded roadways. These questions were the only ones not presented in a random order; they were the final five questions that every participant answered.

Driver Preference for Advance Sign Treatments

Participants viewed the slide shown in Figure 37 and selected their preferred sign option using the corresponding number on the button box. Table 31 shows the percent of participants preferring each sign.

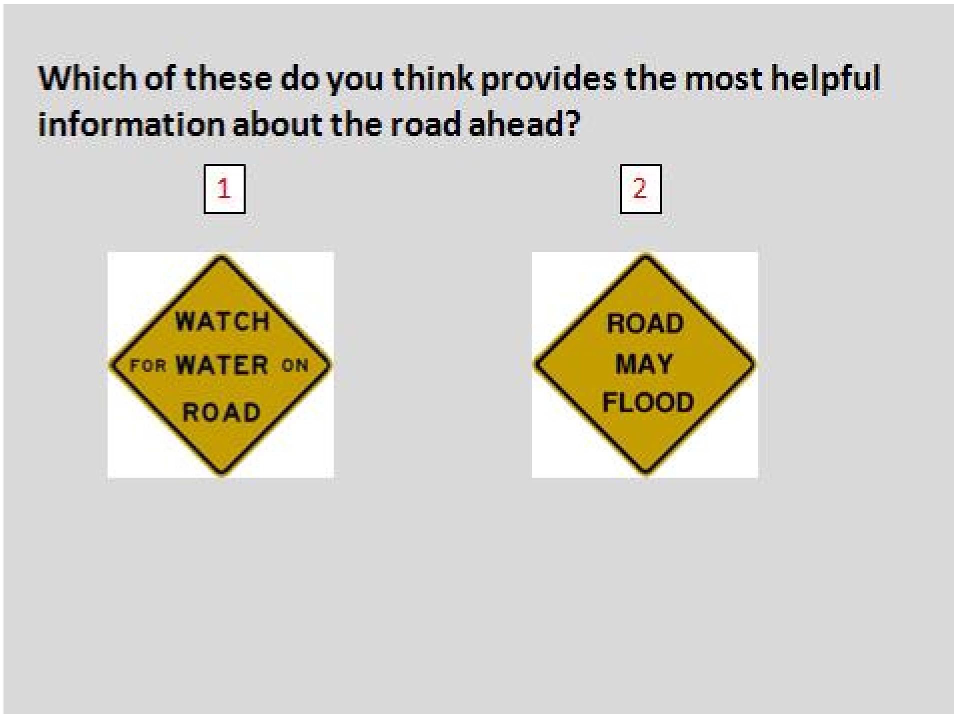


Figure 37. Advance Sign Treatments Tested in Driver Preference Study.

Table 31. Driver Preferences for Sign Treatments in Advance of Water Crossing.

Sign	Percent Preferred
WATCH FOR WATER ON ROAD	42.5%
ROAD MAY FLOOD	57.5%

Sample Size = 200

Of the two advance signs, ROAD MAY FLOOD was preferred by a significant majority of participants. This is consistent with the focus group discussions, in which participants stated a preference for the more specific warning about possible flooding on the roadway.

Driver Preference for Static Signs at Passive Crossings

Participants viewed the slide shown in Figure 38 and selected their preferred sign option using the corresponding number on the button box. Table 32 shows the percent of participants preferring each sign.

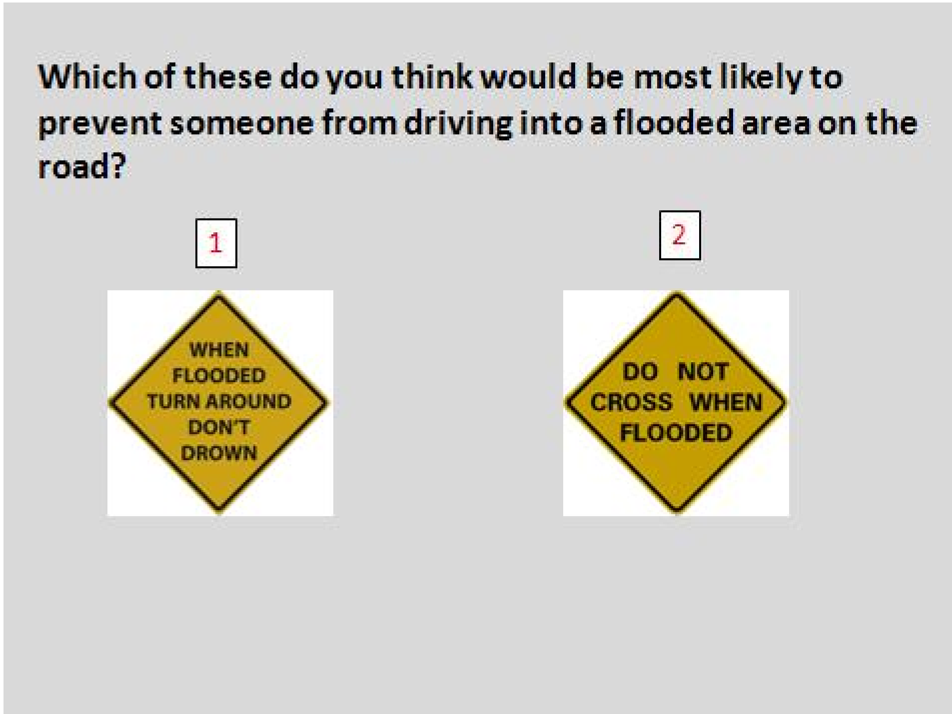


Figure 38. Passive Crossing Static Signs Tested in Driver Preference Study.

Table 32. Driver Preferences for Passive Crossing, Static Sign Treatments.

Sign	Percent Preferred
WHEN FLOODED TURN AROUND DON'T DROWN	47.5
DO NOT CROSS WHEN FLOODED	52.5
Sample Size	200

The percent difference in preference between *When* FLOODED TURN AROUND DON'T DROWN and DO NOT CROSS WHEN FLOODED was not statistically significant.

Driver Preference for Water Depth Gauge Design

Participants viewed the slide shown in Figure 39 and selected their preferred gauge style using the corresponding number on the button box. Table 33 shows the percent of participants preferring each gauge.

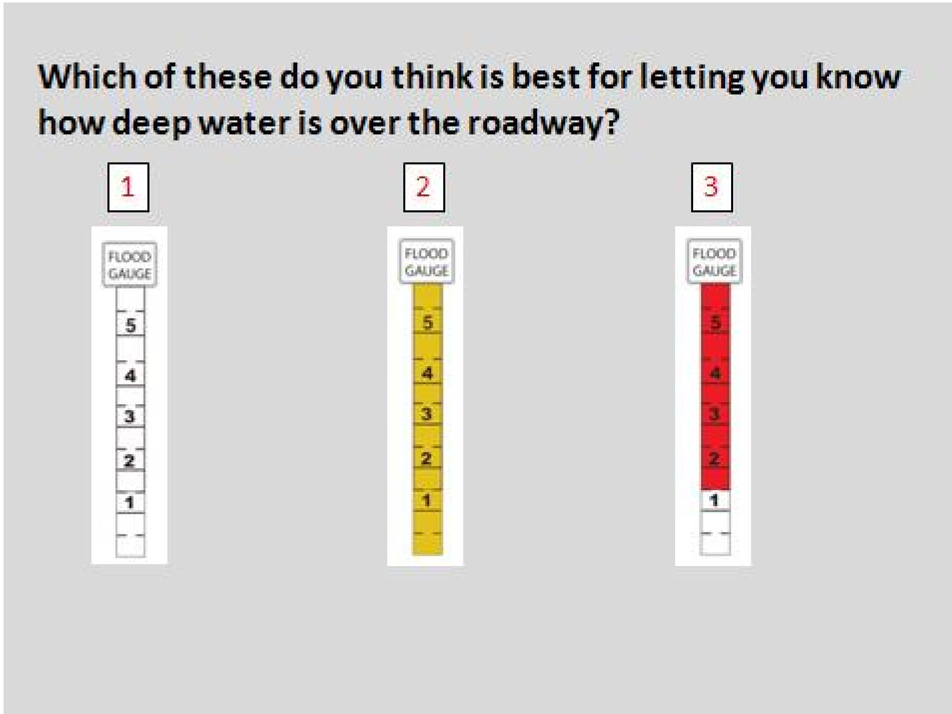


Figure 39. Water Depth Gauge Designs Tested in Driver Preference Study.

Table 33. Driver Preferences for Water Depth Gauge Designs.

Gauge	Percent Preferred
White flood gauge	4.0
Yellow flood gauge	14.5
Red/white flood gauge	81.5
Sample Size	200

A significant difference ($X^2 = 211.2$, $p = .0001$) was found in the percentage of participants who preferred each gauge. The red/white color-coded gauge was preferred by the majority of participants, with the yellow gauge a distant second place.

Driver Preference for Active Warning Signs

Participants viewed the slide shown in Figure 40 and selected their preferred sign option using the corresponding number on the button box. Table 34 shows the percent of participants preferring each sign.

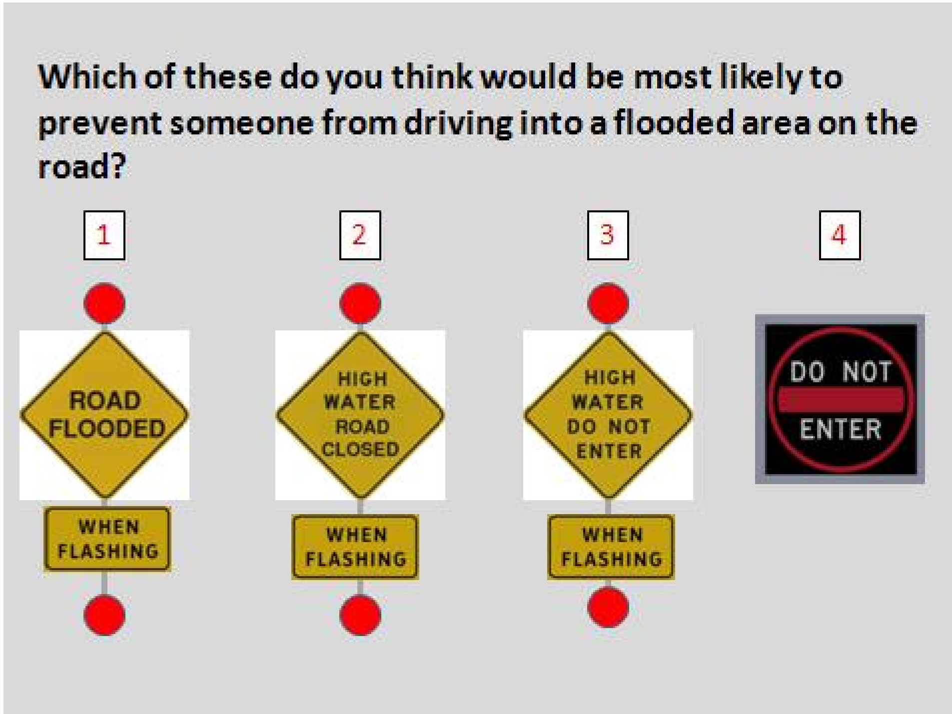


Figure 40. Active Warning Signs Tested in Driver Preference Study.

Table 34. Driver Preferences for Active Warning Sign Treatments.

Sign	Percent Preferred
ROAD FLOODED WHEN FLASHING	9.0
HIGH WATER DO NOT ENTER WHEN FLASHING	30.5
HIGH WATER ROAD CLOSED WHEN FLASHING	35.0
DO NOT ENTER (LED)	25.5
Sample Size	200

Of the four signs, HIGH WATER ROAD CLOSED WHEN FLASHING was preferred by the most participants (35 percent), with HIGH WATER DO NOT ENTER WHEN FLASHING in second place (30 percent of participants). ROAD FLOODED WHEN FLASHING was the least preferred.

Driver Preference for Signing Treatments for Multiple Flood-Prone Crossings in a Road Segment

Participants viewed the slide shown in Figure 41 and selected their preferred sign option using the corresponding number on the button box. Table 35 shows the percent of participants preferring each sign.

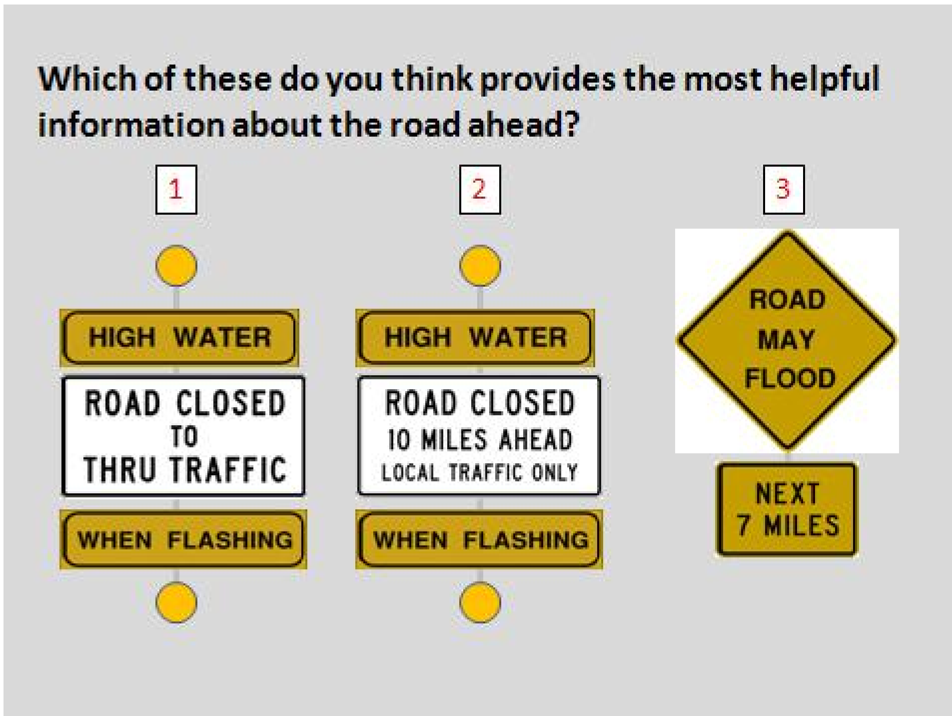


Figure 41. Multiple Flood-Prone Crossing Sign Treatments Tested in Driver Preference Study.

Table 35. Driver Preference for Signing Treatments at Road Segment with Multiple Flood-Prone Crossings.

Sign	Percent Preferred
HIGH WATER—ROAD CLOSED TO THRU TRAFFIC WHEN FLASHING	60.0
HIGH WATER—ROAD CLOSED 10 MILES AHEAD; LOCAL TRAFFIC ONLY—WHEN FLASHING	32.0
ROAD MAY FLOOD NEXT 7 MILES	8.0
Sample Size	200

A significant difference ($X^2 = 80.8$, $p = .0001$) was found in the percentages of participants who preferred each sign, with HIGH WATER ROAD CLOSED TO THRU TRAFFIC preferred by 60 percent of participants.

Summary of Findings from Driver Comprehension Studies

The driver comprehension survey results supported much of what was learned in the focus groups regarding drivers' decision processes when confronted with a water-covered road.

- Drivers look for clues from the roadway and surroundings regarding the depth of the water and the overall safety of the road at the water crossing. The stated water depth (as provided by a gauge) is an important factor, but also important are the width/breadth of the water and the visibility of the pavement edges, edgeline pavement markings, and surrounding ground.

- Participants in the comprehension surveys strongly preferred the color-coded red/white flood gauge over the single-color white or yellow gauges and appeared to understand the implied "white is safe, red is dangerous" message without any explanation being provided. However, responses to the color-coded gauge provide reason to be cautious about implementing it. Water on the road at a 6-inch depth (shown on a white or yellow gauge) deterred an average of 27 percent of respondents from (hypothetically) continuing on the road. When participants viewed the same roads with a color-coded gauge that showed the 6-inch water level in the white "safe" portion of the gauge, that percentage dropped to an average of 19 percent. The arbitrarily located "safe" level designated by the color-coded gauge overrode one of the cues—water depth—that several of the participants would otherwise have used to make their decision. When water was high enough to reach the red "danger" zone, there was no corresponding advantage; the number of participants who stated that they would avoid crossing the water was statistically the same for the standard and the color-coded gauge.

- Static warning signs did not significantly impact the decisions of participants to continue on the roads shown. This is consistent with focus group results; drivers stated that they did not tend to pay much attention to permanent warning signs. However, the presence of a static warning sign just before a flood-prone site (in addition to the gauge at the site) was correlated with an increase in participants' estimates of risk.

- Active warning signs did significantly affect decisions to continue or not continue, at all water levels that were shown. On average, just over half of participants stated that they would not continue on a visibly dry road if an active sign was on. For the active signs positioned at the entrance/intersection to a road warning of multiple (not visible) flooding sites ahead, this went up to 79 percent. Some comments made by participants indicated that they assumed that the activated warning sign meant that there was hazardous flooding ahead that they could not yet see.

- Sign messages that included more specific warnings and active guidance were favored by participants and tended to discourage more participants from continuing on the roads shown.
- The addition of stop bar markings to passive or active warning signs did not alter participant responses.

The signing treatments recommended for flood-prone roadways, based on the results of the driver comprehension surveys and the focus groups, are included in Chapter 7 of this report.

CHAPTER 6. A FRAMEWORK FOR RISK ASSESSMENT OF SIGNING FOR LOW-WATER CROSSINGS

Background

According to a recent report by Clark et al., National Weather Service data from 1969–1981 shows that half of the flood-related deaths during that time occurred in vehicles (*12*). Clark et al. state, "Many of these deaths occurred when people drove into flooded crossings (*12*). Drivers may underestimate how fast small streams can rise in some parts of the country during a flood, and they may ignore the possibility the crossing has already eroded." Gibson reports that Texas had 87 (8.7 per year) flood-related fatalities during a 10-year period, from 1997–2006 (*13*). According to Gibson, South Central Texas rates are even higher (*13*). Furthermore, during a 28-year period, from 1973–2000, total deaths were 274 (9.79 per year). Of these, 203 (74 percent) were flood related and 136 (67 percent) involved vehicles. According to another estimate, 60 percent of all flood deaths involve people in vehicles being swept away by water (*14*).

A cubic-foot of water weighs 62.4 lb and exerts the same amount of lateral force. Water height (depth) increases the force it exerts per square foot. The force of moving water is significantly higher. Water generally flows at 6–12 mph and exerts much higher lateral forces (*13*). One ft of water exerts 500 lb of lateral force, and 2 ft of deep water doubles this force to 1000 lb (*12,13*). Fast moving water (at around 8 mph) may even be dangerous at depths as low as 6 inches if it reaches the door level (*14*). Thus, small cars weighing less are even more vulnerable. The reason is buoyancy, which results in a submerged vehicle weighing less by an amount equivalent to the weight of the water it displaces.

In the selection and design of low-water crossings, engineers are aware of and willing to accept a certain level of associated risks. According to Lohnes et al., an low-water crossing is a structure that provides reasonable access through a stream crossing, allowing a certain level of periodic flooding and resulting road closure to traffic (*15*). However, many key criteria have a subjective nature requiring engineering judgment. A number of agencies use quantitative criteria proposed by Motayed et al. based on an opinion survey (*16*). Table 36 replicates these criteria. Thus, design of an low-water crossing requires the consideration of numerous factors, including traffic volumes and stream-flow patterns under various conditions (*12,16,17*). Stream-flow patterns include base flow, depth of flow, amount of discharge, flow speed, amount of debris carried, breadth of channel, and watershed flow-variation characteristics under different conditions. Equations are available to estimate one flow characteristic (i.e., depth of flow) given other characteristics such as flow rate (*15,17*). Cost is another factor. According to Lohnes et al., three types of low-water crossings include an unvented ford (or a raised unvented ford), a vented ford (costing $15k to $20k), and a low-water bridge (costing $40k to $50K) (*15*).

Table 36. Criteria for Selecting Low-Water Crossing Locations.

Criteria	Most Favorable for Low-Water Crossing	Least Favorable for Low-Water Crossings
Average daily traffic (ADT)	Fewer than 5 vehicles	200 vehicles
Average annual flooding	Less than 2 times per year	10 times per year
Average duration of traffic interruption per occurrence	Less than 24 hours	3 days
Extra travel time for alternate route	Less than 1 hour	2 hours
Possibility of danger to human life	Less than 1 in 1 billion (with excellent warning systems)	1 in 100,000
Property damage	None	1 million dollars
Frequency of using low-water crossings as an emergency route	None	Once per month

Guidelines in Table 36 assume the installation of "excellent warning systems." The typical warning systems include static signs installed at approaches to warn drivers of potential danger when flooded (*12, 15, 17*). When practical, agencies may install depth markers and colored posts to provide a way for drivers to gauge water depth at the crossing. As reported by Gibson, active devices used in a limited number of locations include warning flashers and gates (*13*). Gibson discusses issues related to the installation, communications, and maintenance aspects of advance warning and control devices. However, there is a lack of guidance about when and at which low-water crossings these devices could be most effective. The objective of this effort was to develop a framework for answering this question. A risk-analysis-based approach seemed appropriate for this purpose. Risk analysis quantifies the consequences of a hazard, which depend on the probability of a hazard, the amount of exposure to it, and associated cost (*18*). The guidelines presented in Table 36 incorporate these variables in a subjective manner. Thus, locations with high exposure level (i.e., more traffic and increased flooding potential) and more severe consequences (i.e., longer delay, increased danger to human life) become less favorable for these types of crossings. There is a lack of formal quantitative analysis on the subject. However, relevant applications in other related fields can provide further insights. These fields include highway-rail crossings and bridge design. A brief review follows.

