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16. Abstract

This research, using focus groups and surveys of individuals who had experienced hurricane evacuations in Texas, assessed various hurricane evacuation traffic signs and pavement markings for developing guidelines. This report contains the process and findings from that effort. Other specific issues addressed include the following:

- best means of operating traffic signals during mass evacuation,
- identification of data needs for an after-action review of evacuation traffic operations,
- intelligent transportation system's role in evacuations,
- methods of reducing field staffing requirements during evacuations, and
- applicability of Houston's Beltway 8 East as an evacuation route.

This research also produced tri-fold brochures intended to communicate to the public regarding where and how new contraflow routes will operate during hurricane evacuations. Finally, the report includes findings from traffic simulation computer modeling of various critical locations throughout Texas' evacuation contraflow routes.

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). 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 FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permitting purposes. The engineer in charge of the project was Andrew J. Ballard, P.E. #59027. The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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- Mr. Stuart Corder, P.E., TxDOT Houston District, project advisor;
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- Mr. Ted East, P.E., TxDOT Beaumont District, project advisor;
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- Mr. Paul Frerich, P.E., TxDOT Yoakum District, project advisor;
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- Mr. Jesse Leal, P.E., TxDOT Pharr District, project advisor;
- Ms. Corina Love, City of Houston, project advisor;
- Mr. Wade Odell, P.E., TxDOT Research and Technology Implementation Office, research engineer;
- Mr. Ismael Soto, P.E., TxDOT Corpus Christi District, project advisor; and
- Mr. Brian Stanford, P.E., TxDOT Traffic Operations Division, project advisor.

In addition, the authors express appreciation to the many professionals involved in hurricane evacuation traffic operations in various states along the Gulf of Mexico and the Atlantic Ocean, who provided insights from their evacuation experiences and plans.

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CHAPTER 1. INTRODUCTION

Texas has experienced numerous hurricanes that caused significant damage and loss of life. The backdrop for this research includes the 2004 hurricane season, in which one state (Florida) experienced four hurricanes, and the 2005 hurricane season, in which Hurricane Katrina inflicted significant damage in Louisiana and Hurricane Rita motivated a significant evacuation in Texas.

This research began with issues about signing and markings for hurricane evacuations; it came to include many more aspects of hurricane evacuation traffic operations. To address the hurricane evacuation signs and markings topics, focus groups and motorist surveys formed the basis of the research. Coincident with these questions were topics about motorists' understanding of messages displayed on dynamic message signs (DMS).

In the aftermath of the 2005 hurricane season, the research was expanded to include investigations into the following issues:

- traffic signal operations for evacuation traffic demand,
- intelligent transportation systems (ITS) applications for evacuation,
- data needs evacuation "after-action" review,
- tools for reducing field staffing requirements during evacuation,
- assessment of the applicability of Beltway 8 East as an evacuation route,
- traffic modeling of various critical points on new contraflow routes, and
- development of brochures for informing the public about contraflow.

The following sections of this report address each of these areas of hurricane evacuation traffic operations. In addition, researchers produced two stand-alone products through this research:

- Guidelines for Hurricane Evacuation Signs and Markings (http://tti.tamu.edu/documents/0-4962-P1.pdf)
- Recommended Practices for Hurricane Evacuation Traffic Operations (http://tti.tamu.edu/documents/0-4962-P2.pdf)

CHAPTER 2. FOCUS GROUP STUDIES OF EVACUATING MOTORISTS

Texas Transportation Institute (TTI) researchers conducted a series of focus group studies in key coastal areas of Texas to determine current opinions and recommendations regarding the provision of traffic control signing and markings in support of hurricane evacuation and return. The focus group questions centered on the following main topics:

- the current *Manual on Uniform Traffic Control Devices* (MUTCD) (*1*) hurricane evacuation sign and other hurricane evacuation signing alternatives,
- traffic control techniques to increase traffic flow during hurricane evacuations, and
- motorist information needs during evacuations and when returning from an evacuation.

Researchers conducted focus group studies in the following four Texas locations:

- Beaumont,
- Corpus Christi,
- Galveston, and
- Houston.

For each study, TTI researchers recruited 8 to 10 motorists who had attempted to evacuate in response to an approaching hurricane at least once in the past several years. In Corpus Christi, a few of the participants had evacuated in response to a hurricane several years prior. However, the remainder of the Corpus Christi participants and essentially all of the participants from the other three locations had evacuated in response to Hurricane Rita that came ashore near Beaumont early on Saturday, September 24, 2005. Hurricane Rita spawned a tremendous evacuation from the Houston-Galveston region, creating gridlock and a host of other well-publicized problems for state and local emergency management and transportation officials. The hurricane also created significant damage for residents in the Beaumont-Port Arthur region.

METHODOLOGY

Focus Group Format

The purposes of the focus group discussion for this project were as follows:

- to obtain opinions, perceptions, and input regarding the topics listed above;
- to gauge general levels of agreement or disagreement with the various opinions, perceptions, or statements presented by individual participants; and
- to gather suggestions and recommendations that could aid the research team in developing candidate signing and marking improvements for subsequent testing under laboratory study conditions.

The researchers served as facilitators of each session, guiding the discussion in general terms but allowing participants to debate and discuss items or issues that surfaced however the conversation of the group evolved. The researchers emphasized that the topics did not necessarily have any right or wrong answers, and that the suggestions or recommendations made by the participants would be useful in guiding future research activities. During each focus group session, the researchers (facilitators) followed a detailed discussion guide prepared for the project. Appendix A includes a copy of this guide.

For each session, TTI researchers arrived several hours prior to prepare the meeting room, and organize the various forms and visual aids to be used, etc. Researchers greeted each participant as they arrived, and organized them, as shown in Figure 2-1, around a table for group discussion.

Figure 2-1. Focus Group in Galveston.

Self-introductions were made to familiarize the participants with one another. During the self-introductions, the participants also briefly described their recent experience with hurricane evacuation (their intended destination, route taken, time traveled, problems encountered, etc.). In this way, researchers were able to establish a sense of camaraderie among the participants in each focus group that allowed them to speak more openly. Each session was kept to approximately two hours to minimize participant and researcher fatigue. Participants were compensated for their time.

Demographics

Eight to ten licensed drivers participated at each location for a total of 37 subjects. The goal was to select a sample of drivers based on the demographics of the driving population of Texas with regard to gender, age, and education level. However, since the discussion was on signs and markings used during evacuations, the target population was drivers that had evacuated within the last two years. Because of this requirement, along with recruiting and scheduling difficulties at some of the study sites, researchers did not quite reach this goal. The actual sample had a higher percentage of female drivers, drivers between the ages of 18 and 39, and drivers age 55+ than the Texas driving population. In contrast, the middle age category (between the ages of 40 and 54) had a slightly lower percentage than the Texas driving population.

RESULTS

Hurricane Evacuation Signing

To begin the discussion, the researchers first showed the standard MUTCD evacuation route marker to the participants (Figure 2-2) and asked them whether they had seen any signs of this type when they were evacuating. Researchers also asked the participants whether the signs had been helpful to them in any way during their evacuation.

Figure 2-2. MUTCD Hurricane Evacuation Sign EM-1 (*1*).

Overall, only about one-third (14 of 37) of the participants remembered encountering a sign of this nature during their evacuation. Of those, the participants from Beaumont and Corpus Christi felt that the signs were helpful and reassured them that they were traveling in the right direction. Similarly, the Galveston and Houston participants felt that the signs, although not necessarily very helpful to themselves, would be helpful to those drivers who may be unfamiliar with the evacuation routes in the area. One point raised by participants from Beaumont, Galveston, and Houston was that such signing was not available to them on the "back roads" that they traveled and so limited the usefulness of this type of signing.