For decades, engineers have used active traffic control devices at highway-rail crossings. They have also developed methods to identify candidate locations for priority treatment. TxDOT uses the following priority index formula to prioritized highway-rail crossing for treatment through the Federal Signal Program (*19*):

$$PI = V \times T \times (S \times 0.10) \times P_f \times A^{1.15} \times 0.01$$

Where:

V = average daily traffic in number of vehicles.

T = number of trains in a 24-hour period.

S = maximum train speed.
P_f = protection factor.
Gates = 0.10.
Cantilever Flashers = 0.15.
Mast Flashers = 0.70.
Crossbucks or other = 1.00.
A = number of crashes in the last 5 years.

In the above formula, notice that higher traffic and train volumes, train speeds, and crashes result in higher index values, and use of active control devices, especially gates, significantly reduces the index value. Also, note that crash history is an important data.

The Illinois Department of Transportation (IDOT) uses the following formula for calculating expected number of crashes (*20*):

$$ECF = Traffic\ Factor \times Component\ Factor \times Number\ of\ Trains$$

It accounts for differences in urban and rural environments. The IDOT design manual provides a table with values of traffic factors corresponding to different ADTs (*20*). The component factor accounts for the presence of traffic control devices. In the IDOT manual, the lowest component factor values of 0.08 and 0.19 correspond to urban and rural gates, respectively (*20*). Thus, gates in urban areas are more effective than gates in rural areas. An ECF value of 0.1 means one crash expected every 10 years. The manual outlines the following steps to calculate benefit-cost comparison of a pair of alternates:

1. Calculate ECF for existing installation.
2. Calculate ECF for proposed installation.
3. Find the difference in ECF.
4. Compute Benefit or loss = value in Step 3 times cost of crash.
5. Calculate the cost of each alternate using the formula given below and find the difference: cost of alternate = (initial cost ÷ life in years) + yearly maintenance cost.
6. Divide 4 by 5 to calculate benefit-to-cost ratio.

For crash prediction at highway-rail crossings, the Idaho Transportation Department uses a procedure developed by the U.S. DOT in the 1980s (*21*). This multi-step procedure uses three primary equations as follows:

1. Use a multiplicative equation to obtain a preliminary crash prediction. The factors used account for significant site characteristics maintained in the Federal Railroad Administration's (FRA) inventory. These factors include type of control, exposure, number of trains, speed, pavement type, and lanes.

2. Use the second equation to adjust the preliminary estimate from Step 1 to account for crash history at the site.
3. Calibrate the adjusted value using updates provided by the FRA every two years.

Steps 1 and 2 use factors classified by three types of traffic control devices present at the site. These control types include passive control, flashing lights, and gates. Austin and Carson (*22*), who also developed a crash prediction model based on crash data, describe the above models in detail.

Austin and Carson report the following interesting statistics and findings. According to the FRA, half of the 431 fatalities in 1998 occurred at public crossings with active control devices, which were functioning properly. In 1994, the Federal Highway Administration used a cost-per-fatality figure of 2.3 million to estimate the total cost of economic losses related to crossing fatalities. However, the most interesting finding from the FHWA analysis of the crash data was that while the presence of gates significantly reduced predicted crashes, the presence of flashing lights and bells increased predicted crashes.

The FHWA publication *Design of Encroachments on Flood Plains Using Risk Analysis* provides detailed procedures for risk assessment and cost optimization in bridge design (*23*). The risk assessment approach, however, is not limited to the design of bridges. One key feature of this approach is that it calculates the risk of each alternate as a yearly cost. In this approach, the alternate with the highest cost is the riskiest. With appropriate data and inflation-adjusted factor and cost estimates, these procedures can be applied to the design and assessment of other types of facilities. TxDOT's *Hydraulic Design Manual* also adapts a part of these procedures in its risk assessment section on bridges (*24*). Specifically, the manual demonstrates how to calculate the risk (cost) of traffic diversion associated with a flooded bridge. Table 37 provides the data assumed for calculating the cost of diversion. This type of data is useful but needs updating.

Table 37. Data Used by TxDOT to Estimate Costs of Diversion.

Traffic Composition	Automobiles	70%
	Small Trucks	20%
	Semi-Trailers	10%
Running Costs	Automobiles	\$0.20/mile
	Small Trucks	\$0.30/mile
	Semi-Trailers	\$0.65/mile
Value of Lost Time	\$4/hour/occupant	1.25/vehicle
Average Detour Length (*L*) /Speed (*S*)	2 days	50 mph

Using the above numbers, the formula for detour risk, in dollars per day is:

$$Detour\ Risk\ (\$) = 0.73 \times Detour\ Length \times ADT$$

Procedure to Calculate Risks Associated with Different Signing Options at Low-Water Crossings

Assessment of risk consists of the quantification of hazard, exposure to it, and associated consequence. In the context of this project, hazard exists when it is dangerous to use the crossing. The danger may be because of flooding or a crossing damaged by flooding but not visibly apparent to drivers. Exposure is a function of the number of days in a year the crossing is hazardous, average daily traffic volume, presence of advance and at-crossing signing, and availability and lengths of alternate routes. The number of days in a year a crossing is closed depends on weather conditions in the region and the characteristics of the watershed. Depending on the watershed characteristics, flooding may be flashy or stable. Characteristics of flashy floods include sharply rising water levels, higher flow speeds, and shorter durations. In stable flooding, water rises slowly, but conditions persist for longer periods. Flashy flows may be more dangerous than stable flows because of insufficient warning time. Analysts should determine these characteristics from field data, which should be available from the design stage. These data include geometric characteristics of the site (i.e., approach grades and sight distance), base flow, stream channel velocity, site hydrology (flood frequency, peak design flows, probability of overtopping), and estimates of traffic delays per incident. As mentioned in the previous section, design criteria for low-water crossings contain subjective factors and have room for variations from case to case. Therefore, it is critical to obtain field data (including maintenance records and any crash data) from the site in question or similar sites.

Since budget constraints play a key role in the selection, construction, and maintenance of roadway facilities, the FHWA HEC 17 approach is more appealing than the other reviewed approaches for risk analysis of various low-water crossing signing options. In its simplest form, the proposed equation to calculate risk in monetary terms is:

Yearly Risk ($ value) = Cost associated with installation and maintenance of advance signs
+ Cost associated with the installation of at-crossing signing
+ Cost of traffic diversion and delays
+ Cost of incidents

Because signing options (or alternate designs) can have different service/design lives, installation costs, and maintenance costs, comparison of alternates must be performed using yearly costs. Furthermore, it is easier to calculate these costs on an end-of-year basis. The following subsections provide guidance on the calculation of these costs.

Installation and Maintenance Costs

An agency's records are the best source of installation and yearly maintenance costs. Once these costs have been estimated for the option being considered, the following formula can be used to first distribute its installation cost over each year of its useful life:

$$A = P \times \frac{i \times (1+i)^n}{(1+i)^n - 1}$$

Where:

C_I	=	A, which is the per-year distribution of installation cost, in dollars.
P	=	total installation cost, in dollars.
i	=	discount rate.
n	=	service life.

If an option consists of multiple signing treatments at the same location (i.e., a sign and a gauge at the crossing) and their service lives are different, the above equation can be applied separately to each and then the individual costs added.

In most cases, the yearly maintenance cost (CM) of a given signing treatment may be the same. In that case, the yearly maintenance cost can be added to the above figure. However, if this is not the case, maintenance costs for different years will first need to be converted to their present values. Then the combined costs will have to be distributed using the above equation. The following equation can be used to calculate the present value of a future cost:

$$P = \frac{F}{(1+i)^n}$$

Where:

F	=	a future cost in the nth year.
P	=	present value of future cost.
i	=	discount rate.

For multiple options in a group (i.e., at-crossing treatment using a combination of a flashing beacon, a plaque, and a gauge), yearly costs should be calculated separately and then the total yearly maintenance cost for the group should be obtained. This step is necessary to account for differences in useful lives of individual treatments in a group.

Yearly Cost of Diversions

Estimation of these costs requires the number of days a particular crossing is expected to be closed during a year. It is best to use field data for this purpose. Field data will allow the inclusion of days floodwaters are expected to inundate the crossing of interest plus any time needed to repair damage caused by flooding. In the absence of field data, the analyst can use hydrologic analysis and design flood frequency to estimate this number. However, this approach will not account for any cost resulting from the closing of the low-water crossing due to any pavement damage.

In addition to the number of days a low-water crossing is closed due to flooding, several factors contribute to the cost of diversion. These factors include ADT, traffic mix, operating cost of vehicles, length of detour, detour speed, and value of lost time. The following equation calculates the cost of diversion using these data:

$$C_D = \left[\left((a \times C_a + t \times C_t + s \times C_s) \times L\right) + \left(O \times H \times \frac{L}{S}\right)\right] \times N \times D$$

Where:

- a = fraction of passenger cars in ADT.
- t = fraction of trucks in ADT.
- s = fraction of semi-trailers in ADT.
- C_a = per-mile operating cost of a passenger car in dollars.
- C_t = per-mile operating cost of a passenger car in dollars.
- C_s = per-mile operating cost of a passenger car in dollars.
- L = length of detour in miles.
- O = average per-vehicle occupancy (number of people).
- H = per-hour cost of lost time in dollars.
- S = average speed of detoured vehicles.
- N = vehicles turning around and taking the detour.
- D = expected number of days/year low-water crossing is dangerous to cross or closed.

Note that this cost of diversion might include costs associated with any crashes caused because of traffic diversion. In the absence of any data, the analyst can use figures provided in Table 37 for use in Equation 4. In this table, note that the operating costs for commercial vehicles and semi-trailers are 1.5 and 3.2 times that for passenger vehicles. Additional accuracy may be achieved by using only the additional detour length as compared to the normal trips.

The number of vehicles diverted (N) depends on the effectiveness of at-crossing signing and any advance signing present. With an at-crossing signing treatment only:

$$N = E_c \times ADT$$

Where, E_C is the effectiveness of the at-crossing signing treatment. However, the following alternate equation will apply in the presence of additional advance signing:

$$N = (E_a \times ADT) + E_{c|a} \times [ADT - (E_a \times ADT)]$$

Where, $E_{c|a}$ is the efficiency of the at-crossing treatment in the presence of advance signing. In the absence of more accurate data, the analyst can assume that the efficiency of the at-crossing signing is independent of any advance signing. In that case, this conditional term can be replaced with E_C.

Cost of Incidents

The cost of incidents is a function of property damage, injuries, and fatalities resulting from drivers disregarding signing and proceeding to cross under dangerous conditions. This cost may also include any cost of rescue operations resulting from these incidents. Such incidents will most likely involve a small fraction of vehicles proceeding to cross the low-water crossing. According to the information shown in Table 36, the expected probability of danger to life under this scenario might be 1 in 100,000 or less. This probability will only apply to $(ADT - N) \times D$ vehicles. Estimates of incident costs, however, require accurate data for a number of factors. These factors include probabilities of various types of incidents and associated costs. The literature has no information about the values of most of these costs. Thus, these figures should be derived from department records. The only exceptions are costs of fatalities and injuries described next.

The latest U.S. Department of Transportation guidance, adjusted to 2007 measures of per-capita income, raised to $5.8 million the value of a statistical life (VSL) to be used by analysts in DOTs (*25*). As suggested in the guidelines, an accompanying memorandum from the office of the assistant secretary for transportation policy directs department analysts to prepare additional estimates based on the assumption of $3.2 million and $8.4 million. This report also provides the values of injuries as fractions of VSL. Table 38 reproduces these figures and associated dollar values of injuries corresponding to the above VSL figures.

Table 38. Statistical Values of Injuries and Fatalities.

Injury Severity	Costs as Fractions of VSL and in Million Dollars			
	Fraction	3.2	5.8	8.4
Minor	0.0020	0.00640	0.01160	0.01680
Moderate	0.0155	0.04960	0.08990	0.13020
Serious	0.0575	0.18400	0.33350	0.48300
Severe	0.1875	0.60000	1.08750	1.57500
Critical	0.7625	2.44000	4.42250	6.40500
Fatal	1.0000	3.20000	5.80000	8.40000

CHAPTER 7. CONCLUSIONS AND RECOMMENDATIONS

This chapter provides a summary of the recommended signing treatments and presents candidate signing layouts of roadways with flood-prone crossings.

RECOMMENDED TREATMENTS AT CROSSINGS

The following recommendations are provided for all types of water crossings, regardless of whether the crossing will be operated as a passive or active crossing:

- **Recommendation: Treat low-water crossing and flood-prone crossing similarly.** The results of our focus group studies showed that drivers do not necessarily make a distinction between different types of crossings (flood-prone crossing vs. low-water crossing). Drivers generally take their cue of whether to proceed through a crossing primarily based upon the depth and the speed at which water is flowing through a crossing. Drivers are more likely to proceed through a crossing where they can see pavement (or pavement markings) through the water or have some frame of reference to determine the depth of the water in the crossing.

- **Recommendation: Every crossing should have a water depth gauge and an advance sign.** At a minimum, every crossing should be equipped with a water depth gauge and an advance sign, regardless of whether the crossing is planned to be an active or passive crossing. The water depth gauge allows drivers to determine the depth of the crossing, and the advance sign alerts drivers to the presence of the crossing.

- **Recommendation: Provide stopping sight distance to maximum water height approaching crossing.** Sight distance to the crossing is critical. Many low-water crossings and flood-prone areas can be hidden to drivers because of the geometry of the roadways. Ideally, TxDOT should provide decision sight distance to the "channel" of the crossing (i.e., the typical path that is used through the crossing). To provide maximum safety, it is suggested that all crossings be designed to provide stopping sight distance to the maximum water height of the crossing. This should allow drivers to stop before entering the water.

- **Recommendation: When possible, supplement the flood gauge at the low point of the crossing with another gauge so as to ensure that at least one flood gauge is clearly visible to all drivers from each approach.** The TxMUTCD requires that a flood gauge be located at the lowest point of the crossing; however, this sometimes may place the gauge on the wrong side of the roadway or very far away from the normal eye path of the driver. When practical, TxDOT may want to consider supplementing this gauge with another gauge on the other side of the crossing to increase visibility of the crossing. This is particularly important when the crossing is wide.

- **Recommendation: Use yellow flood gauge.** The findings of the research showed that drivers had a strong preference for the color of the gauge. Overwhelmingly, drivers preferred the red/white gauge over any of the other colors of gauges, as the red/white gauge provides a strong indication of when it is okay for drivers to proceed through the crossing (i.e., if the water is in the red portion, then it is NOT safe to proceed; however, if the water level is in the white portion, then it is safe to proceed). However, our recommendation at this time is to not use the red/white gauge because of concerns about maintenance and conspicuity issues of low-visibility conditions (shading). Therefore, it is our recommendation that TxDOT use the yellow flood gauge. While this treatment did not rate as high as the red/white gauge in terms of driver preference, it performed about the same as the white gauge in the scenarios tested. The yellow gauge is consistent with the national MUTCD.

- **Recommendation: Use "Road May Flood" as advance sign.** For all crossings, including those where only static signs are used as well as those with active warning devices, the research team recommends using the ROAD MAY FLOOD static sign. This sign should be placed upstream of the crossing in accordance with TxDOT's standard Advance Placement Distances that is used for similar types of advance warning sign devices. The ROAD MAY FLOOD advance sign performed well in the driver comprehension study and is easily understood by most drivers. The ROAD MAY FLOOD sign is also the signing treatment recommended by the national MUTCD for this type of situation.

- **Recommendation: Use "Do Not Cross When Flooded" as an optional sign at crossing.** For crossings where only static signs are to be provided, the research team recommends using the DO NOT CROSS WHEN FLOODED static sign located at the crossing. This sign provides an unambiguous message to drivers. The research team recommends placing this sign 25 ft (minimum) to 50 ft (desirable) from the location of maximum water height in the crossing. This would allow drivers ample space to turn around before entering the crossing.

- **Recommendation: Use yellow flashers with active warning assemblies at flood-prone crossings.** The results of the driver comprehension study show little difference in driver performance between red and yellow flashers when used in conjunction with active warning systems at flood-prone crossings. While the red flashers resulted in more drivers indicating that they would not proceed through a flooded crossing, the difference was not significant over yellow flashers. This implies that drivers have become relatively well conditioned to correctly interpret the meaning of the flashers (i.e., that the situation on the warning sign is in effect).

- **Recommendation: Active flood warning treatments should be used at crossings where high potential exists for trapping motorists in flooded crossings.** Active flood warning treatments should be used at flood-prone crossings that exhibit the following characteristics:
    - Where roadway geometrics, roadway curvature, or other factors (such as vegetation, shadows) obscures sight distance and visibility to the crossing, especially at night.
    - Where drivers would have difficulty judging the depths, and width of the crossing as well as the speed for flow of water through the crossing, especially where the center of the channel where the flood depth gauges would be located are a long distance away from the maximum water height.
    - Where there is a history of vehicles becoming trapped or swept downstream because of rapidly rising water. The research team suggests that crossings have a history of 2 or more severe flood-related incidents in a 10-year period be equipped with active warning systems.
    - Where traffic volumes on the highway are sufficiently high so as to create a significant risk exposure to drivers. The amount of traffic varies depending upon the functional class of roadway, the type of traffic using the roadway, the type of adjacent land-use in proximity to the crossing, and the posted speed limit on the roadway.
    - Where crossings are located in isolated locations where a significant delay may exists before the crossing can be visually inspected by TxDOT maintenance or law enforcement personnel.
- **Recommendation: Do not use additional pavement markings at flood-prone crossings.** No additional pavement markings are needed to distinguish a water crossing on the roadway; however, because drivers use pavement edgeline and centerline markings as cues to judge water depth, keeping these markings well maintained through a flood-prone site or water crossing will help drivers' decision processes.
- **Recommendation: Use HIGH WATER ROAD CLOSED TO THRU TRAFFIC with flasher assembly for roadways with multiple flood-prone crossings.** The driver comprehension study showed that the HIGH WATER ROAD CLOSED TO THRU TRAFFIC sign was well understood by drivers and resulted in the least number of drivers likely to enter the roadway. These signs should be placed at major decision points (intersections). Suggested criteria for where to use this treatment include the following:
    - Use only where active flood warning signs are deployed at crossings and where the flasher assembly located at the crossing is not visible from the intersection.

- ◦ Use on sections of highway where a considerable travel distance exist to the last active downstream crossing (e.g., more than 5 miles)or where drivers must travel a significant time to detour around a closed crossing (e.g., more than 15 minutes).
- ◦ Use on sections of highways where multiple crossing are located. The advanced signs should be activated when the flashers at any one crossing are first activated and should remain flashing until the flashers at all crossing are deactivated.

The flasher assemblies would need to be installed with the signs to provide an indication when the condition (ROAD CLOSED TO THRU TRAFFIC) were in effect. Because flasher assemblies are required with this treatment, all the crossings in the section of roadway would also need to use active devices and a communication linkage would need to be established from those crossings to the advance sign to ensure that the flashers were activated during flooded conditions.

CANDIDATE SIGNING LAYOUTS FOR FLOOD-PRONE CROSSINGS

Figure 42 shows the recommended signing treatment for a crossing that uses only static signs. At a minimum, the crossing should use a ROAD MAY FLOOD static sign in advance at the crossing and a flood gauge located at the crossing. An optional DO NOT CROSS WHEN FLOODED sign could be placed 25 to 50 ft upstream of the crossing.

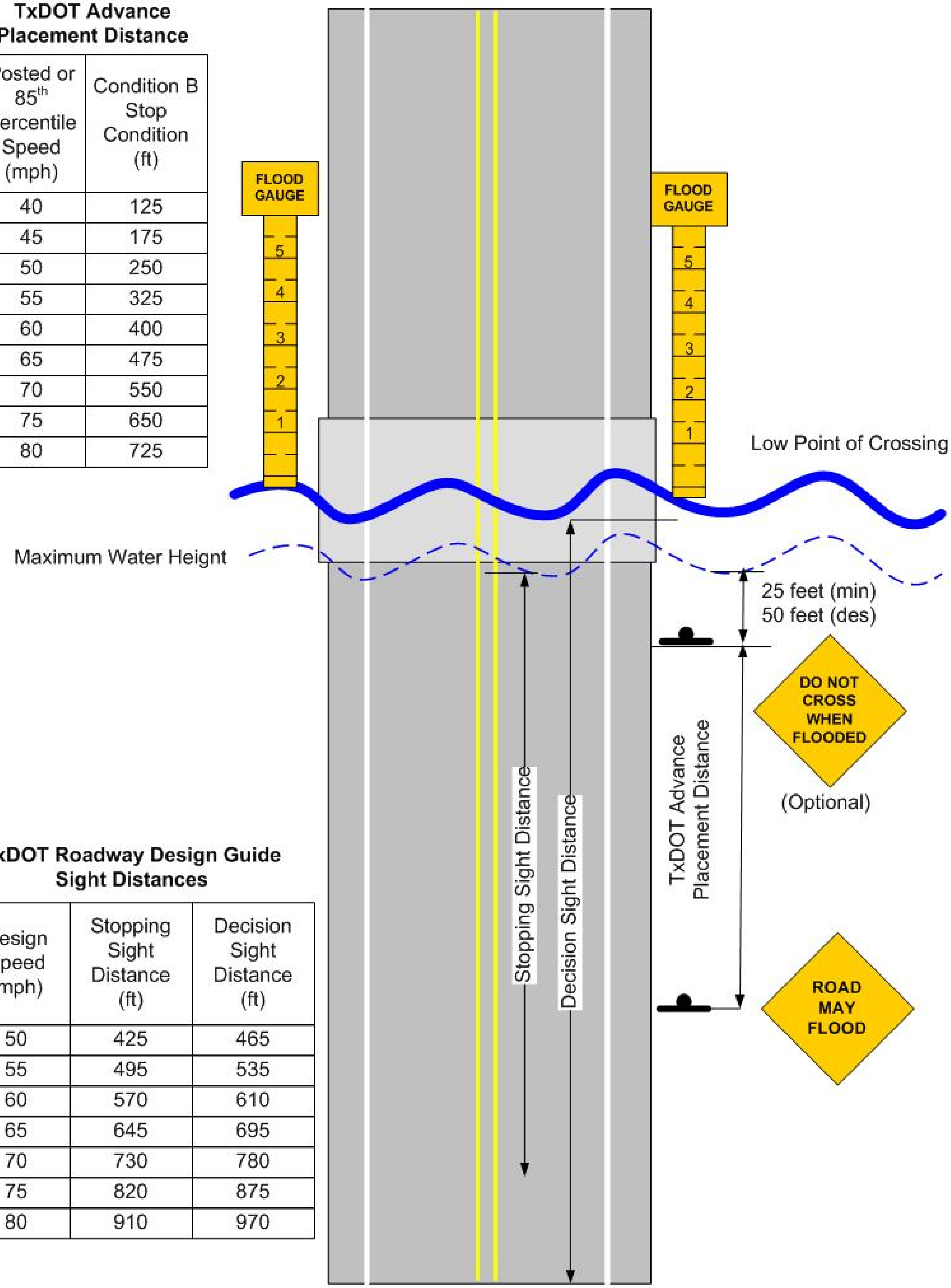
Figure 43 shows the recommended signing layout for use where active warning devices are to be used. In addition to the advance ROAD MAY FLOOD sign and the yellow flood gauge sign at the crossing, a HIGH WATER DO NOT ENTER WHEN FLASHING sign assembly is used at the crossing. Yellow warning flashers are used to alert drivers when the condition is in effect (i.e., when the crossing is flooded). The crossing should also have some system that must detect when the crossing is flooded.

Figure 44 shows an alternative signing treatment that could potentially be used to provide an active warning at flood-prone crossings. The treatment uses a sign composed of red and white LEDs arranged to mimic a standard DO NOT ENTER sign. During times when the crossing is not flooded, the sign would not be illuminated and therefore the DO NOT ENTER message would not be visible to approaching drivers. However, when the crossing is flooded, instead of activating a flasher assembly, the flood detection system would activate the LED sign, causing the DO NOT ENTER message to become visible to approaching drivers. While this sign configuration holds promise and tested well in the driver comprehension study, additional field studies and experimentation are needed before this configuration could be deployed in the field.

Figure 45 shows a recommended signing layout for a roadway that has multiple crossings. It is recommended that when multiple crossings exist on a roadway, active warning devices be used at all the crossings. The detection systems that are used to drive the active warning systems at each crossing could then be used to activate the warning signs at the beginning of the stretch of roadway where the active warning signs would be deployed.

TxDOT Advance Placement Distance

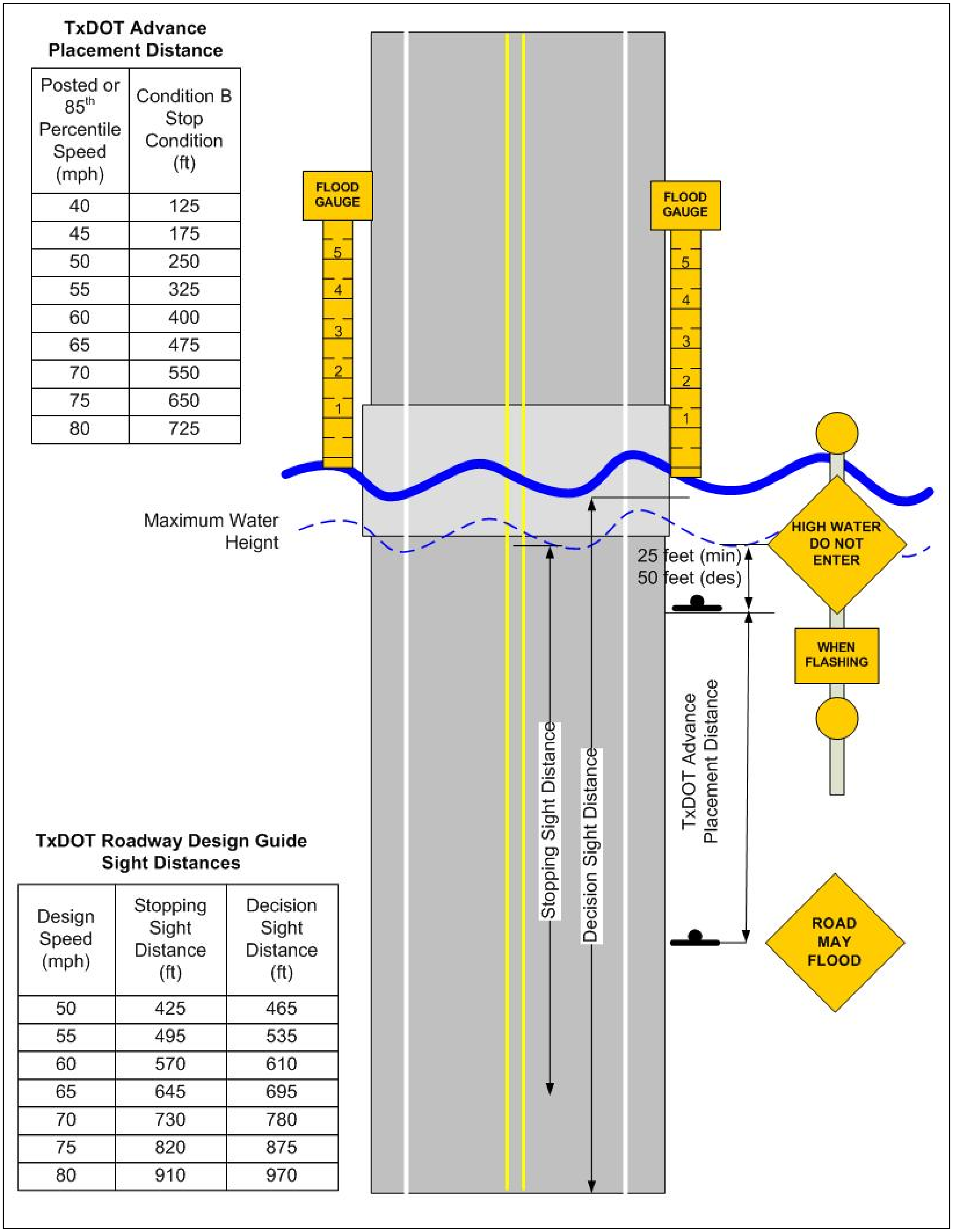
Posted or 85th Percentile Speed (mph)	Condition B Stop Condition (ft)
40	125
45	175
50	250
55	325
60	400
65	475
70	550
75	650
80	725



TxDOT Roadway Design Guide Sight Distances

Design Speed (mph)	Stopping Sight Distance (ft)	Decision Sight Distance (ft)
50	425	465
55	495	535
60	570	610
65	645	695
70	730	780
75	820	875
80	910	970

Figure 42. Candidate Signing Layout for Flood-Prone Crossing—Static Signs Only.



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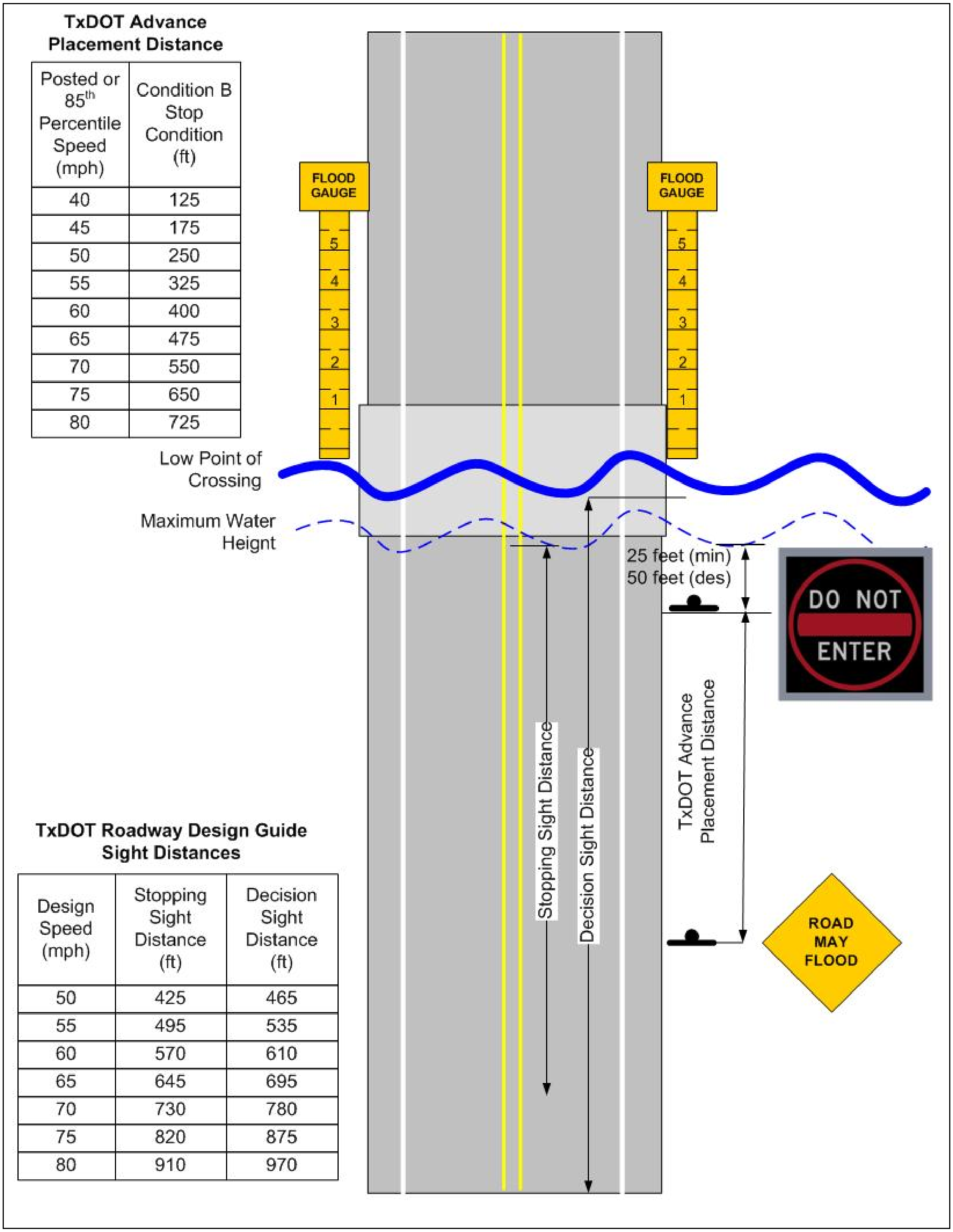
Design Speed (mph)	Stopping Sight Distance (ft)	Decision Sight Distance (ft)
50	425	465
55	495	535
60	570	610
65	645	695
70	730	780
75	820	875
80	910	970

Figure 43. Candidate Signing Layout for Active Warning Devices at Flood-Prone Crossings.



TxDOT Advance Placement Distance

Posted or 85th Percentile Speed (mph)	Condition B Stop Condition (ft)
40	125
45	175
50	250
55	325
60	400
65	475
70	550
75	650
80	725

TxDOT Roadway Design Guide Sight Distances

Design Speed (mph)	Stopping Sight Distance (ft)	Decision Sight Distance (ft)
50	425	465
55	495	535
60	570	610
65	645	695
70	730	780
75	820	875
80	910	970

Figure 44. Candidate Signing Layout for Active Warning Devices at Flood-Prone Crossings—LED "DO NOT ENTER" Sign.

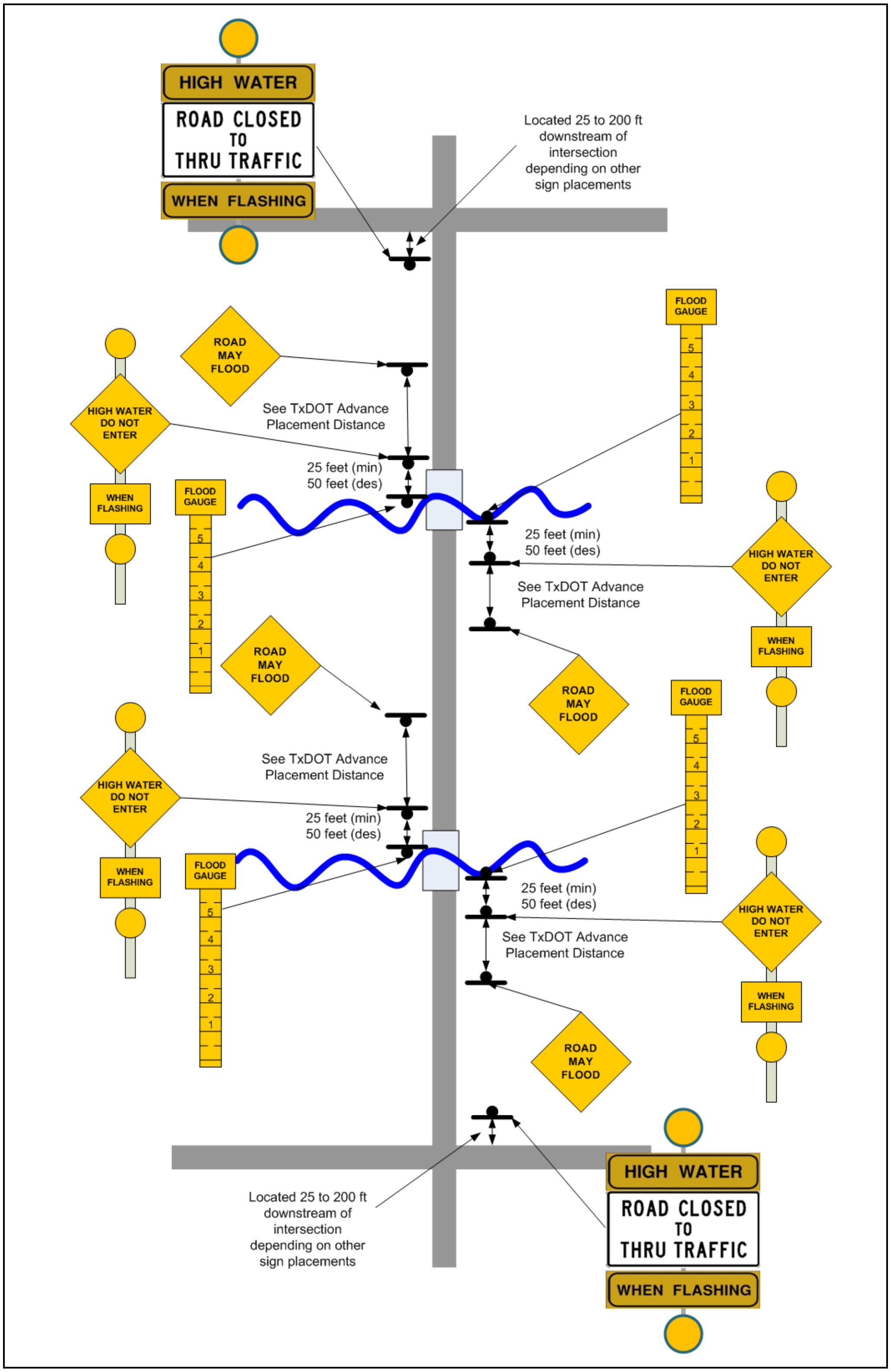


Figure 45. Candidate Signing Layout for Roadway with Multiple Flood-Prone Crossings.

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APPENDIX A. SURVEY INSTRUMENT

Submit by Email | Print Form

Signing Guidelines for Flooding Conditions and Warrants for Flooded Conditions Detection Systems

TxDOT Project No 0-6262

The Texas Transportation Institute is conducting a research project for the Texas Department of Transportation to develop (1) signing guidelines for flooding conditions and (2) warrants for flood condition detection systems.

As part of this research we are conducting a survey to gather information from TxDOT District and Area Offices on their signing practices for warning drivers of low water crossings and flooded roadways. We would also like to identify flood-prone roadway segments and low water crossings in your district.

The attached survey is sent to Directors of Transportation Operations in all TxDOT districts. Your response is very important and will significantly contribute to the success of the project. The survey results along with other research findings will be documented in the final report of TxDOT research project 0-6262.

We would appreciate if you could return the completed survey by February 16, 2009. Please send it via e-mail to g-pesti@tamu.edu or by mail to Geza Pesti, Texas Transportation Institute, 3135 TAMU, College Station, TX 77843-3135. If you have any questions please contact Geza Pesti (Tel: 979-845-9878, e-mail: g-pesti@tamu.edu), or Laura Higgins (Tel.: 979-845-8109, e-mail: l-higgins@tamu.edu).

Thank you in advance for your cooperation.

GENERAL INFORMATION

Name	
TxDOT District	
Position	
Telephone	
Email	

Section 1. LOW WATER CROSSINGS AND FLOOD-PRONE SITES IN YOUR DISTRICT

This section focuses on low water crossings and flood-prone sites in your district.

- A *low water crossing* is a location where water regularly/normally flows over the roadway. Unless the water is unusually high, these crossings can be traversed by a vehicle despite the presence of water on the road.
- *Flood-prone sites* are sites along roadways that can become covered with water under certain conditions (e.g., heavy rain). Water does not flow over the roadway at these locations except under special conditions.

1.1 Please indicate the (approximate) number and type of flood-prone roadway sites along state roadways in your district.

	Low Water Crossings 	**Other Flood-Prone Sites** 
Approximate number of such locations in your district		
List top five locations	1.	1.
	2.	2.
	3.	3.
	4.	4.
	5.	5.

1.2 Some roadways or areas may have multiple flooding locations (low water crossings, temporary flooding locations, or both) that are treated as a group for traffic safety purposes. For example, a sign or barrier may be posted at the beginning or "upstream" point of a roadway that has several potential flooding sites along it. Please indicate any such roadways in your district on the next page.

Roadway	Approximate length of flood-prone roadway segment	Approximate number of low water or flood-prone sites

Section 2. STATIONARY SIGNS

In this section, please identify any stationary, permanently-mounted signs that are used in your district to warn motorists of potential water-related hazards. This does **NOT** include signs that are used on a temporary basis during actual flooding events, or flip-down signs that display warnings only during flooding events.

2.1 What signs are posted to identify ***low water crossings*** (if any) in your district? If a sign is listed in the MUTCD, please specify the sign's MUTCD number. If a sign is not in the MUTCD, please specify the type of sign (diamond/warning sign, rectangular/regulatory sign) and the sign's wording. If there are no low water crossings in your district, please skip to 2.5.

Signs used at low water crossings				
	MUTCD number	OR	Sign color & shape	Message (text or symbol)
1				
2				
3				

2.2 Why did you select the sign(s) identified in 2.1? (Select all that apply.)

- ☐ Listed in the federal MUTCD.
- ☐ Listed in the Texas MUTCD.
- ☐ Listed in another signing standard (specify):
- ☐ It was inexpensive and/or readily available from the TxDOT sign shop.
- ☐ Have found it effective in practice.
- ☐ Other reason (specify):

2.3 In your experience, are the signs effective in warning drivers about potential water hazards at low water crossings?

- ○ Yes
- ○ No
- ○ Not sure/no opinion

2.4 If you could add or change anything about these signs, what would it be?

2.5 What signs are posted to identify other ***flood-prone sites*** in your district? If a sign is from the MUTCD, please specify the sign's MUTCD number. If a sign is not in the MUTCD, please specify the type of sign (diamond/warning sign, rectangular/regulatory sign) and the sign's wording.