The remainder (23 of 37) of the participants had not seen the sign in Figure 2-2 during their evacuation regardless of whether or not they believed they had been on a designated evacuation route. Two of the individuals (one each from Houston and Corpus Christi) acknowledged that they knew they were not on a designated evacuation route, but had decided on using a particular route because it was familiar regardless of whether or not it was an official evacuation route. Three other participants (from Beaumont and Houston) noted that even though they did not see this type of sign, they knew which roadways were evacuation routes because they had obtained that information prior to departing (via television, the Internet, or from a friend). As might be expected, Galveston participants believed that the available evacuation routes out of Galveston were limited and were common knowledge so that signing identifying those roadways was not necessary. Both Beaumont and Galveston participants did note that, in their opinion, signing for evacuation routes did not matter because evacuees were forced to follow police directions (even if the routes to take were confusing or not their chosen path). Researchers asked the participants where such signing should be located, but did not receive a significant amount of input. Several Galveston participants noted that it would be helpful to denote some of the "back roads" with these signs (presumably those roads that the participants would prefer to use). One Corpus Christi participant noted that the evacuation route shield is helpful when displayed on overhead guide signs (see discussion below).

Next, the researchers presented the participants in each group with visual aids depicting alternative formats of the evacuation route sign currently in use. Figure 2-3 shows these alternatives. In all focus group study locations, participants were able to easily recognize the intent of the signs to designate an evacuation route, and believed that all three alternatives essentially meant the same thing. Across all four locations, almost three-fourths of the participants (27 of 37) preferred the signing alternative that incorporated the evacuation route shield and banner text on the overhead guide sign. The primary reason given for this strong level of preference was the fact that such signing is much larger and so more likely to catch the driver's attention. In addition, several Beaumont and Galveston participants liked the fact that the sign also provided destination information about the road. The combination of an evacuation route shield with the route number sign was the second-most preferred alternative, although the level of preference was less than 25 percent. This preference was based primarily upon the inclusion of the hurricane emblem in this sign combination. Only one participant (from Houston) preferred the simple route shield without the hurricane emblem, although the participant did note that his actual preference would be for that sign not to include the arrow. Another participant from Beaumont also noted that the arrow on this sign alternative was confusing and should not be provided. Finally, the researchers noted that all participants from Corpus Christi and Beaumont agreed that emergency management officials should consider using the overhead guide sign with an evacuation route designation as guide signing to direct motorists to the proper evacuation route, and then use the route number sign and evacuation route sign combination to reassure drivers once they had gotten onto that route.

Participants were then asked what types of changes they might make to the alternative signs shown to improve them. Suggestions included (in no particular order of importance):

- Include destinations and/or mileage to destinations.
- Enlarge the evacuation route shield emblem and/or sign in general (this may have been a function of the size of the visual aid shown to the participants).
- Possibly change the color of the sign to distinguish it from road services and tourist information signing.
- Incorporate flashing lights into the sign face to indicate when the sign was "active."
- Cover or use flip signs so that they are visible only during the hurricane season (similar to the use of "bridges may be icy" folding signs that are opened up during the winter months).

A final question asked in this portion of the session was the participants' opinions as to the proper or desirable spacing of such signs on evacuation routes. Suggestions varied widely, from as close as one mile apart (from a Houston participant) to as far as every 10 to 20 miles. Overall, 3- to 5-mile spacing appeared to encompass the greatest number of participant opinions about this question.

Figure 2-3. Alternative Formats for Evacuation Route Signing.

Traffic Control Techniques to Increase Traffic Flow during Hurricane Evacuations

Use of High-Occupancy Vehicle (HOV) Lanes

Researchers queried participants in all four focus groups regarding the use of HOV lanes during hurricane evacuations. Within the four regions sampled in these sessions, only Houston currently has a significant HOV network. Consequently, only a small fraction of the participants (11 percent, or 4 of 37) had actually used an HOV lane during their evacuation. Those who did relied on word of mouth from friends to know that the lane was open to all drivers or simply followed other drivers into the lane as they evacuated. For the majority of participants who did not use an HOV lane to evacuate, the most common (and obvious) reason was that an HOV lane did not exist along their evacuation route. One participant in Houston did note that limited access to the HOV lane was the main reason they did not use the facility.

Participants in Beaumont, Galveston, and Houston were then asked whether enough information was made available to them to decide whether or not to use an HOV lane during the evacuation (Corpus Christi participants were not asked this question since they had no experience or exposure to HOV lanes in their region). Facilitators noted three key information items during the discussions, desiring information on the following topics:

- whether the occupancy restrictions for the HOV lane had been suspended and that evacuation traffic was being allowed to use the lane,
- the actual location of entrances and exits to/from the HOV lane, and
- the actual endpoint of either where the HOV lane ended or where the use of the HOV lane for evacuation traffic terminated.

The researchers also led some discussion as to whether the participants would naturally expect that the HOV lanes were being used for evacuation traffic, or whether the expectancy would be that the lanes would still be used during peak periods for rush hour commuter traffic (i.e., standard peak period direction travel, regardless of the direction of the evacuation). Although there was initially some confusion as to what was being asked, participants at all locations eventually came to the same conclusion that peak period commuter traffic use of the HOV lanes would be suspended during evacuations so that the lanes could be used for evacuation traffic.

Use of Shoulders as Emergency Travel Lanes during a Hurricane

Another traffic control technique examined during this portion of the focus group studies was the signing and pavement markings used in Corpus Christi to convert the shoulder on the evacuation route to an actual temporary travel lane during times of an evacuation. Figure 2-4 illustrates the signs currently in place along I-37 out of Corpus Christi for this purpose. Under non-evacuation (normal) conditions, the shoulder is designated for emergency use as depicted by the top sign. When an evacuation is ordered, the right panel on the sign is changed to indicate that the shoulder is open for use as a travel lane. At the end point of shoulder use, the bottom sign shown in Figure 2-4 is displayed.

Initially, researchers asked the focus group participants whether the signs shown in Figure 2-4 were understandable. Essentially all participants in all four focus groups understood the meaning of the top two signs. Some of the participants in the Corpus Christi group suggested that the standard hurricane symbol could be added to the signs to further improve driver understanding. With regard to the last sign shown in Figure 2-4 which indicates that the shoulder use is ending and that vehicles using the shoulder will need to exit, interpretations were less consistent among participants. For the most part, participants from both Galveston and Beaumont were able to understand the meaning of the bottom sign. However, a few of the Houston and Corpus Christi participants disagreed as to the intended meaning. Specifically, a few of the Houston participants were unable to associate the turn arrow as referring to drivers who were currently using the temporary shoulder travel lane. Instead, their perceptions were that the arrow indicated that the exit was for emergency use only by drivers who were having automobile problems or by authorized emergency vehicles. In other words, the sign to them indicated that drivers should use the shoulder lane as an exit lane only. A slightly different type of confusion arose within the Corpus Christi group. There, participants understood that the arrow indicated that drivers using the temporary travel lane would need to exit (i.e., that the temporary travel lane was ending), but were not sure whether the sign was also indicating that those exiting were leaving the actual evacuation route completely. In addition, some participants questioned whether or not it would be permissible to merge back into the normal travel lanes rather than be forced to exit. Although the answer to such a question would appear obvious under normal operating conditions (i.e., a merge would be acceptable to avoid exiting); similar signing under evacuation conditions may imply to drivers a need for stricter compliance to whatever directions the sign displays. In other words, the driver may feel that the evacuation operation will warrant more law enforcement and stricter compliance, thus having doubt that it is acceptable to merge into the main stream of traffic to avoid exiting.

Figure 2-4. Signing for Temporary Shoulder Use during Evacuations in Corpus Christi.

Researchers also queried participants on whether they felt that shoulders in general should be used as temporary travel lanes during evacuations. On this question, participants reached no clear consensus. Several participants noted the following concerns:

- how such temporary lane use would affect emergency vehicle access and mobility,
- how stalled vehicles that are moved to the shoulder would be affected,
- whether the use of the shoulder as a lane would lead to cases of road rage, and
- how vehicles would behave at the endpoint of the temporary lane itself.

Interestingly, researchers found that about one-fifth of the participants (8 of 37) had actually driven on the shoulder at some point during their evacuation attempt, even though none of these actions occurred on a route where the shoulder was specifically designated as a temporary lane.