Signs used at flood-prone sites				
	MUTCD number	OR	Sign color & shape	Message (text or symbol)
1				
2				
3				

2.6 Why did you select the sign(s) identified in 2.5? (Select all that apply.)

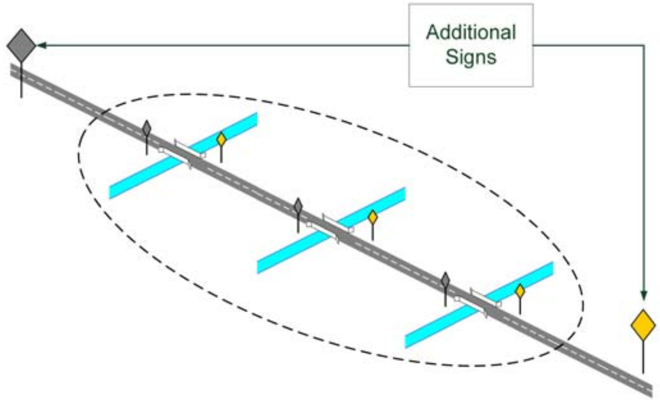
- ☐ Listed in the federal MUTCD.
- ☐ Listed in the Texas MUTCD.
- ☐ Listed in another signing standard (specify):
- ☐ It was inexpensive and/or readily available from the TxDOT sign shop.
- ☐ Have found it effective in practice.
- ☐ Other reason (specify):

2.7 In your experience or opinion, are the signs effective in warning drivers about potential water hazards in flood-prone areas?

- ○ Yes
- ○ No
- ○ Not sure/no opinion

2.8 If you could add or change anything about these signs, what would it be?

As described in Section 1, some roadways or areas may have ***multiple flooding locations*** (low water crossings, temporary flooding locations, or both) that are treated as a group for traffic safety purposes. For example, a sign or barrier may be posted at the beginning or "upstream" point of a roadway that has several potential flooding sites along it, as shown in the following illustration.



2.9 Do you employ different or additional signs for roadways with ***multiple potential flooding sites***?

- ○ No, or do not have any such roadways in the area (skip to Section 3)
- ○ Yes, for one or more of the locations listed for Question 1.2:

2.10 Describe the signs and/or traffic controls used for roadways with multiple flooding sites.

Signs and Traffic Controls for Roadways with <u>Multiple Flooding Sites</u>			
	Sign or Traffic Control Description (or MUTCD number)	Message	Where Placed (e.g., at beginning/entry point of road, other)
1			
2			
3			

2.11 Why did you select the sign(s) identified in 2.10? (Select all that apply.)

- ☐ Listed in the federal MUTCD.
- ☐ Listed in the Texas MUTCD.
- ☐ Listed in another signing standard (specify):
- ☐ It was inexpensive and/or readily available from the TxDOT sign shop.
- ☐ Have found it effective in practice.
- ☐ Other reason (specify):

2.12 In your experience or opinion, are the signs effective in warning drivers about potential water hazards on roadways with multiple flooding sites?

- Yes
- No
- Not sure/no opinion

2.13 If you could add or change anything about these signs, what would it be?

Section 3. FLOOD EVENT SIGNING AND CONTROLS

This section addresses signs, signals, and traffic controls that are placed or activated only when flooding conditions are present or imminent. This section does **not** cover automated flood warning systems (see Section 4).

3.1 When roadway segments or crossings in your district are flooded, do you

3.1.1	post different or additional stationary signs?	YES	NO
3.1.2	display flip-down signs?	YES	NO

If YES to either 3.1.1 or 3.1.2, please describe those signs in the table below. If NO to both, please skip to Question 3.5.

Temporary or flip-down signs displayed at flooded sites				
	MUTCD number	OR	Sign color & shape	Message (text or symbol)
1				
2				
3				

3.2 Why did you select the sign(s) identified in 3.1? (Select all that apply.)

- Listed in the federal MUTCD.
- Listed in the Texas MUTCD.
- Listed in another signing standard (specify):
- It was inexpensive and/or readily available from the TxDOT sign shop.
- Have found it effective in practice.
- Other reason (specify):

3.3 In your experience or opinion, are the signs effective in warning drivers about potential water hazards at flooded roadway sites?

- Yes
- No
- Not sure/no opinion

3.4 If you could add or change anything about these signs, what would it be?

3.5 When roadway segments or crossings in your district are flooded, do you ***activate flashers*** on stationary/permanent signs?

YES NO

If YES, please identify the signs that are equipped with flashers in the table below. If NO, please skip to 3.6.

<u>Flashers are activated</u> on the following signs if flooding is present.				
	MUTCD number	OR	Sign color & shape	Message (text or symbol)
1				
2				
3				

3.6 Who makes the decision to place a temporary flood warning sign, display a flip-down flood warning sign, or activate flashers on a permanent warning sign?

3.7 What are the criteria for placing temporary flood warning signs, displaying the messages on flip-down signs, and/or activating flashers on permanent warning signs?

Some agencies will use their ***dynamic message signs*** (DMSs) to provide motorists with weather-related and road condition information?

3.8 Does your agency use permanent or portable mounted DMSs to provide flood warning information?

NO (please skip to 3.10)

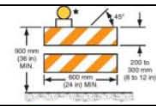
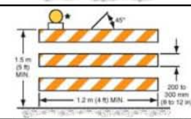
YES, under the following conditions

3.9 If YES to 3.8, what messages have you used on ***DMSs***? Please specify:

Phase	Message
1	
2	
3	

Phase	Message
1	
2	
3	

3.10 Do you use any of the following ***traffic controls*** to prevent traffic from entering flooded roadway sites? (Check all that apply.)

Barricades	
Type II 	☐
Type III 	☐
One-Hand Roll-Out Barricade 	☐
Swing-Steel Gate Barricade 	☐
Other barricade type (describe):	☐
Roll-up sign attached to barricade (specify message):	☐
Law Enforcement Presence	☐
OTHER (specify):	
	☐
	☐

3.11 Who makes the decision to place a barricade across a flooded roadway?

3.12 What are the criteria for placing barricades across a roadway (for a flooding situation)?

Section 4. AUTOMATED FLOOD DETECTION AND WARNING SYSTEMS

Automated flood detection systems use sensors to detect rising water on or near roadways. When water is detected, the systems usually initiate one or more actions, such as notifying DOT, DPS, or emergency management center staff and/or activating flood warning signals and/or barriers. Some systems may also include sensors to measure rainfall, stream or tide levels, and/or other early indicators of potential flooding.

The intent of this section of the survey is to determine the types of flood detection and/or warning systems you may have installed in your district, as well as their capabilities.

4.1 Do you have automated flood detection/warning systems installed and operated in your district?

○ YES ○ NO

If NO, you have completed this survey. Please return as directed on the first page.

If YES, please provide information about the system(s) below. Spaces are provided to describe up to two different systems, if your area has more than one type of flood warning system in use. If there are more than two automated flood warning systems in use in your area, please provide information on the two systems that are the most prevalent in your area.

System Description	System 1	System 2
4.2 Is this a commercial system, or a system developed in-house?	○Commercial ○In-house	○Commercial ○In-house
4.3 If a commercial system, name the company or vendor.		
4.4 If a commercial system, name the make and model.		
4.5 Does the system include roadway water sensors?	○YES ○NO	○YES ○NO
4.6 Does the system include other flood warning sensors (rainfall, tide, stream level, or similar)?	○YES ○NO	○YES ○NO
4.7 When flooding conditions are detected, how does the system respond? (Check all that apply)		
• Notifies DOT staff and/or other safety/emergency management personnel.	☐	☐
• Activates signs, flashers, or other signals along the roadway.	☐	☐
• Activates gates/barriers.	☐	☐
• Sends information to public websites and/or other public information channels (TV, radio).	☐	☐
• Other (please specify):	☐	☐

System Description	System 1	System 2
4.8 What communications infrastructure does the system use? (Check all that apply)		
• Dial-up	☐	☐
• Wireline (coax. Fiber, etc.)	☐	☐
• Radio	☐	☐
• Microwave	☐	☐
• Cellular	☐	☐
• Other (please specify)	☐	☐

For the remainder of this section, if you described two systems in the table above, please provide answers for both systems (as applicable). If your answers to one or more questions differ for the two systems, please include both answers in the space provided and specify "System 1" and "System 2." (e.g., "Sensors on System 1 are tested every six months. System 2 sensors are tested every 12 months.").

Effectiveness of System(s)

4.9 Are you satisfied with the performance of the automated flood warning system(s) used in your jurisdiction? Why or why not?

4.10 How do you evaluate system performance?

4.11 Have you had any "false positive" incidents (i.e., an alert or activation of the system when there is no flooding/high water present)?

○ YES ○ NO

If yes, please describe:

Maintenance of System

4.12 Do you perform regular testing of the system(s)?

○ YES ○ NO

4.13 If yes, what is the frequency of testing?

4.14 If yes to 4.12, how is the system tested?

4.15 Are there system components that need to be tested more frequently than the system as a whole? If yes, what are they?

4.16 Are there components of the system that need to be regularly calibrated? If yes, what are they?

4.17 Are there components of the system that need to be regularly replaced? If yes, what are they?

Criteria for Use

4.18 What criteria do you use to decide if a location needs an automated warning system for flood detection or high water?

4.19 Do you have a formal process for determining this need and/or evaluating these criteria?

○ YES ○ NO

4.20 If yes, may we obtain a copy of it (please send an electronic copy to g-pesti@tamu.edu).

Thank you for completing the survey. Please return it using the "Submit by Email" button, or print and mail it to Texas Transportation Institute, 3135 TAMU, College Station, TX 77843-3135.

Print Form Submit by Email

APPENDIX B. RESULTS OF DRIVER COMPREHENSION STUDY

Number of participants seeing each version of the survey.

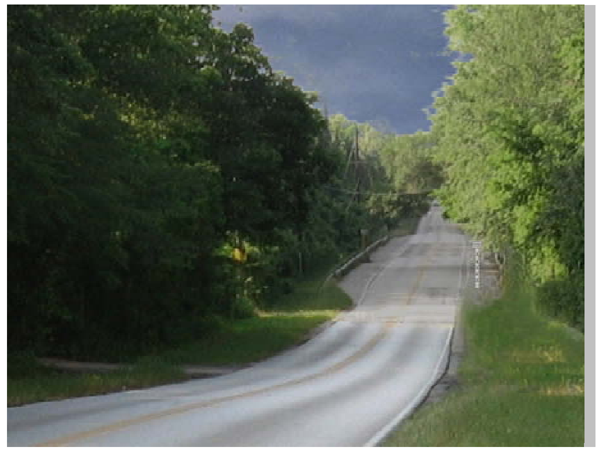
Survey Version	College Station	Odessa	San Angelo	San Antonio	Total
A	8	15	14	13	50
B	9	16	13	13	51
C	9	15	13	13	50
D1	4	6	4	4	18
D2	2	5	4	4	15
D3	2	6	4	4	16
Sample Size	34	63	52	51	200

Scenarios included in each survey version.

	Survey Version					
	A	**B**	**C**	**D1**	**D2**	**D3**
Question Number	1.1	1.2	1.3	1.1	1.2	1.3
	1.6	1.8	1.4	1.6	1.8	1.4
	1.7	1.9	1.5	1.7	1.9	1.5
	1.15	1.10	1.13	1.15	1.10	1.13
	1.16	1.11	1.14	1.16	1.11	1.14
	1.17	1.12	1.19	1.17	1.12	1.19
	1.22	1.18	1.20	1.22	1.18	1.20
	1.23	1.24	1.21	1.23	1.24	1.21
	1.31	1.25	1.29	1.31	1.25	1.29
	1.32	1.26	1.30	1.32	1.26	1.30
	2.3	1.27	2.1	2.2	1.27	2.2
	2.11	1.28	2.5	2.8	1.28	2.8
	2.12	2.4	2.6	2.9	2.2	2.9
	2.13	2.14	2.7	2.10	2.8	2.10
	2.16	2.15	2.22	2.25	2.9	2.25
	2.17	2.19	2.23	2.26	2.10	2.26
	2.18	2.20	2.24	3.4	2.25	3.4
	3.1	2.21	3.3	4.1	2.26	4.3
	4.1	3.2	4.3	5.1	3.4	5.1
	5.1	4.2	5.1	5.2	4.2	5.2
	5.2	5.1	5.2	5.3	5.1	5.3
	5.3	5.2	5.3	5.4	5.2	5.4
	5.4	5.3	5.4	5.5	5.3	5.5
	5.5	5.4	5.5		5.4	
		5.5			5.5	

Question 1.1

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	Dry
Sign at Crossing:	None
Gauge:	White



Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	16.7%	4.8%	11.1%	0.0%	7.4%
	Yes	83.3%	95.2%	88.9%	100.0%	92.6%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	58.3%	76.2%	72.2%	82.4%	73.5%
	2	25.0%	9.5%	11.1%	11.8%	13.2%
	3	0.0%	9.5%	16.7%	5.9%	8.8%
	4	8.3%	0.0%	0.0%	0.0%	1.5%
	5	8.3%	4.8%	0.0%	0.0%	2.9%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	4.8%	0.0%	5.9%	2.9%
	1	0.0%	0.0%	0.0%	5.9%	1.5%
	2	8.3%	4.8%	0.0%	0.0%	2.9%
	3	25.0%	0.0%	5.6%	5.9%	7.4%
	4	0.0%	14.3%	16.7%	0.0%	8.8%
	5	66.7%	76.2%	77.8%	82.4%	76.5%
Sample Size		12	21	18	17	68

Question 1.2

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	Dry
Sign at Crossing:	WHEN FLOODED TURN AROUND DON'T DROWN
Gauge:	White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	18.2%	33.3%	0.0%	5.9%	15.2%
	Yes	81.8%	66.7%	100.0%	94.1%	84.8%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	72.7%	61.9%	88.2%	76.5%	74.2%
	2	9.1%	9.5%	5.9%	5.9%	7.6%
	3	9.1%	0.0%	5.9%	5.9%	4.5%
	4	0.0%	9.5%	0.0%	0.0%	3.0%
	5	9.1%	19.0%	0.0%	11.8%	10.6%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	0.0%	0.0%	0.0%
	1	0.0%	19.0%	0.0%	5.9%	7.6%
	2	0.0%	4.8%	0.0%	0.0%	1.5%
	3	9.1%	0.0%	0.0%	0.0%	1.5%
	4	18.2%	14.3%	11.8%	11.8%	13.6%
	5	72.7%	61.9%	88.2%	82.4%	75.8%
Sample Size		11	21	17	17	66

Question 1.3

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	Dry
Sign at Crossing:	DO NOT CROSS WHEN FLOODED
Gauge:	White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	0.0%	4.8%	11.8%	11.8%	7.6%
	Yes	100.0%	95.2%	88.2%	88.2%	92.4%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	90.9%	81.0%	82.4%	76.5%	81.8%
	2	9.1%	14.3%	0.0%	11.8%	9.1%
	3	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	4.8%	5.9%	5.9%	4.5%
	5	0.0%	0.0%	11.8%	5.9%	4.5%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	0.0%	0.0%	0.0%
	1	0.0%	0.0%	5.9%	0.0%	1.5%
	2	0.0%	0.0%	0.0%	11.8%	3.0%
	3	9.1%	9.5%	0.0%	0.0%	4.5%
	4	0.0%	9.5%	5.9%	0.0%	4.5%
	5	90.9%	81.0%	88.2%	88.2%	86.4%
Sample Size		11	21	17	17	66

Question 1.4

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	Low Water
Sign at Crossing:	None
Gauge:	White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	54.5%	42.9%	29.4%	35.3%	39.4%
	Yes	45.5%	57.1%	70.6%	64.7%	60.6%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	4.8%	11.8%	11.8%	7.6%
	2	36.4%	38.1%	64.7%	52.9%	48.5%
	3	9.1%	33.3%	5.9%	23.5%	19.7%
	4	36.4%	14.3%	11.8%	0.0%	13.6%
	5	18.2%	9.5%	5.9%	11.8%	10.6%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	18.2%	0.0%	0.0%	5.9%	4.5%
	1	18.2%	0.0%	5.9%	5.9%	6.1%
	2	27.3%	0.0%	0.0%	5.9%	6.1%
	3	9.1%	57.1%	29.4%	23.5%	33.3%
	4	18.2%	28.6%	41.2%	41.2%	33.3%
	5	9.1%	14.3%	23.5%	17.6%	16.7%
Sample Size		11	21	17	17	66

Question 1.5

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	Low Water
Sign at Crossing:	None
Gauge:	Red/White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	45.5%	33.3%	11.8%	29.4%	28.8%
	Yes	54.5%	66.7%	88.2%	70.6%	71.2%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	9.1%	0.0%	29.4%	11.8%	12.1%
	2	54.5%	23.8%	35.3%	41.2%	36.4%
	3	9.1%	47.6%	11.8%	17.6%	24.2%
	4	9.1%	19.0%	5.9%	5.9%	10.6%
	5	18.2%	9.5%	17.6%	23.5%	16.7%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	9.1%	4.8%	0.0%	5.9%	4.5%
	1	9.1%	0.0%	0.0%	5.9%	3.0%
	2	18.2%	0.0%	11.8%	11.8%	9.1%
	3	9.1%	33.3%	11.8%	11.8%	18.2%
	4	36.4%	42.9%	29.4%	17.6%	31.8%
	5	18.2%	19.0%	47.1%	47.1%	33.3%
Sample Size		11	21	17	17	66

Question 1.6

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	Low Water
Sign at Crossing:	WHEN FLOODED TURN AROUND DON'T DROWN
Gauge:	White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	58.3%	57.1%	50.0%	58.8%	55.9%
	Yes	41.7%	42.9%	50.0%	41.2%	44.1%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	8.3%	9.5%	22.2%	23.5%	16.2%
	2	33.3%	14.3%	22.2%	17.6%	20.6%
	3	16.7%	38.1%	11.1%	29.4%	25.0%
	4	16.7%	23.8%	44.4%	23.5%	27.9%
	5	25.0%	14.3%	0.0%	5.9%	10.3%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	8.3%	0.0%	0.0%	0.0%	1.5%
	1	8.3%	0.0%	22.2%	17.6%	11.8%
	2	33.3%	28.6%	11.1%	17.6%	22.1%
	3	8.3%	23.8%	22.2%	17.6%	19.1%
	4	25.0%	23.8%	33.3%	23.5%	26.5%
	5	16.7%	23.8%	11.1%	23.5%	19.1%
Sample Size		12	21	18	17	68

Question 1.7

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	Low Water
Sign at Crossing:	WHEN FLOODED TURN AROUND DON'T DROWN
Gauge:	Red/White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	41.7%	42.9%	11.1%	47.1%	35.3%
	Yes	58.3%	57.1%	88.9%	52.9%	64.7%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	14.3%	22.2%	29.4%	17.6%
	2	75.0%	38.1%	50.0%	11.8%	41.2%
	3	8.3%	14.3%	16.7%	29.4%	17.6%
	4	0.0%	9.5%	5.6%	11.8%	7.4%
	5	16.7%	23.8%	5.6%	17.6%	16.2%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	0.0%	11.8%	2.9%
	1	8.3%	19.0%	5.6%	11.8%	11.8%
	2	16.7%	4.8%	5.6%	5.9%	7.4%
	3	16.7%	23.8%	22.2%	11.8%	19.1%
	4	33.3%	19.0%	27.8%	23.5%	25.0%
	5	25.0%	33.3%	38.9%	35.3%	33.8%
Sample Size		41.7%	42.9%	11.1%	47.1%	35.3%

Question 1.8

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	Low Water
Sign at Crossing:	DO NOT CROSS WHEN FLOODED
Gauge:	White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	72.7%	33.3%	17.6%	52.9%	40.9%
	Yes	27.3%	66.7%	82.4%	47.1%	59.1%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	18.2%	14.3%	23.5%	17.6%	18.2%
	2	9.1%	33.3%	41.2%	17.6%	27.3%
	3	27.3%	19.0%	29.4%	23.5%	24.2%
	4	18.2%	9.5%	5.9%	23.5%	13.6%
	5	27.3%	23.8%	0.0%	17.6%	16.7%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	14.3%	0.0%	0.0%	4.5%
	1	0.0%	9.5%	0.0%	23.5%	9.1%
	2	27.3%	9.5%	0.0%	5.9%	9.1%
	3	45.5%	19.0%	17.6%	11.8%	21.2%
	4	9.1%	28.6%	70.6%	47.1%	40.9%
	5	18.2%	19.0%	11.8%	11.8%	15.2%
Sample Size		11	21	17	17	66

Question 1.9

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	Low Water
Sign at Crossing:	DO NOT CROSS WHEN FLOODED
Gauge:	Red/White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	45.5%	38.1%	11.8%	41.2%	33.3%
	Yes	54.5%	61.9%	88.2%	58.8%	66.7%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	9.1%	23.8%	29.4%	23.5%	22.7%
	2	45.5%	38.1%	52.9%	29.4%	40.9%
	3	18.2%	4.8%	11.8%	29.4%	15.2%
	4	9.1%	19.0%	5.9%	5.9%	10.6%
	5	18.2%	14.3%	0.0%	11.8%	10.6%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	9.5%	0.0%	0.0%	3.0%
	1	9.1%	0.0%	0.0%	11.8%	4.5%
	2	0.0%	4.8%	0.0%	0.0%	1.5%
	3	27.3%	19.0%	11.8%	17.6%	18.2%
	4	36.4%	28.6%	47.1%	41.2%	37.9%
	5	27.3%	38.1%	41.2%	29.4%	34.8%
Sample Size		11	21	17	17	66

Question 1.10

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	High Water
Sign at Crossing:	None
Gauge:	White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	85.7%	76.5%	94.1%	87.9%
	Yes	0.0%	14.3%	23.5%	5.9%	12.1%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	4.8%	0.0%	0.0%	1.5%
	2	0.0%	4.8%	17.6%	5.9%	7.6%
	3	18.2%	14.3%	11.8%	11.8%	13.6%
	4	9.1%	19.0%	29.4%	29.4%	22.7%
	5	72.7%	57.1%	41.2%	52.9%	54.5%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	9.1%	19.0%	5.9%	23.5%	15.2%
	1	45.5%	33.3%	35.3%	29.4%	34.8%
	2	27.3%	19.0%	17.6%	11.8%	18.2%
	3	18.2%	19.0%	29.4%	11.8%	19.7%
	4	0.0%	4.8%	11.8%	17.6%	9.1%
	5	0.0%	4.8%	0.0%	5.9%	3.0%
Sample Size		11	21	17	17	66

Question 1.11

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	High Water
Sign at Crossing:	None
Gauge:	Yellow

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	95.2%	88.2%	94.1%	93.9%
	Yes	0.0%	4.8%	11.8%	5.9%	6.1%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	4.8%	0.0%	5.9%	3.0%
	2	0.0%	4.8%	11.8%	0.0%	4.5%
	3	18.2%	19.0%	17.6%	0.0%	13.6%
	4	18.2%	23.8%	41.2%	35.3%	30.3%
	5	63.6%	47.6%	29.4%	58.8%	48.5%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	18.2%	23.8%	17.6%	17.6%	19.7%
	1	27.3%	9.5%	17.6%	23.5%	18.2%
	2	27.3%	38.1%	17.6%	29.4%	28.8%
	3	27.3%	14.3%	29.4%	5.9%	18.2%
	4	0.0%	4.8%	17.6%	17.6%	10.6%
	5	0.0%	9.5%	0.0%	5.9%	4.5%
Sample Size		11	21	17	17	66

Question 1.12

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	High Water
Sign at Crossing:	None
Gauge:	Red/White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	100.0%	94.1%	100.0%	98.5%
	Yes	0.0%	0.0%	5.9%	0.0%	1.5%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	0.0%	5.9%	1.5%
	2	0.0%	4.8%	5.9%	0.0%	3.0%
	3	9.1%	14.3%	0.0%	0.0%	6.1%
	4	27.3%	28.6%	52.9%	23.5%	33.3%
	5	63.6%	52.4%	41.2%	70.6%	56.1%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	36.4%	19.0%	17.6%	35.3%	25.8%
	1	18.2%	33.3%	23.5%	5.9%	21.2%
	2	18.2%	23.8%	23.5%	0.0%	16.7%
	3	9.1%	4.8%	11.8%	11.8%	9.1%
	4	0.0%	0.0%	0.0%	5.9%	1.5%
	5	18.2%	19.0%	23.5%	41.2%	25.8%
Sample Size		11	21	17	17	66

Question 1.13

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	High Water
Sign at Crossing:	WHEN FLOODED TURN AROUND DON'T DROWN
Gauge:	White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	100.0%	94.1%	100.0%	98.5%
	Yes	0.0%	0.0%	5.9%	0.0%	1.5%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	0.0%	0.0%	0.0%
	3	9.1%	9.5%	5.9%	5.9%	7.6%
	4	9.1%	28.6%	23.5%	41.2%	27.3%
	5	81.8%	61.9%	70.6%	52.9%	65.2%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	54.5%	23.8%	23.5%	17.6%	27.3%
	1	36.4%	23.8%	29.4%	41.2%	31.8%
	2	0.0%	19.0%	41.2%	17.6%	21.2%
	3	0.0%	19.0%	0.0%	17.6%	10.6%
	4	9.1%	4.8%	0.0%	5.9%	4.5%
	5	0.0%	9.5%	5.9%	0.0%	4.5%
Sample Size		11	21	17	17	66

Question 1.14

Advance Sign: WATCH FOR WATER ON ROAD
Road Condition: High Water
Sign at Crossing: WHEN FLOODED TURN AROUND DON'T DROWN
Gauge: Red/White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	95.2%	100.0%	94.1%	97.0%
	Yes	0.0%	4.8%	0.0%	5.9%	3.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	0.0%	0.0%	0.0%
	3	9.1%	9.5%	0.0%	5.9%	6.1%
	4	9.1%	14.3%	35.3%	17.6%	19.7%
	5	81.8%	76.2%	64.7%	76.5%	74.2%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	45.5%	19.0%	5.9%	23.5%	21.2%
	1	18.2%	23.8%	58.8%	41.2%	36.4%
	2	18.2%	23.8%	23.5%	17.6%	21.2%
	3	9.1%	19.0%	5.9%	0.0%	9.1%
	4	9.1%	9.5%	5.9%	0.0%	6.1%
	5	0.0%	4.8%	0.0%	17.6%	6.1%
Sample Size		11	21	17	17	66

Question 1.15

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	High Water
Sign at Crossing:	DO NOT CROSS WHEN FLOODED
Gauge:	White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	95.2%	88.9%	100.0%	95.6%
	Yes	0.0%	4.8%	11.1%	0.0%	4.4%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	4.8%	0.0%	0.0%	1.5%
	2	8.3%	0.0%	5.6%	5.9%	4.4%
	3	0.0%	0.0%	11.1%	0.0%	2.9%
	4	25.0%	23.8%	27.8%	23.5%	25.0%
	5	66.7%	71.4%	55.6%	70.6%	66.2%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	25.0%	19.0%	11.1%	29.4%	20.6%
	1	33.3%	42.9%	33.3%	29.4%	35.3%
	2	25.0%	28.6%	22.2%	17.6%	23.5%
	3	8.3%	4.8%	27.8%	5.9%	11.8%
	4	8.3%	4.8%	0.0%	11.8%	5.9%
	5	0.0%	0.0%	5.6%	5.9%	2.9%
Sample Size		12	21	18	17	68

Question 1.16

Advance Sign:	WATCH FOR WATER ON ROAD
Road Condition:	High Water
Sign at Crossing:	DO NOT CROSS WHEN FLOODED
Gauge:	Red/White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	91.7%	90.5%	94.4%	88.2%	91.2%
	Yes	8.3%	9.5%	5.6%	11.8%	8.8%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	5.6%	0.0%	1.5%
	2	0.0%	4.8%	5.6%	0.0%	2.9%
	3	0.0%	9.5%	11.1%	5.9%	7.4%
	4	25.0%	19.0%	33.3%	23.5%	25.0%
	5	75.0%	66.7%	44.4%	70.6%	63.2%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	33.3%	23.8%	16.7%	23.5%	23.5%
	1	33.3%	38.1%	27.8%	47.1%	36.8%
	2	25.0%	19.0%	33.3%	11.8%	22.1%
	3	0.0%	14.3%	16.7%	5.9%	10.3%
	4	8.3%	0.0%	0.0%	5.9%	2.9%
	5	0.0%	4.8%	5.6%	5.9%	4.4%
Sample Size		12	21	18	17	68

Question 1.17

Advance Sign:	ROAD MAY FLOOD
Road Condition:	Dry
Sign at Crossing:	None
Gauge:	White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	0.0%	0.0%	0.0%	0.0%	0.0%
	Yes	100.0%	100.0%	100.0%	100.0%	100.0 %
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	100.0%	95.2%	94.4%	100.0%	97.1%
	2	0.0%	4.8%	5.6%	0.0%	2.9%
	3	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	0.0%	0.0%	0.0%	0.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	0.0%	0.0%	0.0%
	1	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	4.8%	11.1%	0.0%	4.4%
	5	100.0%	95.2%	88.9%	100.0%	95.6%
Sample Size		100.0%	95.2%	94.4%	100.0%	97.1%

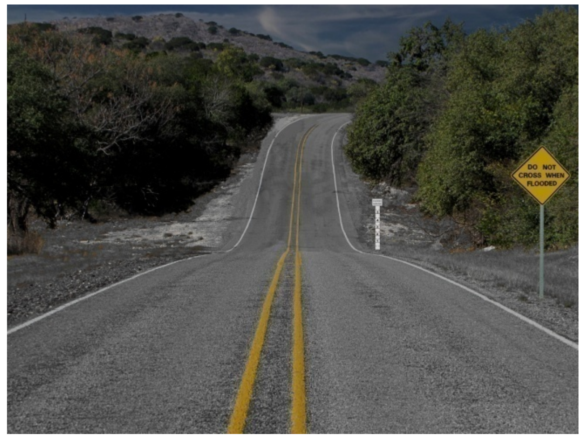
Question 1.18

Advance Sign:	ROAD MAY FLOOD
Road Condition:	Dry
Sign at Crossing:	WHEN FLOODED TURN AROUND DON'T DROWN
Gauge:	White

Question and Response		**College Station**	**Odessa**	**San Angelo**	**San Antonio**	**Total**
a: Would you continue on this road?	**No**	0.0%	9.5%	0.0%	0.0%	3.0%
	Yes	100.0%	90.5%	100.0%	100.0%	97.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	100.0%	81.0%	88.2%	94.1%	89.4%
	2	0.0%	4.8%	11.8%	0.0%	4.5%
	3	0.0%	0.0%	0.0%	0.0%	0.0%
	4	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	14.3%	0.0%	5.9%	6.1%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	0.0%	0.0%	0.0%
	1	0.0%	4.8%	0.0%	11.8%	4.5%
	2	0.0%	4.8%	5.9%	0.0%	3.0%
	3	0.0%	4.8%	0.0%	0.0%	1.5%
	4	0.0%	0.0%	0.0%	0.0%	0.0%
	5	100.0%	85.7%	94.1%	88.2%	90.9%
Sample Size		11	21	17	17	66

Question 1.19

Advance Sign:	ROAD MAY FLOOD
Road Condition:	Dry
Sign at Crossing:	DO NOT CROSS WHEN FLOODED
Gauge:	White



Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	0.0%	9.5%	0.0%	5.9%	4.5%
	Yes	100.0%	90.5%	100.0%	94.1%	95.5%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	81.8%	85.7%	100.0%	88.2%	89.4%
	2	9.1%	4.8%	0.0%	5.9%	4.5%
	3	9.1%	4.8%	0.0%	0.0%	3.0%
	4	0.0%	0.0%	0.0%	0.0%	0.0%
	5	0.0%	4.8%	0.0%	5.9%	3.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	4.8%	0.0%	0.0%	1.5%
	1	0.0%	4.8%	0.0%	5.9%	3.0%
	2	0.0%	0.0%	0.0%	5.9%	1.5%
	3	0.0%	9.5%	0.0%	0.0%	3.0%
	4	18.2%	4.8%	0.0%	0.0%	4.5%
	5	81.8%	76.2%	100.0%	88.2%	86.4%
Sample Size		11	21	17	17	66

Question 1.20

Advance Sign:	ROAD MAY FLOOD
Road Condition:	Low Water
Sign at Crossing:	None
Gauge:	White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	27.3%	14.3%	5.9%	5.9%	12.1%
	Yes	72.7%	85.7%	94.1%	94.1%	87.9%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	27.3%	66.7%	82.4%	52.9%	60.6%
	2	18.2%	28.6%	11.8%	29.4%	22.7%
	3	45.5%	0.0%	0.0%	11.8%	10.6%
	4	9.1%	4.8%	5.9%	0.0%	4.5%
	5	0.0%	0.0%	0.0%	5.9%	1.5%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	0.0%	0.0%	0.0%
	1	0.0%	0.0%	5.9%	5.9%	3.0%
	2	18.2%	0.0%	0.0%	0.0%	3.0%
	3	18.2%	19.0%	0.0%	11.8%	12.1%
	4	36.4%	23.8%	23.5%	17.6%	24.2%
	5	27.3%	57.1%	70.6%	64.7%	57.6%
Sample Size		11	21	17	17	66

Question 1.21

Advance Sign:	ROAD MAY FLOOD
Road Condition:	Low Water
Sign at Crossing:	None
Gauge:	Red/White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	9.1%	4.8%	0.0%	5.9%	4.5%
	Yes	90.9%	95.2%	100.0%	94.1%	95.5%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	27.3%	47.6%	76.5%	82.4%	60.6%
	2	45.5%	38.1%	23.5%	5.9%	27.3%
	3	18.2%	9.5%	0.0%	5.9%	7.6%
	4	9.1%	4.8%	0.0%	5.9%	4.5%
	5	0.0%	0.0%	0.0%	0.0%	0.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	9.5%	0.0%	0.0%	3.0%
	1	0.0%	0.0%	0.0%	0.0%	0.0%
	2	9.1%	4.8%	0.0%	5.9%	4.5%
	3	18.2%	4.8%	0.0%	0.0%	4.5%
	4	18.2%	33.3%	11.8%	0.0%	16.7%
	5	54.5%	47.6%	88.2%	94.1%	71.2%
Sample Size		11	21	17	17	66

Question 1.22

Advance Sign: ROAD MAY FLOOD
Road Condition: Low Water
Sign at Crossing: WHEN FLOODED TURN AROUND DON'T DROWN
Gauge: White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	0.0%	4.8%	11.1%	5.9%	5.9%
	Yes	100.0%	95.2%	88.9%	94.1%	94.1%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	50.0%	42.9%	38.9%	47.1%	44.1%
	2	33.3%	38.1%	33.3%	29.4%	33.8%
	3	16.7%	19.0%	16.7%	11.8%	16.2%
	4	0.0%	0.0%	5.6%	0.0%	1.5%
	5	0.0%	0.0%	5.6%	11.8%	4.4%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	4.8%	0.0%	11.8%	4.4%
	1	0.0%	0.0%	0.0%	0.0%	0.0%
	2	8.3%	4.8%	0.0%	0.0%	2.9%
	3	8.3%	14.3%	11.1%	11.8%	11.8%
	4	25.0%	33.3%	44.4%	17.6%	30.9%
	5	58.3%	42.9%	44.4%	58.8%	50.0%
Sample Size		12	21	18	17	68

Question 1.23

Advance Sign:	ROAD MAY FLOOD
Road Condition:	Low Water
Sign at Crossing:	WHEN FLOODED TURN AROUND DON'T DROWN
Gauge:	Red/White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	0.0%	4.8%	5.6%	11.8%	5.9%
	Yes	100.0%	95.2%	94.4%	88.2%	94.1%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	50.0%	57.1%	50.0%	52.9%	52.9%
	2	25.0%	33.3%	38.9%	23.5%	30.9%
	3	25.0%	9.5%	5.6%	11.8%	11.8%
	4	0.0%	0.0%	0.0%	5.9%	1.5%
	5	0.0%	0.0%	5.6%	5.9%	2.9%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	4.8%	5.6%	5.9%	4.4%
	1	0.0%	0.0%	0.0%	0.0%	0.0%
	2	8.3%	4.8%	0.0%	0.0%	2.9%
	3	0.0%	4.8%	11.1%	11.8%	7.4%
	4	33.3%	14.3%	22.2%	0.0%	16.2%
	5	58.3%	71.4%	61.1%	82.4%	69.1%
Sample Size		12	21	18	17	68

Question 1.24

Advance Sign:	ROAD MAY FLOOD
Road Condition:	Low Water
Sign at Crossing:	DO NOT CROSS WHEN FLOODED
Gauge:	White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	9.1%	9.5%	0.0%	11.8%	7.6%
	Yes	90.9%	90.5%	100.0%	88.2%	92.4%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	45.5%	47.6%	58.8%	64.7%	54.5%
	2	36.4%	33.3%	35.3%	17.6%	30.3%
	3	9.1%	4.8%	5.9%	17.6%	9.1%
	4	9.1%	4.8%	0.0%	0.0%	3.0%
	5	0.0%	9.5%	0.0%	0.0%	3.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	0.0%	0.0%	0.0%
	1	0.0%	4.8%	0.0%	5.9%	3.0%
	2	0.0%	0.0%	0.0%	5.9%	1.5%
	3	0.0%	0.0%	11.8%	5.9%	4.5%
	4	27.3%	9.5%	11.8%	17.6%	15.2%
	5	72.7%	85.7%	76.5%	64.7%	75.8%
Sample Size		11	21	17	17	66

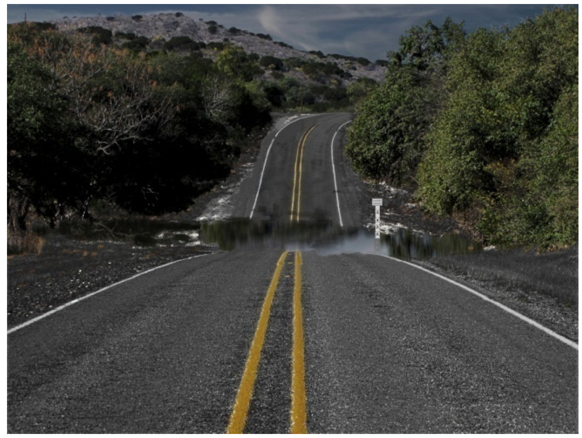
Question 1.25

Advance Sign:	ROAD MAY FLOOD
Road Condition:	Low Water
Sign at Crossing:	DO NOT CROSS WHEN FLOODED
Gauge:	Red/White

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	9.1%	4.8%	0.0%	11.8%	6.1%
	Yes	90.9%	95.2%	100.0%	88.2%	93.9%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	27.3%	52.4%	64.7%	76.5%	57.6%
	2	63.6%	33.3%	17.6%	11.8%	28.8%
	3	0.0%	9.5%	11.8%	0.0%	6.1%
	4	9.1%	0.0%	0.0%	5.9%	3.0%
	5	0.0%	4.8%	5.9%	5.9%	4.5%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	0.0%	0.0%	0.0%
	1	0.0%	0.0%	0.0%	5.9%	1.5%
	2	0.0%	4.8%	0.0%	0.0%	1.5%
	3	0.0%	0.0%	0.0%	0.0%	0.0%
	4	45.5%	23.8%	17.6%	29.4%	27.3%
	5	54.5%	71.4%	82.4%	64.7%	69.7%
Sample Size		11	21	17	17	66

Question 1.26

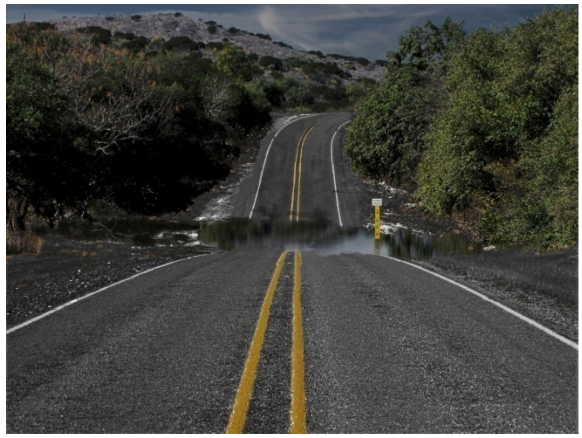
Advance Sign:	ROAD MAY FLOOD
Road Condition:	High Water
Sign at Crossing:	None
Gauge:	White



Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	81.8%	61.9%	47.1%	58.8%	60.6%
	Yes	18.2%	38.1%	52.9%	41.2%	39.4%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	9.5%	11.8%	5.9%	7.6%
	2	9.1%	19.0%	23.5%	29.4%	21.2%
	3	27.3%	28.6%	41.2%	23.5%	30.3%
	4	27.3%	19.0%	23.5%	29.4%	24.2%
	5	36.4%	23.8%	0.0%	11.8%	16.7%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	14.3%	0.0%	11.8%	7.6%
	1	9.1%	4.8%	5.9%	11.8%	7.6%
	2	27.3%	9.5%	11.8%	5.9%	12.1%
	3	45.5%	38.1%	35.3%	23.5%	34.8%
	4	18.2%	9.5%	23.5%	41.2%	22.7%
	5	0.0%	23.8%	23.5%	5.9%	15.2%
Sample Size		11	21	17	17	66

Question 1.27

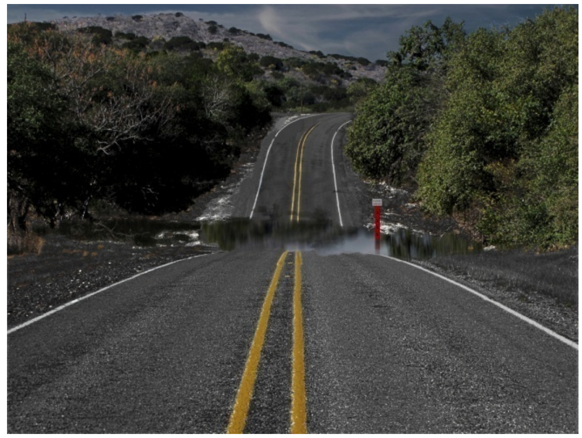
Advance Sign:	ROAD MAY FLOOD
Road Condition:	High Water
Sign at Crossing:	None
Gauge:	Yellow



Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	81.8%	61.9%	41.2%	70.6%	62.1%
	Yes	18.2%	38.1%	58.8%	29.4%	37.9%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	4.8%	5.9%	5.9%	4.5%
	2	9.1%	28.6%	29.4%	11.8%	21.2%
	3	27.3%	28.6%	35.3%	23.5%	28.8%
	4	27.3%	9.5%	23.5%	29.4%	21.2%
	5	36.4%	28.6%	5.9%	29.4%	24.2%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	14.3%	5.9%	5.9%	7.6%
	1	18.2%	4.8%	5.9%	11.8%	9.1%
	2	18.2%	9.5%	23.5%	11.8%	15.2%
	3	36.4%	42.9%	17.6%	23.5%	30.3%
	4	27.3%	19.0%	29.4%	41.2%	28.8%
	5	0.0%	9.5%	17.6%	5.9%	9.1%
Sample Size		11	21	17	17	66

Question 1.28

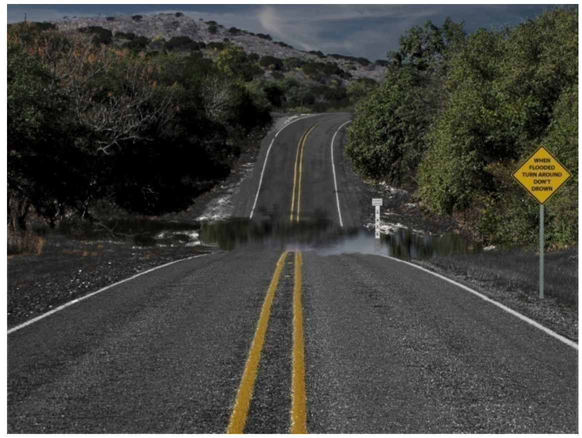
Advance Sign:	ROAD MAY FLOOD
Road Condition:	High Water
Sign at Crossing:	None
Gauge:	Red/White



Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	72.7%	57.1%	52.9%	76.5%	63.6%
	Yes	27.3%	42.9%	47.1%	23.5%	36.4%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	9.5%	5.9%	5.9%	6.1%
	2	18.2%	4.8%	23.5%	17.6%	15.2%
	3	9.1%	28.6%	29.4%	11.8%	21.2%
	4	36.4%	19.0%	41.2%	23.5%	28.8%
	5	36.4%	38.1%	0.0%	41.2%	28.8%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	14.3%	0.0%	17.6%	9.1%
	1	9.1%	4.8%	17.6%	5.9%	9.1%
	2	45.5%	19.0%	11.8%	17.6%	21.2%
	3	18.2%	42.9%	11.8%	23.5%	25.8%
	4	27.3%	9.5%	35.3%	17.6%	21.2%
	5	0.0%	9.5%	23.5%	17.6%	13.6%
Sample Size		11	21	17	17	66

Question 1.29

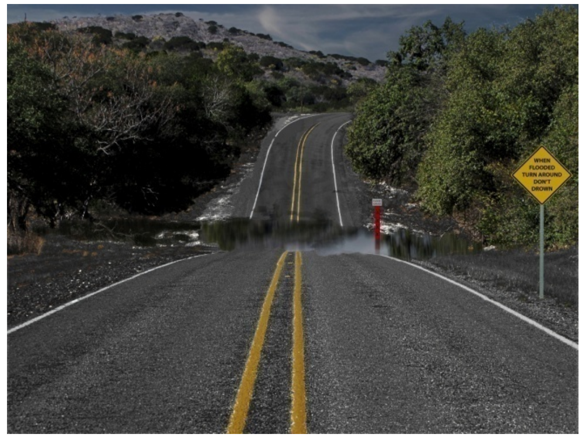
Advance Sign:	ROAD MAY FLOOD
Road Condition:	High Water
Sign at Crossing:	WHEN FLOODED TURN AROUND DON'T DROWN
Gauge:	White



Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	57.1%	64.7%	58.8%	66.7%
	Yes	0.0%	42.9%	35.3%	41.2%	33.3%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	11.8%	0.0%	3.0%
	2	0.0%	14.3%	11.8%	23.5%	13.6%
	3	27.3%	28.6%	35.3%	35.3%	31.8%
	4	45.5%	33.3%	29.4%	17.6%	30.3%
	5	27.3%	23.8%	11.8%	23.5%	21.2%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	9.1%	4.8%	5.9%	0.0%	4.5%
	1	36.4%	19.0%	11.8%	11.8%	18.2%
	2	36.4%	28.6%	5.9%	23.5%	22.7%
	3	18.2%	38.1%	47.1%	17.6%	31.8%
	4	0.0%	4.8%	11.8%	47.1%	16.7%
	5	0.0%	4.8%	17.6%	0.0%	6.1%
Sample Size		11	21	17	17	66

Question 1.30

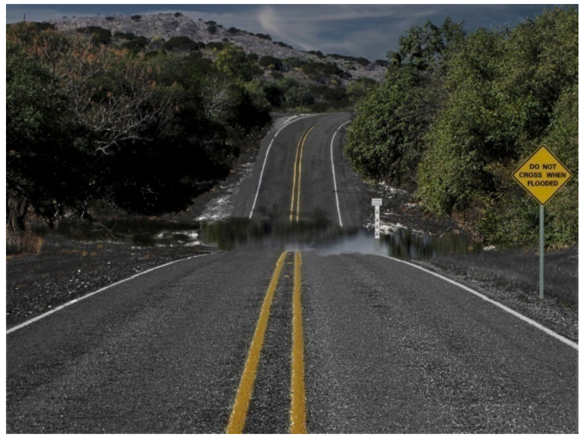
Advance Sign: ROAD MAY FLOOD
Road Condition: High Water
Sign at Crossing: WHEN FLOODED TURN AROUND DON'T DROWN
Gauge: Red/White



Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	76.2%	70.6%	76.5%	78.8%
	Yes	0.0%	23.8%	29.4%	23.5%	21.2%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	5.9%	0.0%	1.5%
	2	0.0%	9.5%	5.9%	11.8%	7.6%
	3	27.3%	19.0%	35.3%	35.3%	28.8%
	4	18.2%	52.4%	23.5%	23.5%	31.8%
	5	54.5%	19.0%	29.4%	29.4%	30.3%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	18.2%	4.8%	0.0%	11.8%	7.6%
	1	27.3%	28.6%	17.6%	5.9%	19.7%
	2	36.4%	19.0%	17.6%	17.6%	21.2%
	3	0.0%	23.8%	52.9%	58.8%	36.4%
	4	18.2%	23.8%	5.9%	5.9%	13.6%
	5	0.0%	0.0%	5.9%	0.0%	1.5%
Sample Size		11	21	17	17	66

Question 1.31

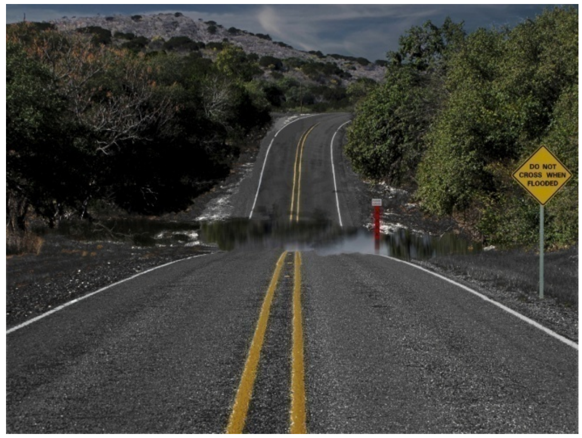
Advance Sign:	ROAD MAY FLOOD
Road Condition:	High Water
Sign at Crossing:	DO NOT CROSS WHEN FLOODED
Gauge:	White



Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	66.7%	76.2%	77.8%	70.6%	73.5%
	Yes	33.3%	23.8%	22.2%	29.4%	26.5%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	4.8%	0.0%	5.9%	2.9%
	2	8.3%	14.3%	27.8%	5.9%	14.7%
	3	58.3%	42.9%	16.7%	47.1%	39.7%
	4	25.0%	19.0%	33.3%	11.8%	22.1%
	5	8.3%	19.0%	22.2%	29.4%	20.6%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	5.6%	5.9%	2.9%
	1	8.3%	0.0%	16.7%	17.6%	10.3%
	2	33.3%	42.9%	11.1%	17.6%	26.5%
	3	41.7%	33.3%	33.3%	35.3%	35.3%
	4	16.7%	14.3%	27.8%	5.9%	16.2%
	5	0.0%	9.5%	5.6%	17.6%	8.8%
Sample Size		12	21	18	17	68

Question 1.32

Advance Sign:	ROAD MAY FLOOD
Road Condition:	High Water
Sign at Crossing:	DO NOT CROSS WHEN FLOODED
Gauge:	Red/White



Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	83.3%	76.2%	66.7%	82.4%	76.5%
	Yes	16.7%	23.8%	33.3%	17.6%	23.5%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	23.8%	22.2%	11.8%	16.2%
	3	41.7%	23.8%	27.8%	29.4%	29.4%
	4	50.0%	23.8%	16.7%	35.3%	29.4%
	5	8.3%	28.6%	33.3%	23.5%	25.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	16.7%	5.9%	5.9%
	1	33.3%	33.3%	0.0%	11.8%	19.1%
	2	33.3%	19.0%	27.8%	35.3%	27.9%
	3	16.7%	28.6%	33.3%	29.4%	27.9%
	4	16.7%	9.5%	22.2%	11.8%	14.7%
	5	0.0%	9.5%	0.0%	5.9%	4.4%
Sample Size		12	21	18	17	68

Question 2.1

Road Condition:	Dry
Sign at Crossing:	ROAD FLOODED WHEN FLASHING
Active Element:	Beacons Flashing Red
Special Note:	Presents a "*false alarm*" condition

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	66.7%	20.0%	30.8%	30.8%	34.0%
	Yes	33.3%	80.0%	69.2%	69.2%	66.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	11.1%	46.7%	46.2%	61.5%	44.0%
	2	11.1%	20.0%	7.7%	7.7%	12.0%
	3	11.1%	13.3%	23.1%	15.4%	16.0%
	4	33.3%	13.3%	0.0%	15.4%	14.0%
	5	33.3%	6.7%	23.1%	0.0%	14.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	11.1%	0.0%	0.0%	0.0%	2.0%
	1	33.3%	6.7%	23.1%	15.4%	18.0%
	2	11.1%	0.0%	0.0%	7.7%	4.0%
	3	11.1%	13.3%	7.7%	0.0%	8.0%
	4	0.0%	26.7%	7.7%	7.7%	12.0%
	5	33.3%	53.3%	61.5%	69.2%	56.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	44.4%	80.0%	53.8%	46.2%	58.0%
	Yes	55.6%	20.0%	46.2%	53.8%	42.0%
Sample Size		9	15	13	13	50

Question 2.2

Road Condition:	Dry
Sign at Crossing:	HIGH WATER DO NOT ENTER WHEN FLASHING
Active Element:	Beacons Flashing Red
Special Note:	Presents a "*false alarm*" condition

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	50.0%	47.1%	50.0%	41.7%	46.9%
	Yes	50.0%	52.9%	50.0%	58.3%	53.1%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	37.5%	23.5%	50.0%	33.3%	34.7%
	2	0.0%	5.9%	0.0%	25.0%	8.2%
	3	37.5%	11.8%	25.0%	16.7%	20.4%
	4	12.5%	23.5%	8.3%	8.3%	14.3%
	5	12.5%	35.3%	16.7%	16.7%	22.4%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	12.5%	5.9%	8.3%	8.3%	8.2%
	1	0.0%	5.9%	16.7%	25.0%	12.2%
	2	25.0%	17.6%	0.0%	8.3%	12.2%
	3	25.0%	5.9%	25.0%	8.3%	14.3%
	4	0.0%	47.1%	16.7%	8.3%	22.4%
	5	37.5%	17.6%	33.3%	41.7%	30.6%
d: Do you think you could get a ticket for continuing past this sign?	**No**	25.0%	52.9%	25.0%	41.7%	38.8%
	Yes	75.0%	47.1%	75.0%	58.3%	61.2%
Sample Size		8	17	12	12	49

Question 2.3

Road Condition:	Dry
Sign at Crossing:	HIGH WATER ROAD CLOSED WHEN FLASHING
Active Element:	Beacons Flashing Red
Special Note:	Presents a "*false alarm*" condition

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	75.0%	40.0%	64.3%	46.2%	54.0%
	Yes	25.0%	60.0%	35.7%	53.8%	46.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	12.5%	33.3%	35.7%	38.5%	32.0%
	2	25.0%	33.3%	14.3%	7.7%	20.0%
	3	25.0%	6.7%	28.6%	7.7%	16.0%
	4	0.0%	13.3%	7.1%	15.4%	10.0%
	5	37.5%	13.3%	14.3%	30.8%	22.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	12.5%	13.3%	0.0%	0.0%	6.0%
	1	0.0%	0.0%	7.1%	23.1%	8.0%
	2	12.5%	0.0%	0.0%	7.7%	4.0%
	3	25.0%	26.7%	42.9%	7.7%	26.0%
	4	12.5%	13.3%	21.4%	30.8%	20.0%
	5	37.5%	46.7%	28.6%	30.8%	36.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	75.0%	46.7%	35.7%	38.5%	46.0%
	Yes	25.0%	53.3%	64.3%	61.5%	54.0%
Sample Size		8	15	14	13	50

Question 2.4

Road Condition:	Dry
Sign at Crossing:	DO NOT ENTER (LED)
Active Element:	LED On
Special Note:	Presents a "*false alarm*" condition

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	77.8%	81.3%	84.6%	53.8%	74.5%
	Yes	22.2%	18.8%	15.4%	46.2%	25.5%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	33.3%	6.3%	15.4%	38.5%	21.6%
	2	11.1%	18.8%	15.4%	23.1%	17.6%
	3	0.0%	12.5%	7.7%	7.7%	7.8%
	4	11.1%	12.5%	23.1%	15.4%	15.7%
	5	44.4%	50.0%	38.5%	15.4%	37.3%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	11.1%	12.5%	30.8%	0.0%	13.7%
	1	11.1%	18.8%	7.7%	7.7%	11.8%
	2	11.1%	18.8%	23.1%	15.4%	17.6%
	3	22.2%	18.8%	7.7%	30.8%	19.6%
	4	22.2%	12.5%	23.1%	23.1%	19.6%
	5	22.2%	18.8%	7.7%	23.1%	17.6%
d: Do you think you could get a ticket for continuing past this sign?	**No**	33.3%	31.3%	15.4%	30.8%	27.5%
	Yes	66.7%	68.8%	84.6%	69.2%	72.5%
Sample Size		9	16	13	13	51

Question 2.5

Road Condition: Low Water
Sign at Crossing: ROAD FLOODED WHEN FLASHING
Active Element: Beacons Off
Special Note: *None*

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	33.3%	20.0%	15.4%	7.7%	18.0%
	Yes	66.7%	80.0%	84.6%	92.3%	82.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	13.3%	15.4%	38.5%	18.0%
	2	55.6%	46.7%	69.2%	30.8%	50.0%
	3	0.0%	20.0%	0.0%	23.1%	12.0%
	4	33.3%	6.7%	7.7%	0.0%	10.0%
	5	11.1%	13.3%	7.7%	7.7%	10.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	0.0%	0.0%	0.0%
	1	22.2%	6.7%	0.0%	7.7%	8.0%
	2	22.2%	20.0%	7.7%	0.0%	12.0%
	3	11.1%	13.3%	15.4%	15.4%	14.0%
	4	33.3%	40.0%	38.5%	53.8%	42.0%
	5	11.1%	20.0%	38.5%	23.1%	24.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	66.7%	80.0%	84.6%	92.3%	82.0%
	Yes	33.3%	20.0%	15.4%	7.7%	18.0%
Sample Size		9	15	13	13	50

Question 2.6

Road Condition:	Low Water
Sign at Crossing:	ROAD FLOODED WHEN FLASHING
Active Element:	Beacons Flashing Yellow
Special Note:	Presents a "*false alarm*" condition

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	55.6%	60.0%	38.5%	53.8%	52.0%
	Yes	44.4%	40.0%	61.5%	46.2%	48.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	11.1%	0.0%	15.4%	0.0%	6.0%
	2	22.2%	26.7%	38.5%	38.5%	32.0%
	3	22.2%	26.7%	23.1%	30.8%	26.0%
	4	33.3%	20.0%	23.1%	23.1%	24.0%
	5	11.1%	26.7%	0.0%	7.7%	12.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	6.7%	0.0%	0.0%	2.0%
	1	11.1%	13.3%	7.7%	15.4%	12.0%
	2	33.3%	13.3%	7.7%	23.1%	18.0%
	3	11.1%	33.3%	38.5%	15.4%	26.0%
	4	44.4%	26.7%	23.1%	30.8%	30.0%
	5	0.0%	6.7%	23.1%	15.4%	12.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	44.4%	60.0%	69.2%	38.5%	54.0%
	Yes	55.6%	40.0%	30.8%	61.5%	46.0%
Sample Size		9	15	13	13	50

Question 2.7

Road Condition:	Low Water
Sign at Crossing:	ROAD FLOODED WHEN FLASHING
Active Element:	Beacons Flashing Red
Special Note:	Presents a “*false alarm*” condition

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	77.8%	53.3%	38.5%	61.5%	56.0%
	Yes	22.2%	46.7%	61.5%	38.5%	44.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	7.7%	7.7%	4.0%
	2	11.1%	33.3%	53.8%	15.4%	30.0%
	3	33.3%	26.7%	23.1%	46.2%	32.0%
	4	33.3%	20.0%	15.4%	23.1%	22.0%
	5	22.2%	20.0%	0.0%	7.7%	12.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	11.1%	6.7%	0.0%	0.0%	4.0%
	1	22.2%	6.7%	0.0%	7.7%	8.0%
	2	55.6%	0.0%	15.4%	23.1%	20.0%
	3	11.1%	60.0%	30.8%	23.1%	34.0%
	4	0.0%	20.0%	38.5%	30.8%	24.0%
	5	0.0%	6.7%	15.4%	15.4%	10.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	22.2%	66.7%	46.2%	23.1%	42.0%
	Yes	77.8%	33.3%	53.8%	76.9%	58.0%
Sample Size		9	15	13	13	50

Question 2.8

Road Condition: Low Water
Sign at Crossing: HIGH WATER DO NOT ENTER WHEN FLASHING
Active Element: Beacons Off
Special Note: *None*


Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	37.5%	29.4%	33.3%	41.7%	34.7%
	Yes	62.5%	70.6%	66.7%	58.3%	65.3%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	25.0%	11.8%	16.7%	41.7%	22.4%
	2	50.0%	35.3%	50.0%	25.0%	38.8%
	3	0.0%	17.6%	8.3%	16.7%	12.2%
	4	12.5%	23.5%	8.3%	8.3%	14.3%
	5	12.5%	11.8%	16.7%	8.3%	12.2%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	12.5%	5.9%	8.3%	0.0%	6.1%
	1	0.0%	5.9%	8.3%	8.3%	6.1%
	2	12.5%	5.9%	16.7%	16.7%	12.2%
	3	0.0%	11.8%	25.0%	8.3%	12.2%
	4	12.5%	35.3%	16.7%	25.0%	24.5%
	5	62.5%	35.3%	25.0%	41.7%	38.8%
d: Do you think you could get a ticket for continuing past this sign?	**No**	100.0%	76.5%	75.0%	66.7%	77.6%
	Yes	0.0%	23.5%	25.0%	33.3%	22.4%
Sample Size		8	17	12	12	49

Question 2.9

Road Condition:	Low Water
Sign at Crossing:	HIGH WATER DO NOT ENTER WHEN FLASHING
Active Element:	Beacons Flashing Yellow
Special Note:	Presents a "*false alarm*" condition

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	62.5%	58.8%	83.3%	75.0%	69.4%
	Yes	37.5%	41.2%	16.7%	25.0%	30.6%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	5.9%	16.7%	16.7%	10.2%
	2	50.0%	11.8%	16.7%	25.0%	22.4%
	3	12.5%	35.3%	8.3%	8.3%	18.4%
	4	12.5%	29.4%	8.3%	8.3%	16.3%
	5	25.0%	17.6%	50.0%	41.7%	32.7%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	25.0%	11.8%	16.7%	0.0%	12.2%
	1	12.5%	0.0%	41.7%	25.0%	18.4%
	2	0.0%	11.8%	8.3%	16.7%	10.2%
	3	25.0%	23.5%	25.0%	33.3%	26.5%
	4	25.0%	23.5%	0.0%	16.7%	16.3%
	5	12.5%	29.4%	8.3%	8.3%	16.3%
d: Do you think you could get a ticket for continuing past this sign?	**No**	37.5%	52.9%	25.0%	16.7%	34.7%
	Yes	62.5%	47.1%	75.0%	83.3%	65.3%
Sample Size		8	17	12	12	49

Question 2.10

Road Condition:	Low Water
Sign at Crossing:	HIGH WATER DO NOT ENTER WHEN FLASHING
Active Element:	Beacons Flashing Red
Special Note:	Presents a "*false alarm*" condition