Researchers asked participants about the types of information they would need as they approached a section of roadway where the shoulder is being opened for use as a temporary travel lane. Suggestions varied, but included the following main items:

- Identify the length of the temporary travel lane (presumably so that the driver could assess whether it would be worth the effort to move over and get into that lane).
- Use signing (such as that illustrated in Figure 2-4) that would indicate that the shoulder is open for use as a travel lane.
- Provide advance notice of the location where the lane ends and traffic must merge back into the normal travel lanes.
- Clarify acceptable maneuvers for traffic in the temporary travel lane at the merge point; i.e., that the driver can merge back into the normal travel lanes or exit, but not forward continuing to use the shoulder as a lane.

In addition to the signs shown in Figure 2-4, Corpus Christi has also placed the standard hurricane symbol as a pavement marking on the shoulder to indicate that it is available for use as a travel lane during evacuations. Figure 2-5 shows such a pavement marking.

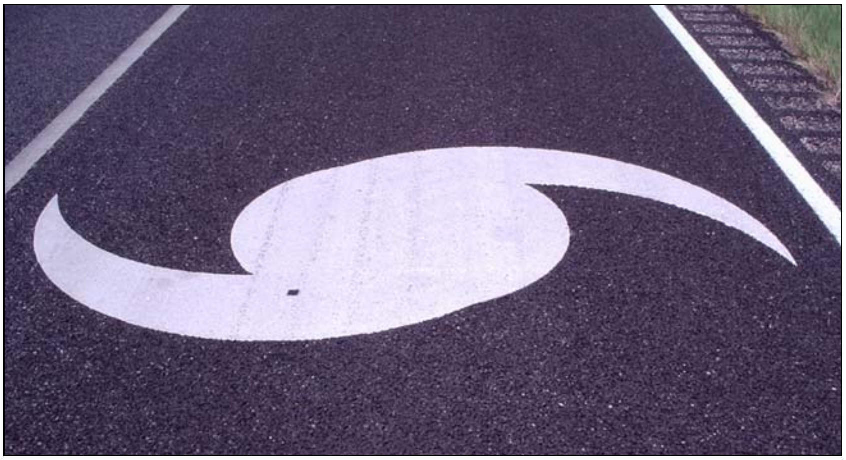


Figure 2-5. Example of Hurricane Symbol Pavement Marking on a Shoulder.

Not surprisingly, all of the Corpus Christi participants and one of the Houston participants (27 percent overall) had seen this type of pavement marking before. Even though many had not actually seen a pavement marking of this type, essentially all participants recognized the symbol as indicative of an evacuation route or lane. All but two of the participants believed that such markings would be useful and helpful positioned on a shoulder that is to serve as a temporary travel lane during evacuations. Researchers then asked whether there were other locations where this marking would be useful. In response, participants identified the following locations:

- roads in front of evacuation shelters to help evacuees identify such shelters,
- HOV lanes to indicate that it will be used for evacuation traffic when necessary, and
- major arterials as guidance to main evacuation routes, beginning approximately two miles away and using the symbol with arrows to indicate that the evacuation route is ahead.

Finally, researchers asked participants if there were any other types of pavement markings that would be helpful to motorists when evacuating or returning home after an evacuation. Participants in both Houston and Galveston expressed fondness for the horizontal signing applications used at several freeway interchanges in Houston (route shield emblems, highway numbers, arrows, etc.) because it helps them position themselves in their desired lane to travel through an interchange. However, the groups recognized that this was not necessarily an evacuation-specific application. One issue that Beaumont participants raised was the concern that the use of a shoulder as a temporary travel lane would mean that there would not be a right edge line to guide drivers at night (i.e., the edge line would be on the left side). Here, participants suggested that it may be useful to place red retroreflective raised pavement markers along the outside edge of the shoulder as a way to delineate the edge of pavement without confusing drivers with normal lane and edge lines.

Contraflow Lane Use and Operations

Researchers then directed the discussions to the potential use of contraflow lanes during hurricane evacuations. Overall, researchers found that 6 of the 28 participants (21 percent) from the Beaumont, Galveston, and Houston focus groups had utilized a contraflow lane during their evacuation. The remainder did not evacuate on a route with a specified contraflow lane, although three of the Beaumont participants admitted to driving in the opposing lane on a Farm-to-Market (FM) road during their evacuation.

Those participants from Galveston who did use the contraflow lanes indicated that there were some difficulties with merging back to the regular lanes at the end of the contraflow section. In addition, these individuals specifically noted the lack of information available as to the location(s) where drivers could enter the contraflow lanes, how long the contraflow lanes existed, and the days/hours of when the contraflow operation would be in effect. For the Houston participant who used the contraflow lanes, the biggest complaint was that it was not possible to exit from the lanes once there. Instead, all vehicles were forced to remain on the contraflow lanes to their terminus.

Researchers asked the focus group participants for suggestions as to what signs or other information transportation agencies should provide when implementing a contraflow operation. The following list encompasses the range of suggestions offered:

- information on how to enter/exit the lanes,
- times that the contraflow operations will be in effect,
- advance warning signs posted on the normal (non-contraflow) direction indicating that the lanes will be used for contraflow operations during the evacuation,
- signs (possibly flip-down signs) on the contraflow side of the roadway in the contraflow direction so that motorists would know that they are going in the correct direction and that the lanes are indeed operating in a contraflow manner (this implied concern among participants of incorrectly assuming a contraflow operation was in effect and entering the wrong way onto the opposing direction and into a head-on collision), and
- information on the distance to the next exit point for vehicles using the contraflow lanes.

Interestingly, at least one participant indicated that any signing developed should be considered supplemental to providing law enforcement officers at the entrance and exit points of the contraflow operations.

Researchers also asked about possible pavement markings that should be used. Overall, participants felt that markings would not be very useful. Several participants again emphasized the importance of having law enforcement and direct control of traffic entering and exiting the contraflow lane in lieu of any type of signing or markings. Participants also discussed the need for pavement markings at ramps and agreed that such markings were not likely to be very useful. In the Houston focus group, participants did debate the notion of using trucks and barricades to block ramps when implementing the contraflow lanes so that law enforcement officers could be used elsewhere. However, several other participants noted that many drivers would likely attempt to go around any type of blockade created if officers were not present, and create a very hazardous situation.

Researchers then asked participants in each group to brainstorm ideas for signs or other information sources that would be useful to convey the information they desire during a contraflow operation. As might be expected, there was some degree of collusion among participants in a given group, which often led to similar derivations of a single basic theme. Researchers took the drawings from each focus group, organized them, and identified the following main themes as outlined below. Figure 2-6 through Figure 2-9 illustrate these graphically.

- As shown in Figure 2-6, one sign theme suggested by several participants was simply a general notification or trailblazing sign that would reassure drivers that the roadway was operating in a contraflow mode and thus it was okay to be in the lanes. Common components included in these types of signs were a hurricane symbol, an arrow (typically pointing up) to indicate allowable direction of travel, and some text, i.e., “ALL LANES OPEN” or “ALL LANES NORTH.”
- Figure 2-7 shows a second theme built upon the concepts identified above, but included lane information in the form of solid and skip lines to indicate the number of lanes

available. Arrows (pointing upward) conveyed the notion that all lanes were heading in the same direction. Some participants also suggested text, i.e., "HURRICANE CONTRAFLOW LANES," "EVACUATION ROUTE," "ALL LANES ONE WAY."