Question and Response		**College Station**	**Odessa**	**San Angelo**	**San Antonio**	**Total**
a: Would you continue on this road?	**No**	75.0%	47.1%	83.3%	75.0%	67.3%
	Yes	25.0%	52.9%	16.7%	25.0%	32.7%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	12.5%	5.9%	8.3%	16.7%	10.2%
	2	37.5%	29.4%	16.7%	8.3%	22.4%
	3	25.0%	29.4%	8.3%	16.7%	20.4%
	4	0.0%	23.5%	33.3%	8.3%	18.4%
	5	25.0%	11.8%	33.3%	50.0%	28.6%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	12.5%	17.6%	16.7%	0.0%	12.2%
	1	12.5%	11.8%	33.3%	25.0%	20.4%
	2	25.0%	17.6%	8.3%	33.3%	20.4%
	3	12.5%	11.8%	25.0%	8.3%	14.3%
	4	25.0%	23.5%	16.7%	16.7%	20.4%
	5	12.5%	17.6%	0.0%	16.7%	12.2%
d: Do you think you could get a ticket for continuing past this sign?	**No**	50.0%	29.4%	33.3%	16.7%	30.6%
	Yes	50.0%	70.6%	66.7%	83.3%	69.4%
Sample Size		8	17	12	12	49

Question 2.11

Road Condition:	Low Water
Sign at Crossing:	HIGH WATER ROAD CLOSED WHEN FLASHING
Active Element:	Beacons Off
Special Note:	None

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	37.5%	33.3%	21.4%	15.4%	26.0%
	Yes	62.5%	66.7%	78.6%	84.6%	74.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	12.5%	20.0%	14.3%	23.1%	18.0%
	2	25.0%	46.7%	57.1%	23.1%	40.0%
	3	37.5%	20.0%	7.1%	38.5%	24.0%
	4	12.5%	0.0%	14.3%	15.4%	10.0%
	5	12.5%	13.3%	7.1%	0.0%	8.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	0.0%	0.0%	0.0%
	1	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	26.7%	0.0%	15.4%	12.0%
	3	37.5%	33.3%	28.6%	23.1%	30.0%
	4	37.5%	20.0%	35.7%	30.8%	30.0%
	5	25.0%	20.0%	35.7%	30.8%	28.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	87.5%	93.3%	92.9%	61.5%	84.0%
	Yes	12.5%	6.7%	7.1%	38.5%	16.0%
Sample Size		8	15	14	13	50

Question 2.12

Road Condition:	Low Water
Sign at Crossing:	HIGH WATER ROAD CLOSED WHEN FLASHING
Active Element:	Beacons Flashing Yellow
Special Note:	Presents a “*false alarm*” condition

Question and Response		**College Station**	**Odessa**	**San Angelo**	**San Antonio**	**Total**
a: Would you continue on this road?	**No**	50.0%	53.3%	57.1%	46.2%	52.0%
	Yes	50.0%	46.7%	42.9%	53.8%	48.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	12.5%	13.3%	0.0%	15.4%	10.0%
	2	12.5%	46.7%	28.6%	23.1%	30.0%
	3	37.5%	20.0%	14.3%	23.1%	22.0%
	4	25.0%	13.3%	35.7%	23.1%	24.0%
	5	12.5%	6.7%	21.4%	15.4%	14.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	0.0%	0.0%	0.0%
	1	12.5%	6.7%	7.1%	7.7%	8.0%
	2	0.0%	20.0%	14.3%	23.1%	16.0%
	3	37.5%	33.3%	28.6%	23.1%	30.0%
	4	50.0%	26.7%	42.9%	15.4%	32.0%
	5	0.0%	13.3%	7.1%	30.8%	14.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	75.0%	46.7%	57.1%	7.7%	44.0%
	Yes	25.0%	53.3%	42.9%	92.3%	56.0%
Sample Size		8	15	14	13	50

Question 2.13

Road Condition:	Low Water
Sign at Crossing:	HIGH WATER ROAD CLOSED WHEN FLASHING
Active Element:	Beacons Flashing Red
Special Note:	Presents a “*false alarm*” condition

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	75.0%	53.3%	57.1%	61.5%	60.0%
	Yes	25.0%	46.7%	42.9%	38.5%	40.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	25.0%	13.3%	0.0%	23.1%	14.0%
	2	0.0%	13.3%	35.7%	7.7%	16.0%
	3	12.5%	53.3%	42.9%	23.1%	36.0%
	4	25.0%	0.0%	14.3%	15.4%	12.0%
	5	37.5%	20.0%	7.1%	30.8%	22.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	6.7%	0.0%	0.0%	2.0%
	1	25.0%	0.0%	0.0%	15.4%	8.0%
	2	12.5%	40.0%	42.9%	23.1%	32.0%
	3	12.5%	26.7%	14.3%	38.5%	24.0%
	4	37.5%	20.0%	28.6%	15.4%	24.0%
	5	12.5%	6.7%	14.3%	7.7%	10.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	37.5%	33.3%	35.7%	7.7%	28.0%
	Yes	62.5%	66.7%	64.3%	92.3%	72.0%
Sample Size		8	15	14	13	50

Question 2.14

Road Condition:	Low Water
Sign at Crossing:	DO NOT ENTER (LED)
Active Element:	LED Off
Special Note:	None

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	44.4%	25.0%	0.0%	23.1%	21.6%
	Yes	55.6%	75.0%	100.0%	76.9%	78.4%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	33.3%	18.8%	53.8%	15.4%	29.4%
	2	11.1%	43.8%	38.5%	53.8%	39.2%
	3	11.1%	25.0%	7.7%	23.1%	17.6%
	4	44.4%	6.3%	0.0%	0.0%	9.8%
	5	0.0%	6.3%	0.0%	7.7%	3.9%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	0.0%	0.0%	0.0%
	1	0.0%	0.0%	0.0%	0.0%	0.0%
	2	11.1%	6.3%	0.0%	15.4%	7.8%
	3	22.2%	31.3%	0.0%	7.7%	15.7%
	4	44.4%	43.8%	38.5%	53.8%	45.1%
	5	22.2%	18.8%	61.5%	23.1%	31.4%
d: Do you think you could get a ticket for continuing past this sign?	**No**	100.0%	93.8%	100.0%	84.6%	94.1%
	Yes	0.0%	6.3%	0.0%	15.4%	5.9%
Sample Size		9	16	13	13	51

Question 2.15

Road Condition:	Low Water
Sign at Crossing:	DO NOT ENTER (LED)
Active Element:	LED On
Special Note:	Presents a "*false alarm*" condition

c

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	66.7%	62.5%	84.6%	69.2%	70.6%
	Yes	33.3%	37.5%	15.4%	30.8%	29.4%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	22.2%	6.3%	15.4%	7.7%	11.8%
	2	22.2%	12.5%	15.4%	23.1%	17.6%
	3	11.1%	25.0%	23.1%	23.1%	21.6%
	4	33.3%	12.5%	7.7%	7.7%	13.7%
	5	11.1%	43.8%	38.5%	38.5%	35.3%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	11.1%	12.5%	23.1%	7.7%	13.7%
	1	0.0%	12.5%	15.4%	7.7%	9.8%
	2	22.2%	18.8%	23.1%	15.4%	19.6%
	3	33.3%	25.0%	23.1%	23.1%	25.5%
	4	11.1%	25.0%	7.7%	46.2%	23.5%
	5	22.2%	6.3%	7.7%	0.0%	7.8%
d: Do you think you could get a ticket for continuing past this sign?	**No**	33.3%	25.0%	7.7%	7.7%	17.6%
	Yes	66.7%	75.0%	92.3%	92.3%	82.4%
Sample Size		9	16	13	13	51

Question 2.16

Road Condition:	High Water
Sign at Crossing:	ROAD FLOODED WHEN FLASHING
Active Element:	Beacons Off
Special Note:	Presents a "*System Failure*" condition


Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	87.5%	80.0%	78.6%	92.3%	84.0%
	Yes	12.5%	20.0%	21.4%	7.7%	16.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	6.7%	0.0%	7.7%	4.0%
	2	0.0%	13.3%	7.1%	0.0%	6.0%
	3	25.0%	6.7%	21.4%	15.4%	16.0%
	4	25.0%	33.3%	35.7%	30.8%	32.0%
	5	50.0%	40.0%	35.7%	46.2%	42.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	12.5%	6.7%	0.0%	23.1%	10.0%
	1	50.0%	20.0%	21.4%	23.1%	26.0%
	2	0.0%	40.0%	0.0%	23.1%	18.0%
	3	12.5%	13.3%	64.3%	23.1%	30.0%
	4	25.0%	13.3%	14.3%	7.7%	14.0%
	5	0.0%	6.7%	0.0%	0.0%	2.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	100.0%	80.0%	85.7%	30.8%	72.0%
	Yes	0.0%	20.0%	14.3%	69.2%	28.0%
Sample Size		8	15	14	13	50

Question 2.17

Road Condition:	High Water
Sign at Crossing:	ROAD FLOODED WHEN FLASHING
Active Element:	Beacons Flashing Yellow
Special Note:	None

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	87.5%	93.3%	100.0%	100.0%	96.0%
	Yes	12.5%	6.7%	0.0%	0.0%	4.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	6.7%	0.0%	0.0%	2.0%
	2	0.0%	0.0%	7.1%	7.7%	4.0%
	3	37.5%	13.3%	7.1%	7.7%	14.0%
	4	0.0%	13.3%	14.3%	7.7%	10.0%
	5	62.5%	66.7%	71.4%	76.9%	70.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	12.5%	13.3%	7.1%	7.7%	10.0%
	1	50.0%	6.7%	42.9%	30.8%	30.0%
	2	25.0%	60.0%	28.6%	38.5%	40.0%
	3	0.0%	6.7%	21.4%	7.7%	10.0%
	4	12.5%	0.0%	0.0%	7.7%	4.0%
	5	0.0%	13.3%	0.0%	7.7%	6.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	37.5%	46.7%	42.9%	7.7%	34.0%
	Yes	62.5%	53.3%	57.1%	92.3%	66.0%
Sample Size		8	15	14	13	50

Question 2.18

Road Condition:	High Water
Sign at Crossing:	ROAD FLOODED WHEN FLASHING
Active Element:	Beacons Flashing Red
Special Note:	None

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	93.3%	100.0%	100.0%	98.0%
	Yes	0.0%	6.7%	0.0%	0.0%	2.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	20.0%	21.4%	0.0%	12.0%
	4	12.5%	33.3%	35.7%	30.8%	30.0%
	5	87.5%	46.7%	42.9%	69.2%	58.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	25.0%	13.3%	7.1%	23.1%	16.0%
	1	50.0%	46.7%	28.6%	23.1%	36.0%
	2	12.5%	6.7%	35.7%	38.5%	24.0%
	3	12.5%	13.3%	21.4%	0.0%	12.0%
	4	0.0%	13.3%	7.1%	7.7%	8.0%
	5	0.0%	6.7%	0.0%	7.7%	4.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	37.5%	53.3%	35.7%	7.7%	34.0%
	Yes	62.5%	46.7%	64.3%	92.3%	66.0%
Sample Size		8	15	14	13	50

Question 2.19

Road Condition:	High Water
Sign at Crossing:	HIGH WATER DO NOT ENTER WHEN FLASHING
Active Element:	Beacons Off
Special Note:	Presents a "*System Failure*" condition

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	77.8%	56.3%	69.2%	92.3%	72.5%
	Yes	22.2%	43.8%	30.8%	7.7%	27.5%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	11.1%	0.0%	0.0%	7.7%	3.9%
	2	11.1%	25.0%	15.4%	0.0%	13.7%
	3	0.0%	37.5%	53.8%	15.4%	29.4%
	4	22.2%	12.5%	23.1%	23.1%	19.6%
	5	55.6%	25.0%	7.7%	53.8%	33.3%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	11.1%	12.5%	7.7%	30.8%	15.7%
	1	0.0%	6.3%	15.4%	15.4%	9.8%
	2	33.3%	0.0%	7.7%	7.7%	9.8%
	3	22.2%	43.8%	46.2%	23.1%	35.3%
	4	11.1%	31.3%	23.1%	15.4%	21.6%
	5	22.2%	6.3%	0.0%	7.7%	7.8%
d: Do you think you could get a ticket for continuing past this sign?	**No**	88.9%	68.8%	76.9%	46.2%	68.6%
	Yes	11.1%	31.3%	23.1%	53.8%	31.4%
Sample Size		9	16	13	13	51

Question 2.20

Road Condition:	High Water
Sign at Crossing:	HIGH WATER DO NOT ENTER WHEN FLASHING
Active Element:	Beacons Flashing Yellow
Special Note:	None


Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	100.0%	100.0%	100.0%	100.0 %
	Yes	0.0%	0.0%	0.0%	0.0%	0.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	12.5%	15.4%	0.0%	7.8%
	3	11.1%	25.0%	23.1%	0.0%	15.7%
	4	22.2%	25.0%	23.1%	30.8%	25.5%
	5	66.7%	37.5%	38.5%	69.2%	51.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	11.1%	6.3%	30.8%	23.1%	17.6%
	1	22.2%	12.5%	15.4%	23.1%	17.6%
	2	33.3%	37.5%	30.8%	7.7%	27.5%
	3	22.2%	37.5%	7.7%	30.8%	25.5%
	4	11.1%	0.0%	15.4%	7.7%	7.8%
	5	0.0%	6.3%	0.0%	7.7%	3.9%
d: Do you think you could get a ticket for continuing past this sign?	**No**	77.8%	37.5%	38.5%	0.0%	35.3%
	Yes	22.2%	62.5%	61.5%	100.0%	64.7%
Sample Size		9	16	13	13	51

Question 2.21

Road Condition:	High Water
Sign at Crossing:	HIGH WATER DO NOT ENTER WHEN FLASHING
Active Element:	Beacons Flashing Red
Special Note:	None


Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	75.0%	100.0%	100.0%	92.2%
	Yes	0.0%	25.0%	0.0%	0.0%	7.8%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	6.3%	7.7%	0.0%	3.9%
	2	0.0%	6.3%	0.0%	0.0%	2.0%
	3	11.1%	25.0%	7.7%	15.4%	15.7%
	4	11.1%	6.3%	38.5%	7.7%	15.7%
	5	77.8%	56.3%	46.2%	76.9%	62.7%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	22.2%	18.8%	23.1%	30.8%	23.5%
	1	44.4%	18.8%	38.5%	38.5%	33.3%
	2	22.2%	12.5%	23.1%	7.7%	15.7%
	3	11.1%	31.3%	7.7%	7.7%	15.7%
	4	0.0%	12.5%	7.7%	15.4%	9.8%
	5	0.0%	6.3%	0.0%	0.0%	2.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	44.4%	43.8%	15.4%	0.0%	25.5%
	Yes	55.6%	56.3%	84.6%	100.0%	74.5%
Sample Size		9	16	13	13	51

Question 2.22

Road Condition:	High Water
Sign at Crossing:	HIGH WATER ROAD CLOSED WHEN FLASHING
Active Element:	Beacons Off
Special Note:	Presents a "*System Failure*" condition

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	80.0%	84.6%	84.6%	86.0%
	Yes	0.0%	20.0%	15.4%	15.4%	14.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	20.0%	7.7%	7.7%	10.0%
	3	33.3%	20.0%	23.1%	23.1%	24.0%
	4	22.2%	13.3%	38.5%	30.8%	26.0%
	5	44.4%	46.7%	30.8%	38.5%	40.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	33.3%	20.0%	0.0%	23.1%	18.0%
	1	33.3%	20.0%	46.2%	0.0%	24.0%
	2	11.1%	13.3%	15.4%	23.1%	16.0%
	3	22.2%	33.3%	23.1%	30.8%	28.0%
	4	0.0%	13.3%	15.4%	23.1%	14.0%
	5	0.0%	0.0%	0.0%	0.0%	0.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	66.7%	73.3%	53.8%	46.2%	60.0%
	Yes	33.3%	26.7%	46.2%	53.8%	40.0%
Sample Size		9	15	13	13	50

Question 2.23

Road Condition:	High Water
Sign at Crossing:	HIGH WATER ROAD CLOSED WHEN FLASHING
Active Element:	Beacons Flashing Yellow
Special Note:	None

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	93.3%	84.6%	100.0%	94.0%
	Yes	0.0%	6.7%	15.4%	0.0%	6.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	13.3%	30.8%	0.0%	12.0%
	4	22.2%	26.7%	30.8%	23.1%	26.0%
	5	77.8%	60.0%	38.5%	76.9%	62.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	44.4%	13.3%	23.1%	15.4%	22.0%
	1	44.4%	26.7%	30.8%	38.5%	34.0%
	2	0.0%	20.0%	7.7%	15.4%	12.0%
	3	11.1%	26.7%	30.8%	23.1%	24.0%
	4	0.0%	13.3%	7.7%	0.0%	6.0%
	5	0.0%	0.0%	0.0%	7.7%	2.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	22.2%	33.3%	15.4%	7.7%	20.0%
	Yes	77.8%	66.7%	84.6%	92.3%	80.0%
Sample Size		9	15	13	13	50

Question 2.24

Road Condition:	High Water
Sign at Crossing:	HIGH WATER ROAD CLOSED WHEN FLASHING
Active Element:	Beacons Flashing Red
Special Note:	None

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	88.9%	93.3%	84.6%	100.0%	92.0%
	Yes	11.1%	6.7%	15.4%	0.0%	8.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	15.4%	0.0%	4.0%
	3	0.0%	13.3%	7.7%	15.4%	10.0%
	4	44.4%	33.3%	15.4%	15.4%	26.0%
	5	55.6%	53.3%	61.5%	69.2%	60.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	44.4%	6.7%	7.7%	7.7%	14.0%
	1	33.3%	33.3%	23.1%	46.2%	34.0%
	2	11.1%	26.7%	30.8%	30.8%	26.0%
	3	11.1%	20.0%	15.4%	15.4%	16.0%
	4	0.0%	13.3%	7.7%	0.0%	6.0%
	5	0.0%	0.0%	15.4%	0.0%	4.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	11.1%	40.0%	0.0%	0.0%	14.0%
	Yes	88.9%	60.0%	100.0%	100.0%	86.0%
Sample Size		9	15	13	13	50

Question 2.25

Road Condition:	High Water
Sign at Crossing:	DO NOT ENTER (LED)
Active Element:	LED Off
Special Note:	Presents a "*System Failure*" condition


Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	88.2%	75.0%	75.0%	83.7%
	Yes	0.0%	11.8%	25.0%	25.0%	16.3%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	8.3%	16.7%	6.1%
	2	0.0%	11.8%	16.7%	0.0%	8.2%
	3	25.0%	5.9%	0.0%	33.3%	14.3%
	4	50.0%	29.4%	41.7%	25.0%	34.7%
	5	25.0%	52.9%	33.3%	25.0%	36.7%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	12.5%	11.8%	33.3%	16.7%	18.4%
	1	12.5%	35.3%	16.7%	16.7%	22.4%
	2	0.0%	17.6%	16.7%	8.3%	12.2%
	3	50.0%	23.5%	16.7%	0.0%	20.4%
	4	12.5%	5.9%	8.3%	41.7%	16.3%
	5	12.5%	5.9%	8.3%	16.7%	10.2%
d: Do you think you could get a ticket for continuing past this sign?	**No**	87.5%	64.7%	66.7%	66.7%	69.4%
	Yes	12.5%	35.3%	33.3%	33.3%	30.6%
Sample Size		8	17	12	12	49

Question 2.26

Road Condition:	High Water
Sign at Crossing:	DO NOT ENTER (LED)
Active Element:	LED On
Special Note:	None


Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	100.0%	91.7%	100.0%	98.0%
	Yes	0.0%	0.0%	8.3%	0.0%	2.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	0.0%	8.3%	0.0%	2.0%
	3	0.0%	11.8%	0.0%	8.3%	6.1%
	4	37.5%	29.4%	16.7%	16.7%	24.5%
	5	62.5%	58.8%	75.0%	75.0%	67.3%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	25.0%	23.5%	41.7%	25.0%	28.6%
	1	50.0%	52.9%	41.7%	25.0%	42.9%
	2	25.0%	5.9%	0.0%	0.0%	6.1%
	3	0.0%	5.9%	0.0%	25.0%	8.2%
	4	0.0%	11.8%	16.7%	25.0%	14.3%
	5	0.0%	0.0%	0.0%	0.0%	0.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	12.5%	11.8%	16.7%	0.0%	10.2%
	Yes	87.5%	88.2%	83.3%	100.0%	89.8%
Sample Size		8	17	12	12	49

Question 3.1

Road Condition: High Water
Sign at Crossing: DO NOT CROSS WHEN FLOODED
Active Element:
Other: Stop Bar

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	87.5%	93.3%	85.7%	100.0%	92.0%
	Yes	12.5%	6.7%	14.3%	0.0%	8.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	0.0%	0.0%	0.0%
	2	12.5%	6.7%	7.1%	0.0%	6.0%
	3	0.0%	13.3%	14.3%	0.0%	8.0%
	4	12.5%	20.0%	35.7%	38.5%	28.0%
	5	75.0%	60.0%	42.9%	61.5%	58.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	25.0%	13.3%	14.3%	23.1%	18.0%
	1	25.0%	26.7%	21.4%	38.5%	28.0%
	2	12.5%	40.0%	21.4%	23.1%	26.0%
	3	12.5%	13.3%	21.4%	7.7%	14.0%
	4	12.5%	6.7%	7.1%	0.0%	6.0%
	5	12.5%	0.0%	14.3%	7.7%	8.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	50.0%	53.3%	42.9%	7.7%	38.0%
	Yes	50.0%	46.7%	57.1%	92.3%	62.0%
Sample Size		8	15	14	13	50

Question 3.2

Road Condition:	High Water
Sign at Crossing:	HIGH WATER DO NOT ENTER WHEN FLASHING
Active Element:	Beacons Flashing Red
Other:	Stop Bar

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	93.8%	92.3%	100.0%	96.1%
	Yes	0.0%	6.3%	7.7%	0.0%	3.9%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	6.3%	7.7%	0.0%	3.9%
	2	0.0%	6.3%	0.0%	0.0%	2.0%
	3	0.0%	25.0%	15.4%	15.4%	15.7%
	4	22.2%	12.5%	38.5%	7.7%	19.6%
	5	77.8%	50.0%	38.5%	76.9%	58.8%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	11.1%	12.5%	15.4%	46.2%	21.6%
	1	44.4%	18.8%	30.8%	15.4%	25.5%
	2	22.2%	50.0%	38.5%	7.7%	31.4%
	3	22.2%	18.8%	0.0%	23.1%	15.7%
	4	0.0%	0.0%	15.4%	0.0%	3.9%
	5	0.0%	0.0%	0.0%	7.7%	2.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	66.7%	31.3%	30.8%	0.0%	29.4%
	Yes	33.3%	68.8%	69.2%	100.0%	70.6%
Sample Size		9	16	13	13	51

Question 3.3

Road Condition:	High Water
Sign at Crossing:	HIGH WATER ROAD CLOSED WHEN FLASHING
Active Element:	Beacons Flashing Red
Other:	Stop Bar

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**No**	100.0%	86.7%	92.3%	100.0%	94.0%
	Yes	0.0%	13.3%	7.7%	0.0%	6.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	6.7%	7.7%	0.0%	4.0%
	3	11.1%	13.3%	15.4%	7.7%	12.0%
	4	11.1%	13.3%	23.1%	23.1%	18.0%
	5	77.8%	66.7%	53.8%	69.2%	66.0%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	55.6%	20.0%	0.0%	23.1%	22.0%
	1	22.2%	20.0%	61.5%	15.4%	30.0%
	2	11.1%	26.7%	7.7%	30.8%	20.0%
	3	11.1%	20.0%	23.1%	23.1%	20.0%
	4	0.0%	13.3%	7.7%	7.7%	8.0%
	5	0.0%	0.0%	0.0%	0.0%	0.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	22.2%	46.7%	15.4%	0.0%	22.0%
	Yes	77.8%	53.3%	84.6%	100.0%	78.0%
Sample Size		9	15	13	13	50

Question 3.4

Road Condition:	High Water
Sign at Crossing:	DO NOT ENTER (LED)
Active Element:	LED On
Other:	Stop Bar

Question and Response		**College Station**	**Odessa**	**San Angelo**	**San Antonio**	**Total**
a: Would you continue on this road?	**No**	100.0%	94.1%	100.0%	100.0%	98.0%
	Yes	0.0%	5.9%	0.0%	0.0%	2.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	0.0%	0.0%	8.3%	2.0%
	2	0.0%	0.0%	0.0%	0.0%	0.0%
	3	0.0%	17.6%	8.3%	0.0%	8.2%
	4	12.5%	5.9%	16.7%	16.7%	12.2%
	5	87.5%	76.5%	75.0%	75.0%	77.6%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	25.0%	23.5%	41.7%	25.0%	28.6%
	1	62.5%	29.4%	33.3%	25.0%	34.7%
	2	12.5%	11.8%	8.3%	8.3%	10.2%
	3	0.0%	23.5%	0.0%	25.0%	14.3%
	4	0.0%	11.8%	8.3%	16.7%	10.2%
	5	0.0%	0.0%	8.3%	0.0%	2.0%
d: Do you think you could get a ticket for continuing past this sign?	**No**	25.0%	0.0%	8.3%	8.3%	8.2%
	Yes	75.0%	100.0%	91.7%	91.7%	91.8%
Sample Size		8	17	12	12	49

Question 4.1

Sign at Intersection:	HIGH WATER ROAD CLOSED TO THRU TRAFFIC WHEN FLASHING
Active Element:	Beacons Flashing Yellow

Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**Yes**	83.3%	85.7%	77.8%	70.6%	79.4%
	No	16.7%	14.3%	22.2%	29.4%	20.6%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	9.5%	11.1%	29.4%	13.2%
	2	0.0%	4.8%	16.7%	5.9%	7.4%
	3	25.0%	9.5%	5.6%	11.8%	11.8%
	4	33.3%	28.6%	33.3%	5.9%	25.0%
	5	41.7%	47.6%	33.3%	47.1%	42.6%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	23.8%	11.1%	5.9%	11.8%
	1	41.7%	19.0%	5.6%	0.0%	14.7%
	2	8.3%	19.0%	22.2%	29.4%	20.6%
	3	41.7%	19.0%	22.2%	35.3%	27.9%
	4	0.0%	19.0%	22.2%	11.8%	14.7%
	5	8.3%	0.0%	16.7%	17.6%	10.3%
Sample Size		12	21	18	17	68

Question 4.2

Sign at Intersection:	HIGH WATER ROAD CLOSED USE ALTERNATE ROUTE WHEN FLASHING
Active Element:	Beacons Flashing Yellow

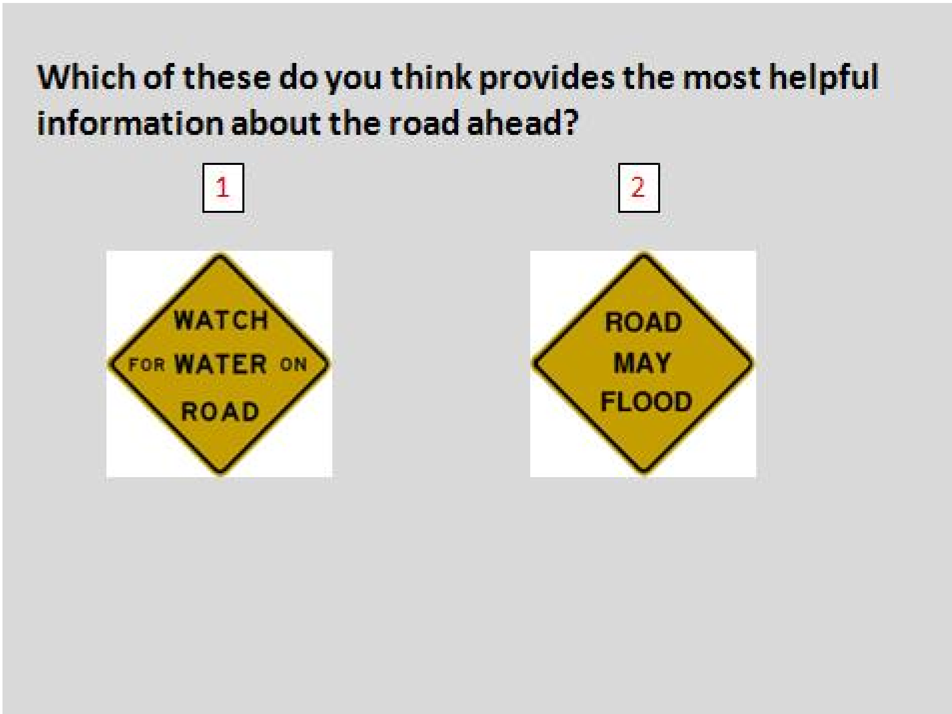
Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**Yes**	100.0%	76.2%	76.5%	70.6%	78.8%
	No	0.0%	23.8%	23.5%	29.4%	21.2%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	0.0%	4.8%	0.0%	17.6%	6.1%
	2	18.2%	4.8%	29.4%	5.9%	13.6%
	3	18.2%	9.5%	17.6%	5.9%	12.1%
	4	0.0%	28.6%	17.6%	23.5%	19.7%
	5	63.6%	52.4%	35.3%	47.1%	48.5%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	9.1%	9.5%	5.9%	17.6%	10.6%
	1	18.2%	19.0%	17.6%	11.8%	16.7%
	2	9.1%	14.3%	17.6%	17.6%	15.2%
	3	45.5%	28.6%	35.3%	23.5%	31.8%
	4	18.2%	14.3%	11.8%	17.6%	15.2%
	5	0.0%	14.3%	11.8%	11.8%	10.6%
Sample Size		11	21	17	17	66

Question 4.3

Sign at Intersection:	ROAD MAY FLOOD NEXT 7 MILES
Active Element:	None

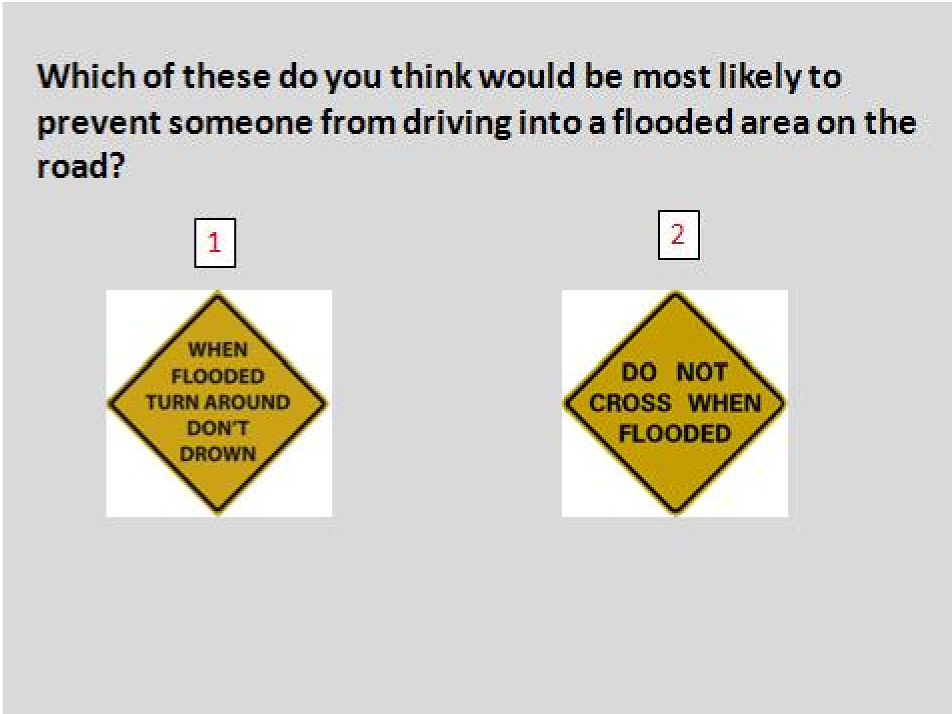
Question and Response		College Station	Odessa	San Angelo	San Antonio	Total
a: Would you continue on this road?	**Yes**	0.0%	0.0%	0.0%	11.8%	3.0%
	No	100.0%	100.0%	100.0%	88.2%	97.0%
b: How risky do you think it would be to continue on this road? 1 = Not at all risky 5 = Extremely risky	**1**	27.3%	52.4%	58.8%	52.9%	50.0%
	2	36.4%	28.6%	23.5%	5.9%	22.7%
	3	36.4%	19.0%	11.8%	29.4%	22.7%
	4	0.0%	0.0%	5.9%	5.9%	3.0%
	5	0.0%	0.0%	0.0%	5.9%	1.5%
c: How many other drivers do you think would continue on this road? 0 out of 5 to 5 out of 5	**0**	0.0%	0.0%	0.0%	0.0%	0.0%
	1	0.0%	0.0%	0.0%	0.0%	0.0%
	2	0.0%	4.8%	0.0%	5.9%	3.0%
	3	9.1%	4.8%	0.0%	17.6%	7.6%
	4	27.3%	19.0%	17.6%	23.5%	21.2%
	5	63.6%	71.4%	82.4%	52.9%	68.2%
Sample Size		11	21	17	17	66

Question 5.1



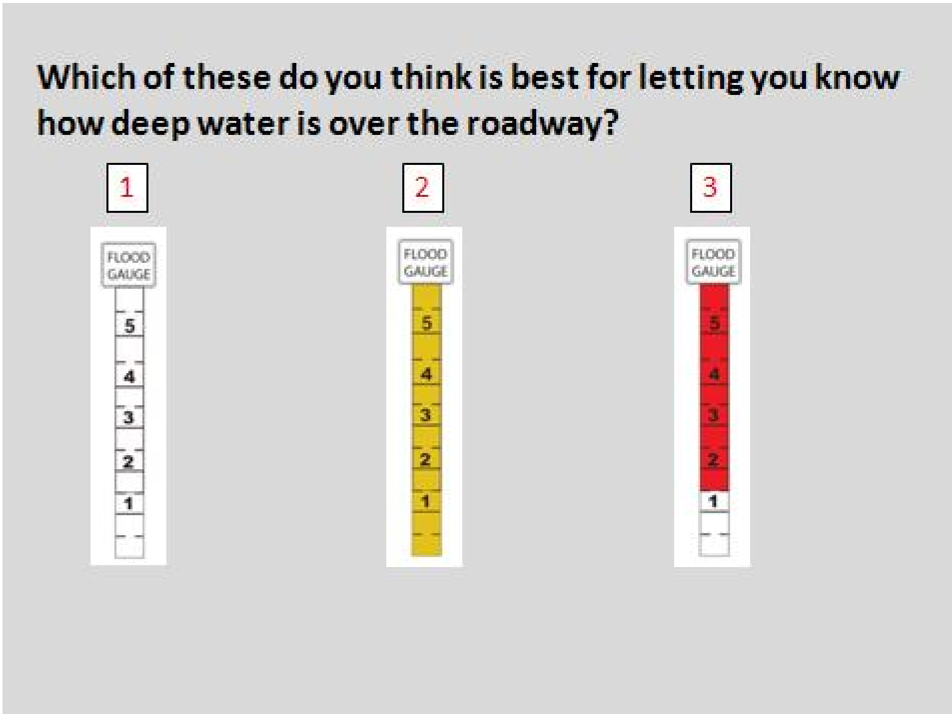
Which of these do you think provides the most helpful information about the road ahead?	College Station	Odessa	San Angelo	San Antonio	Total
WATCH FOR WATER ON ROAD	35.3%	34.9%	46.2%	52.9%	42.5%
ROAD MAY FLOOD	64.7%	65.1%	53.8%	47.1%	57.5%
Sample Size	34	63	52	51	200

Question 5.2



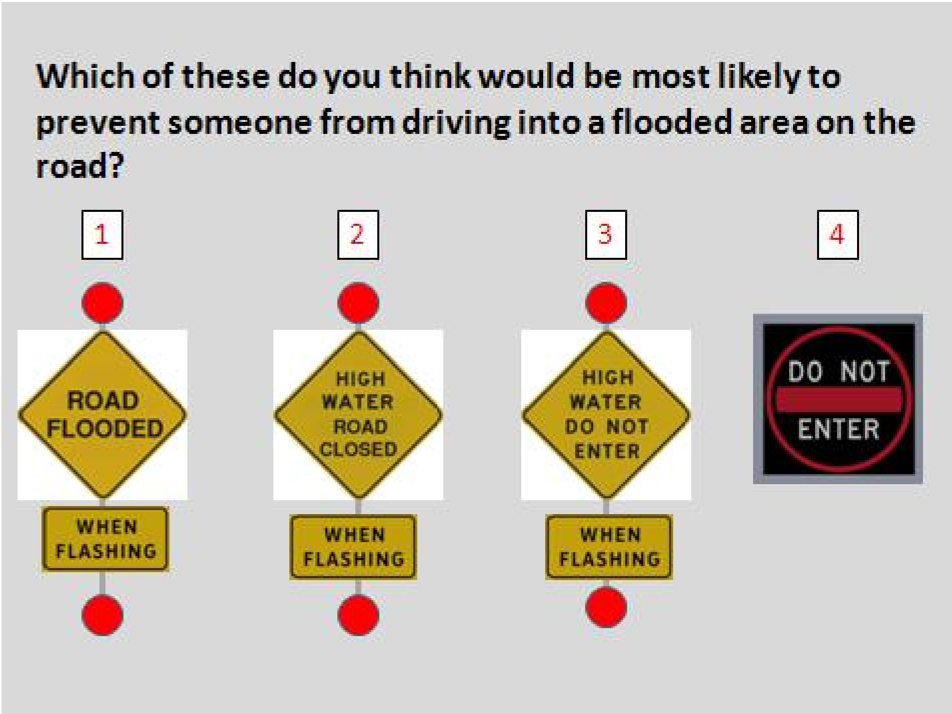
Which of these do you think would be most likely to prevent someone from driving into a flooded part of the road?	**College Station**	**Odessa**	**San Angelo**	**San Antonio**	**Total**
WHEN FLOODED TURN AROUND DON'T DROWN	35.3%	57.1%	38.5%	52.9%	47.5%
DO NOT CROSS WHEN FLOODED	64.7%	42.9%	61.5%	47.1%	52.5%
Sample Size	34	63	52	51	200

Question 5.3



Which of these do you think is best for letting you know how high water is over the roadway?	College Station	Odessa	San Angelo	San Antonio	Total
White flood gauge	2.9%	6.3%	0.0%	5.9%	4.0%
Yellow flood gauge	14.7%	17.5%	7.7%	17.6%	14.5%
Red/white flood gauge	82.4%	76.2%	92.3%	76.5%	81.5%
Sample Size	34	63	52	51	200

Question 5.4



Which of these do you think would be most likely to prevent someone from driving into a flooded part of the road?	College Station	Odessa	San Angelo	San Antonio	Total
ROAD FLOODED WHEN FLASHING	5.9%	11.1%	5.8%	11.8%	9.0%
HIGH WATER DO NOT ENTER WHEN FLASHING	52.9%	20.6%	32.7%	25.5%	30.5%
HIGH WATER ROAD CLOSED WHEN FLASHING	14.7%	39.7%	34.6%	43.1%	35.0%
DO NOT ENTER (LED)	26.5%	28.6%	26.9%	19.6%	25.5%
Sample Size	34	63	52	51	200

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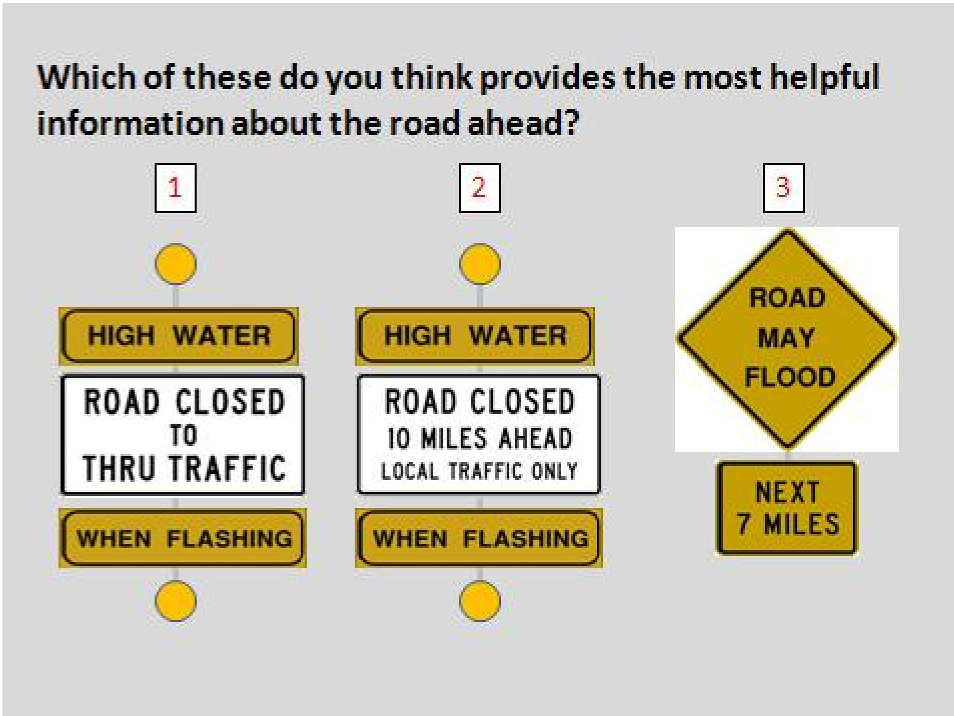
Question 5.5



Which of these do you think provides the most helpful information about the road ahead?	**College Station**	**Odessa**	**San Angelo**	**San Antonio**	**Total**
HIGH WATER ROAD CLOSED TO THRU TRAFFIC WHEN FLASHING	55.9%	63.5%	67.3%	51.0%	60.0%
HIGH WATER ROAD CLOSED 10 MILES AHEAD LOCAL TRAFFIC ONLY WHEN FLASHING	41.2%	25.4%	32.7%	33.3%	32.0%
ROAD MAY FLOOD NEXT 7 MILES	2.9%	11.1%	0.0%	15.7%	8.0%
Sample Size	34	63	52	51	200