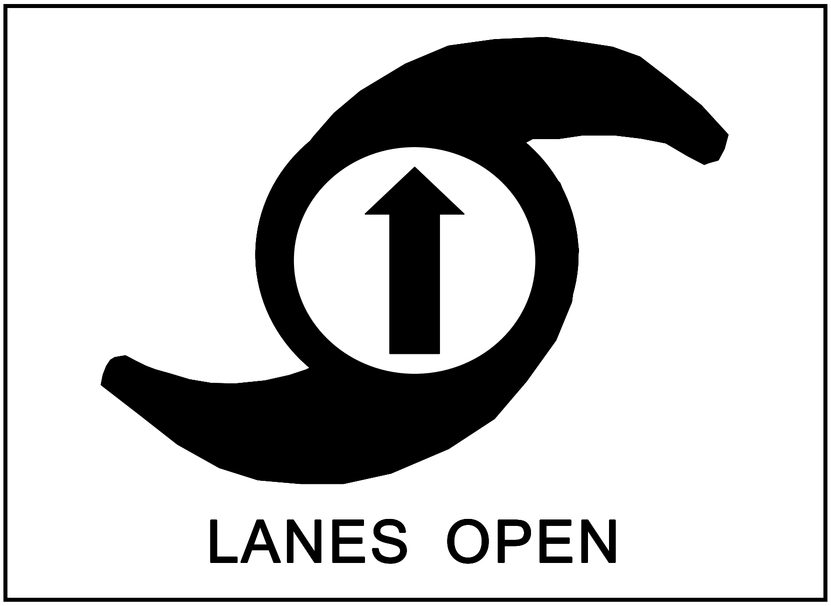
- In Figure 2-8, a third type of sign suggestion appeared to be intended for situations where traffic on one side of the roadway is to be crossed over the median into the contraflow lanes on the typically opposing lanes of travel. For this situation, participants included curvilinear arrows across the median to convey the maneuver that would be required. This crossover point appears to be a key concern to many drivers, possibly because such a maneuver is inherently contrary to what motorists are taught and typical operations.
- A fourth traffic control theme suggested is shown in Figure 2-9. It utilized the concept of lane control signals or similar indications placed over the contraflow travel lanes (or at least conveyed that way on a sign) that would indicate that travel in that direction on those lanes is allowable. Arrows and green lights were suggested as possible indicators when contraflow was operating, while the indications would either be blank or display a red indication (i.e., an X) when contraflow as not in effect.

Traffic Signal Operations

The last traffic control technique discussed during this portion of the focus group was that of traffic signal operations. Often there are problems with signals during or after a hurricane evacuation. The intent of the discussion was to try and ascertain whether interpretations of flashing red or flashing yellow displays as drivers approach an intersection are generally altered under hurricane evacuation conditions.

Researchers showed each focus group an animated graphic of a traffic signal at an intersection. The indication to the cross street traffic could not be seen. Researchers then asked participants what they thought the condition would most likely be at that intersection. The first graphic portrayed a flashing red indication to approaching drivers. As would be hoped, all participants indicated that they would stop at the intersection. Researchers attempted to investigate whether any strong opinions existed as to what would be assumed to be the operating condition on the cross-street. A large majority of participants expected that the cross-street display would also be a red indication (i.e., a four-way stop). Only three participants overall indicated that they would expect the cross-street traffic to have a yellow indication displayed to them (i.e., a caution condition only for the cross-street traffic). Researchers next queried the participants about any signs, markings, or other devices they would like to see at a situation such as this to help them know how to properly react. Only a few suggestions were offered, primarily the possibility of adding temporary stop signs (which would be redundant with the notion of the flashing red indication anyway), or to include some type of flashing beacons or strobes somewhere on the signal head to increase the conspicuity of the indication.

Researchers also showed a graphic of an intersection with a flashing yellow indication visible to approaching drivers. The majority (33 of 37) of participants indicated that they would slow down and use caution as they traversed the intersection, whereas four participants stated that they would go ahead and stop. When asked what they expected was the signal indication being displayed to cross-street traffic, 31 of 37 participants assumed that the other direction would see a flashing red display. Meanwhile, three participants assumed the cross-street would also be viewing a flashing yellow indication, and another three participants were unsure.



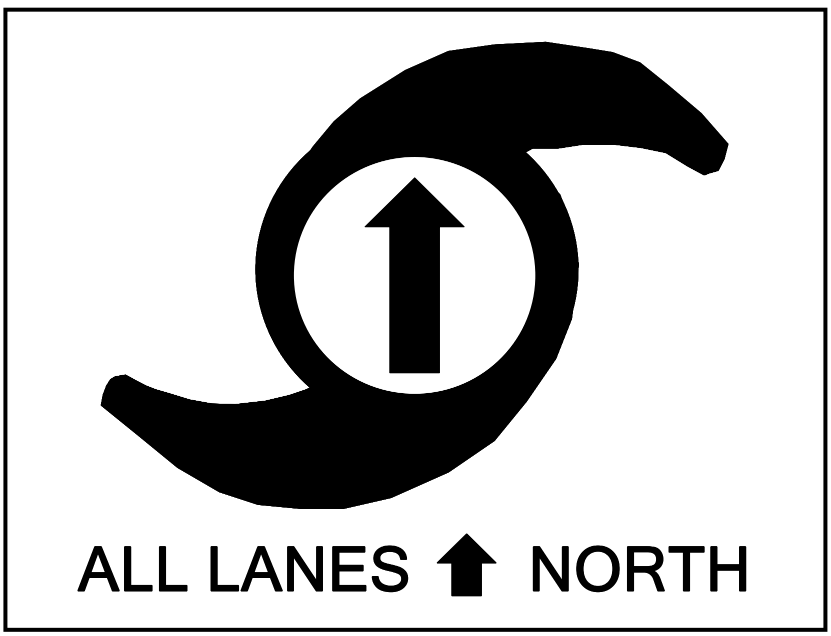


Figure 2-6. Contraflow General Notification or Trailblazing Signs.

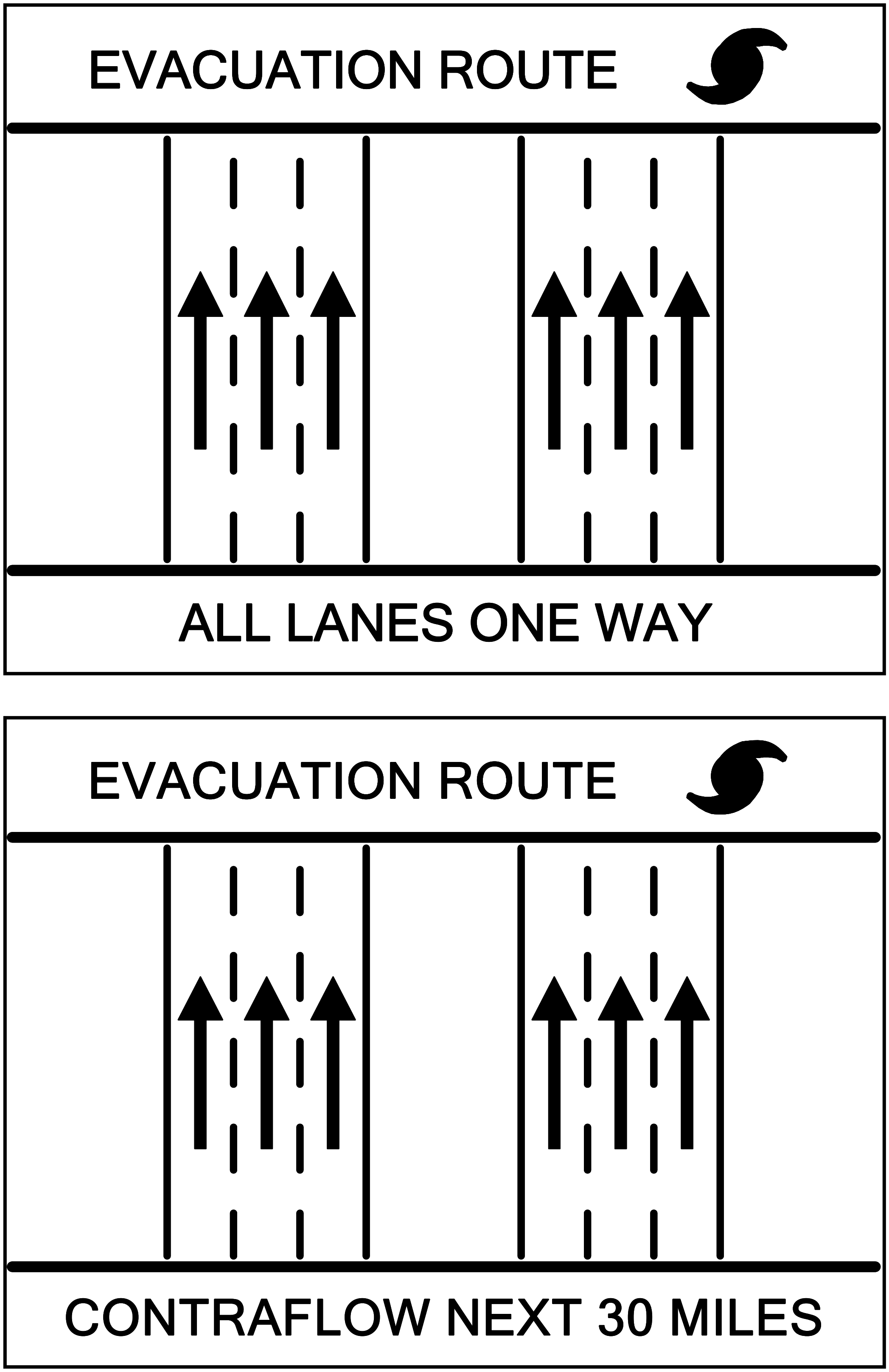


Figure 2-7. Contraflow Evacuation Route Signs.

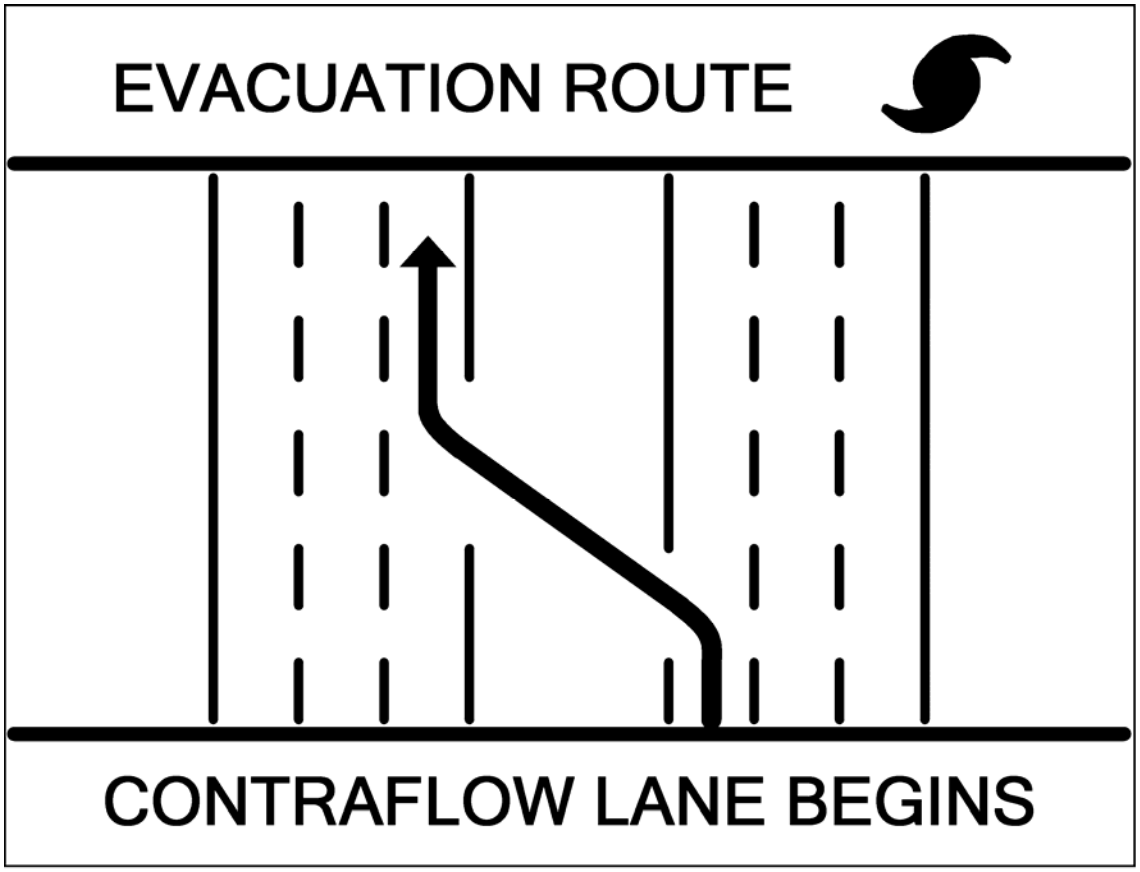


Figure 2-8. Contraflow Sign Where Traffic Crosses Over to Opposing Travel Lanes.

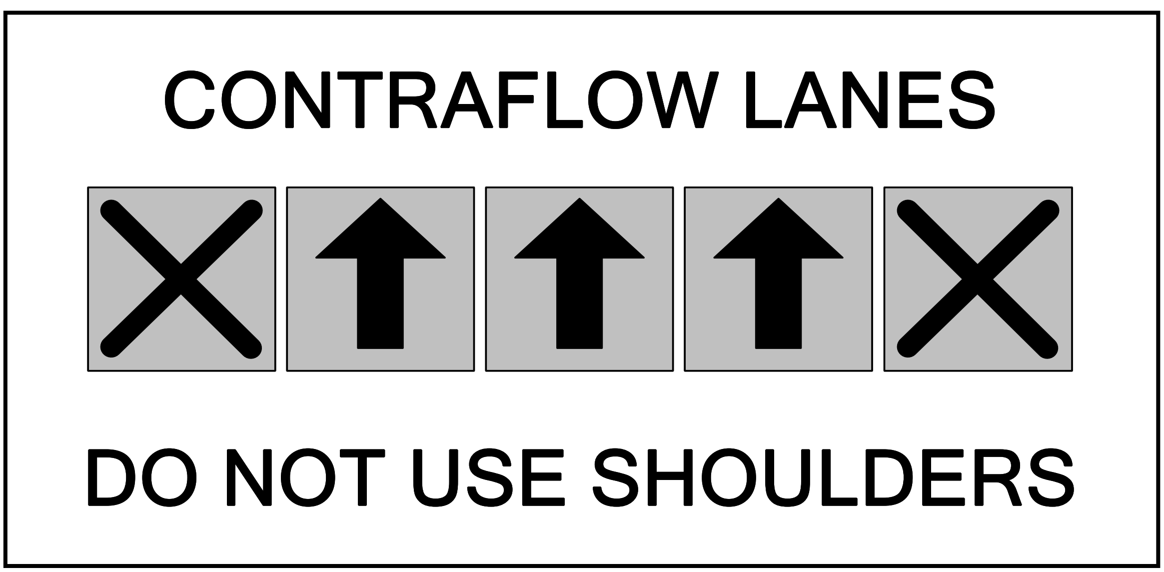


Figure 2-9. Contraflow Sign Utilizing Lane Control Signals.

With respect to recommendations on how to improve driver understanding at intersections of this type, one suggestion made was to eliminate the use of flashing yellow indications entirely during evacuation and recovery conditions, and just use all-red flashing displays. Other suggestions included adding signs that indicate "proceed with caution" or "yield" (again, redundant with the notion of a flashing yellow signal).

Finally, researchers presented participants with a graphic of an intersection with a non-functioning traffic signal. Participant responses to the question "what would you do?" indicated that all would stop in such a situation. Furthermore, most participants expected that drivers on the cross-street would stop as well. A few participants in the Beaumont focus group said that they expected cross-street traffic to use caution and slow down through the intersection. However, these two responses may simply imply a lower level of confidence in how traffic would respond in such situations rather than any inherent expectancy of a response to a non-function signal.

Motorist Information Needs during Evacuations and When Returning from an Evacuation

Information Needs during Evacuations

For this segment of the focus group, researchers had participants in each group identify a list of information items needed while on the road evacuating their region. Following the creation of this list, participants were asked to rank the items from highest priority to lowest. In addition, participants rated each item by giving a score from 1 to 5, with 1 indicating high importance and 5 indicating low importance, designating how important that particular information item would be to a motorist attempting to evacuate. Participants could score all items equally if they felt that all of the items were equally important to drivers.

A summary of the various information items identified is presented in Table 2-1, ranked in order of priority from highest to lowest at each focus group study location. Since the participants themselves first came up with the list and then ranked them, not all of the items in the lists are the same. It is interesting to note, however, that several key items consistently showed up in these lists:

- Which gas stations are still open and have gasoline?
- Where are restrooms available for use?
- Which roads are closed or cannot be accessed from a particular direction?
- Where are shelters with available room located?
- What are the current travel times on evacuation routes?

Participants in Beaumont, Galveston, and Houston identified these last two items; this directly reflects the difficulties experienced by many motorists in this region during the Hurricane Rita evacuation in 2005. In fact, one sees a fairly substantial difference in the types of information items identified and prioritized by the Corpus Christi participants, who were less affected by Hurricane Rita events, and those of the other three locations.

Another factor to consider regarding the last item on travel times could be that Corpus Christi does not have permanent DMSs, and therefore the local motorists may not be accustomed to seeing posted travel times.

Other information items suggested at one or two of the focus group locations included the following:

- What is the current direction (heading) of the hurricane? (Corpus Christi)
- What are the hurricane evacuation routes to follow? (Corpus Christi)
- What are the alternative evacuation routes that are available? (Galveston)
- Where can medical assistance be obtained? (Galveston)
- What is the next available exit? (Houston)
- Where is a working telephone located? (Beaumont)
- Where are accidents or significant delays being experienced? (Houston)
- Where are there hotel rooms available? (Beaumont, Galveston)
- Where are the alternate shelter locations if primary ones are filled? (Beaumont)
- Where are gas stations that are accepting credit cards? (Beaumont)
- Where can non-emergency evacuation information be obtained? (Galveston, Corpus Christi)
- What radio stations have evacuation and hurricane-related information available? (Houston)
- What is the estimated time until hurricane landfall? (Houston)
- What zones are prone to flooding and should evacuate? (Corpus Christi)
- Where are functioning Automated Teller Machines (ATMs) located? (Corpus Christi)

Participants were not necessarily restricted to considering information needs they would want to obtain from signs or markings, but were asked to identify issues of interest during an evacuation. Many of the needs identified are highly time-sensitive and dynamic in nature.

As a basis of comparison for the relative ratings, Figure 2-10 through Figure 2-13 present the average levels of importance that participants from each focus group location placed on the information items they identified. Again, some degree of consistency is evident among the ratings from the Beaumont, Galveston, and Houston groups as compared to those from Corpus Christi. Gasoline availability, shelter availability (except in Corpus Christi), road closures and/or alternative route availability, and food/water/ice availability were consistently rated as higher priority information needs than the other items listed. Conversely, information about zones prone to flooding, locations of ATM availability, hotel availability, gas stations accepting credit cards, and alternate shelter locations tended to be rated lower in importance (but still generally considered to be moderately important) during hurricane evacuations.

Table 2-1. Focus Group Information Needed When Evacuating: Relative Rankings by Location.

Relative Rankings	Beaumont	Galveston	Houston	Corpus Christi
High	Gas Stations Open	Gas Stations Open	Gas Stations Open	Direction of Hurricane
.	Food/Water Availability	Food/Water Availability	Shelter Availability	Evacuation Route
.	Restroom Availability	Medical Assistance	Road Closures	Gas Stations Open
.	Road Closures	Alternate Routes Available	Next Open Exit	Non-Emergency Evacuation Information
.	Alternate Routes Available	Restroom Availability	Food/Water Availability	Road Closures
.	Travel Times	Road Closures	Restroom Availability	Restroom Availability
.	Shelter Availability	Shelter Availability	Travel Times	Radio Station for More Info
.	Telephone Availability	Non-Emergency Evacuation Information	Accidents/Delays	Emergency Phone Number
.	Hotel Availability	Travel Times	Estimated Time until Landfall	Flooding Zones
.	Gas Stations Closed	Hotel Availability	Radio Station for More Info	ATM Availability
.	Gas Stations Accepting Credit Cards			Shelter Availability
Low	Alternate Shelter Locations			

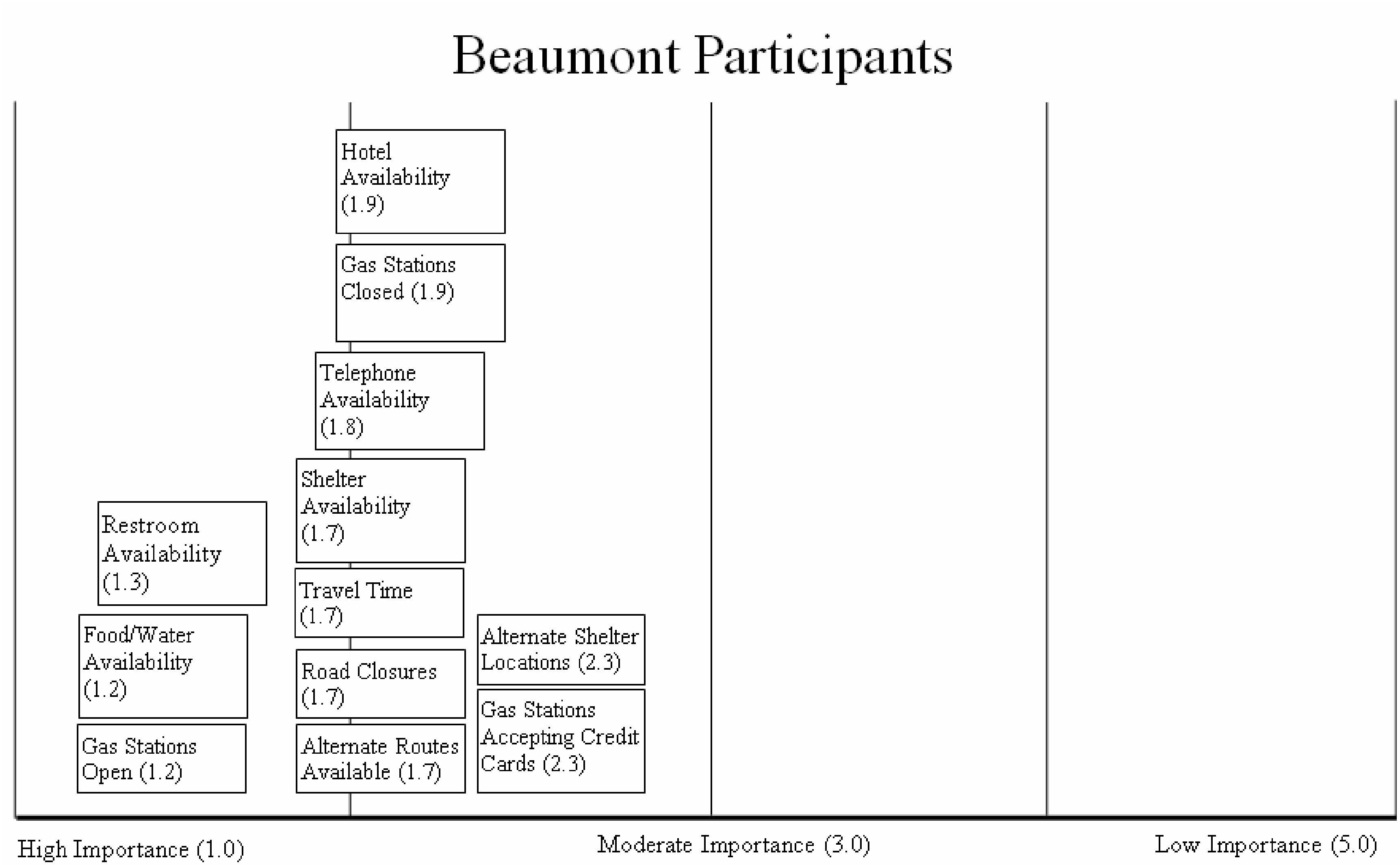


Figure 2-10. Absolute Ratings of Importance of Evacuation Information Needed: Beaumont Participants.

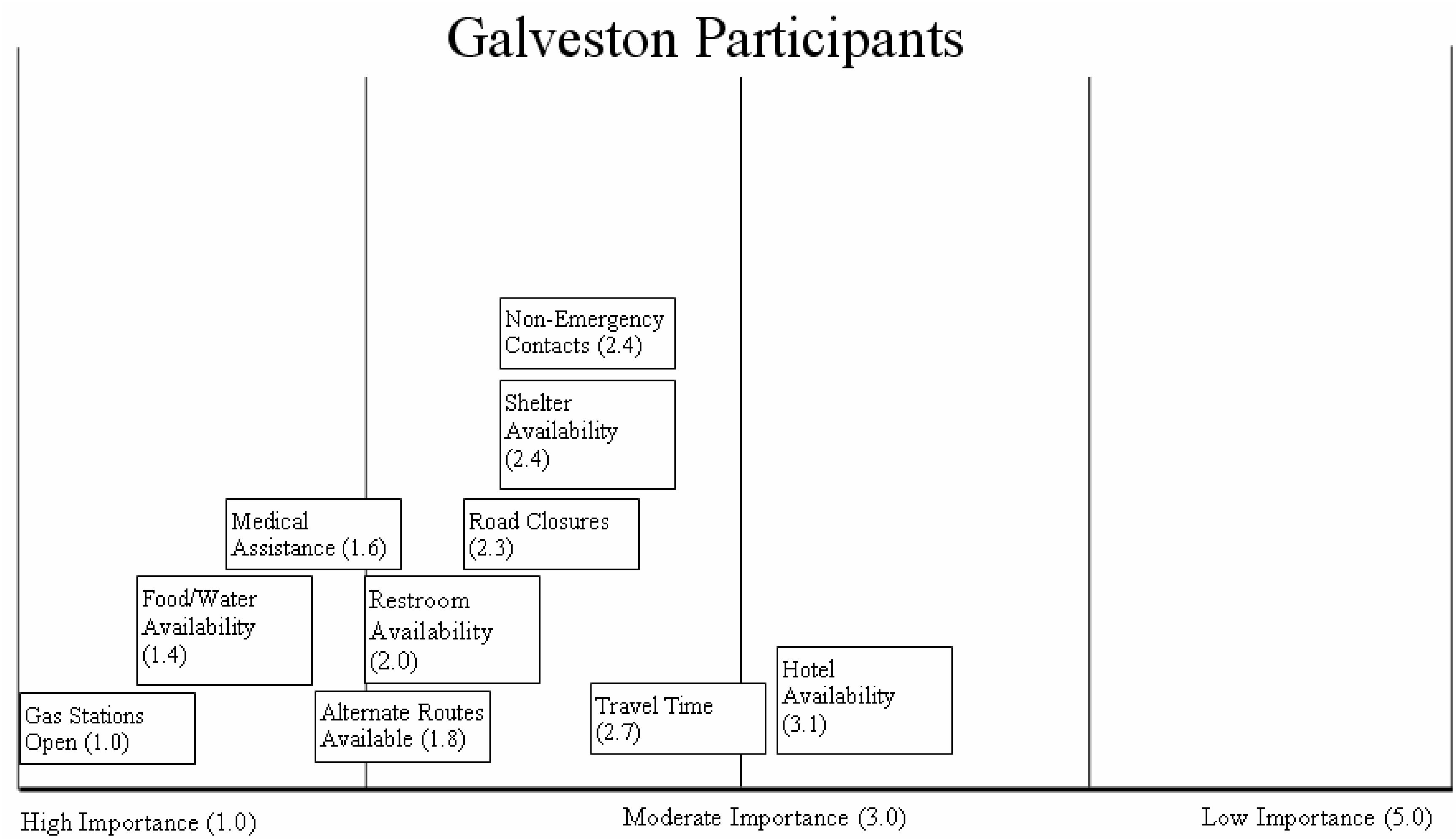


Figure 2-11. Absolute Ratings of Importance of Evacuation Information Needed: Galveston Participants.

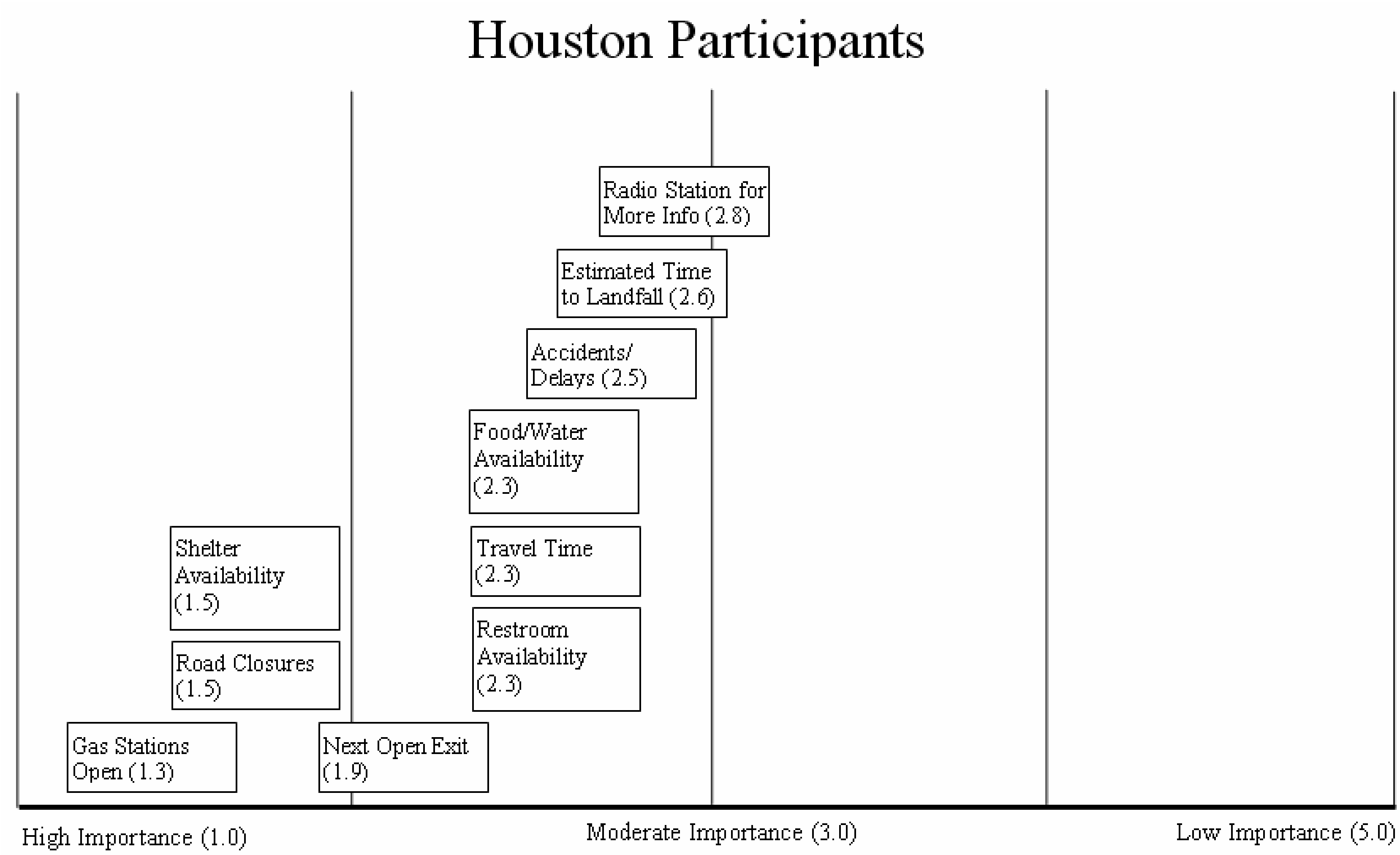


Figure 2-12. Absolute Ratings of Importance of Evacuation Information Needed: Houston Participants.

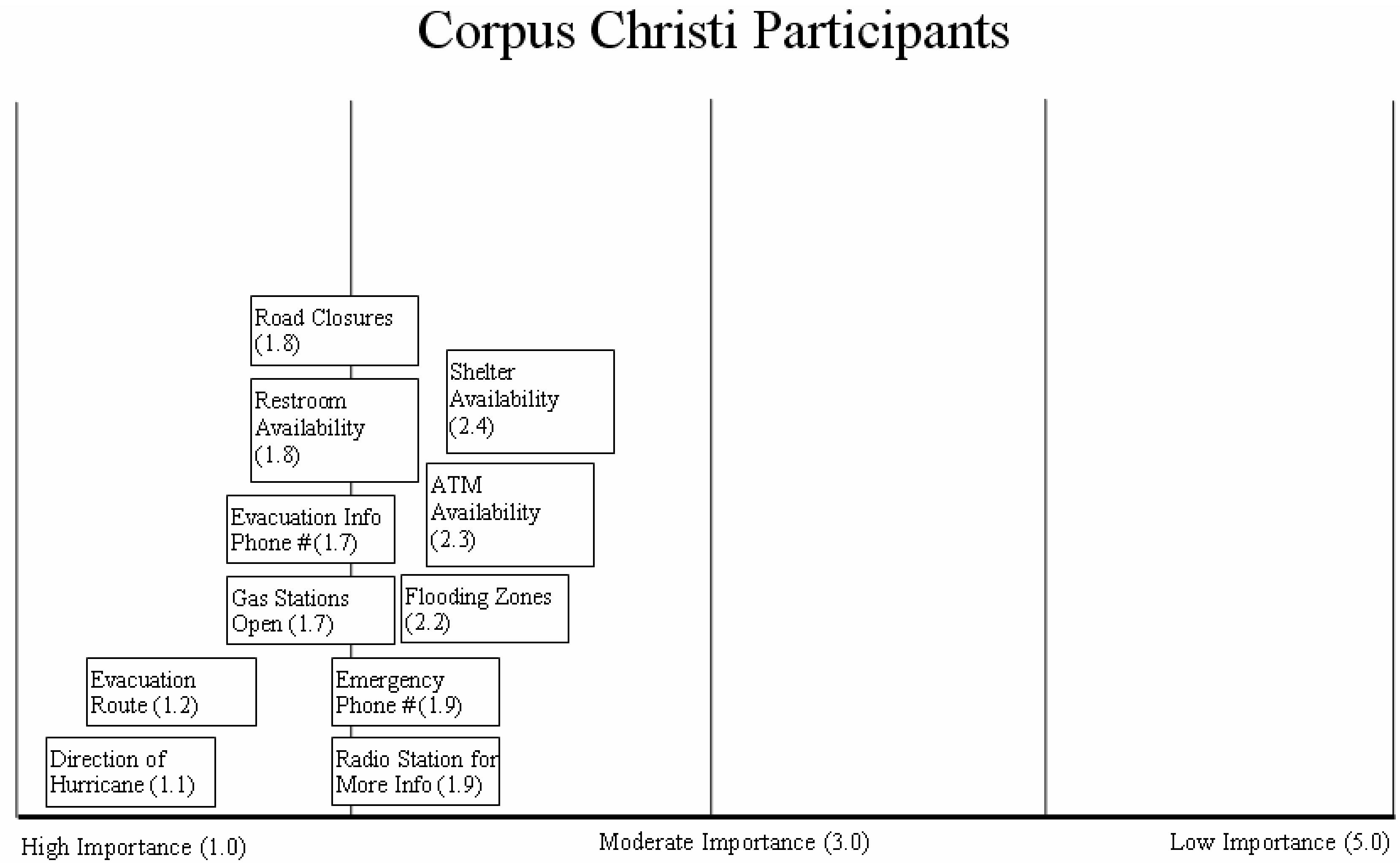


Figure 2-13. Absolute Ratings of Importance of Evacuation Information Needed: Corpus Christi Participants.

After the various information items were ranked and rated, researchers asked the participants how this information should be disseminated. To some extent, the responses to this question depended on the participant's prior experiences and exposure to the various information sources. All participants did mention DMS as a good mechanism for disseminating hurricane-related information because of the dynamic nature of the situation and the ease (in their opinion) with which information can be updated. The participants felt that the majority of the items listed above should be displayed via the DMS, even those not necessarily within the public-sector realm (i.e., gas stations with fuel available, locations of restroom facilities available for use, etc.). However, Houston participants did not think a DMS would be appropriate for disseminating information about the expected time of hurricane landfall.

Most of the participants also stated that the radio would be a good mechanism for disseminating hurricane information, especially locations with gasoline, available shelter locations, accident and travel delay information on evacuation routes, and time of hurricane landfall. One interesting suggestion made by Houston participants was that the radio stations could each be coordinated to provide information specific to one particular area of the city. In this way, drivers could more easily target information of direct relevance to them based on where they were located. Participants in both Corpus Christi and Beaumont noted that TxDOT-owned radio (i.e., Highway Advisory Radio [HAR]) had been used to convey hurricane information in the past to the public. Beaumont participants stated that such information was good but that they preferred commercial radio for their information. (The Beaumont District decommissioned its HAR system due to unreliable connections.)

In Beaumont and Galveston, participants suggested that the logo signs with gasoline stations be equipped to allow an "X" or circle-slash symbol to be put over each logo that is out of gas. Road closed and alternate route information could also be presented via static signs, according to several of the participants. Television was cited as another good potential information source, especially for providing up-to-date shelter location and availability information and key telephone numbers. Participants suggested Internet websites as the best way to obtain information about hotel availability.

One other related information dissemination issue raised during the focus group discussion was the challenge of maintaining personal communication during the evacuation. Both land-line and cellular telephone lines were overloaded so that it was nearly impossible to get through to reach anyone. One lesson that a few participants learned during their experiences was that text messages were easier to get through (although they did take a little while to be received) than obtaining a voice connection. In fact, many families maintained communication during the evacuation almost exclusively by text messaging.

Information Needs When Returning after an Evacuation

Following the discussion of information needs during evacuation, researchers repeated the process of information item identification, ranking, and rating for the return trip after the hurricane. Table 2-2 summarizes the ranked list of desired information items from each focus group location. Again, a few items appeared across three or all four focus group study locations:

- At what locations are food/water/ice available?
- Is electricity available?
- Where are locations that gasoline is available?
- What are curfew times (if in effect)?
- Which roads are closed?
- Is there a functioning hospital (and where)?
- What is the contact number for assistance?
- Where are available shelters located if needed?

In addition to these common items, the following list includes additional suggestions heard at only one or two of the focus group locations:

- Are stores open for business? (Beaumont, Corpus Christi)
- What radio station has more info about conditions, returning, etc.? (Beaumont)
- Is the water safe to drink? (Beaumont, Houston)
- Is the city open for returning evacuees? (Galveston, Houston)
- What locations are flooded? (Houston)
- What routes are available to return home? (Houston)
- Where are locations that electrical lines are down? (Houston, Corpus Christi)
- Where are locations where there is debris still in the road? (Houston)
- Is it safe for evacuees to return? (Corpus Christi)
- What areas are safe to travel into? (Corpus Christi)
- Who is allowed back into the city? (Corpus Christi)
- Is Martial Law in effect? (Corpus Christi)
- Where can veterinary assistance be obtained? (Corpus Christi)

Figure 2-14 through Figure 2-17 presented the participant ratings of each of the information items identified at that particular focus group location. Fairly consistent high ratings were given across the focus groups for electricity availability, food/water/ice availability, road closures, and gasoline availability. Conversely, curfew times was only rated as moderately important by the focus group participants, as was whether or not stores were open. The remaining ratings were scattered in between these high and moderately rated information items.

Table 2-2. Focus Group Information Needed When Returning after an Evacuation: Relative Rankings by Location.

Relative Rankings	Beaumont	Galveston	Houston	Corpus Christi
High	Food/Water/Ice Availability	Electricity Availability	Road Closures	Functioning Hospital(s)
.	Gas Availability	City Open	Electricity Availability	Safe Areas
.	Contact Info for Assistance	Food/Water/Ice Availability	Flooded Locations	Food/Water/Ice Availability
.	Road Closures	Road Closures	City Open	Road Closures
.	Radio Station for More Info	Gas Availability	Return Route Availability	Gas Availability
.	Electricity Availability	Flooded Locations	Gas Availability	Return Route Availability
.	Drinking Water Safe	Contact Info for Assistance	Shelter Availability	Shelter Availability
.	Functioning Hospital(s)	Curfew Times	Food/Water/Ice Availability	When Safe to Return
.	Shelter Availability	Functioning Hospital(s)	Downed Electrical Line Locations	Is Martial Law in Effect
.	Open Stores			Stores Open
.	Curfew Times		Contact Info for Assistance	Contact Info for Assistance
.			Debris in Road	Who is Allowed to Return
.			Curfew Times	Downed Electrical Line Locations
.			Stores Open	
.				Curfew Times
Low				Veterinary Assistance

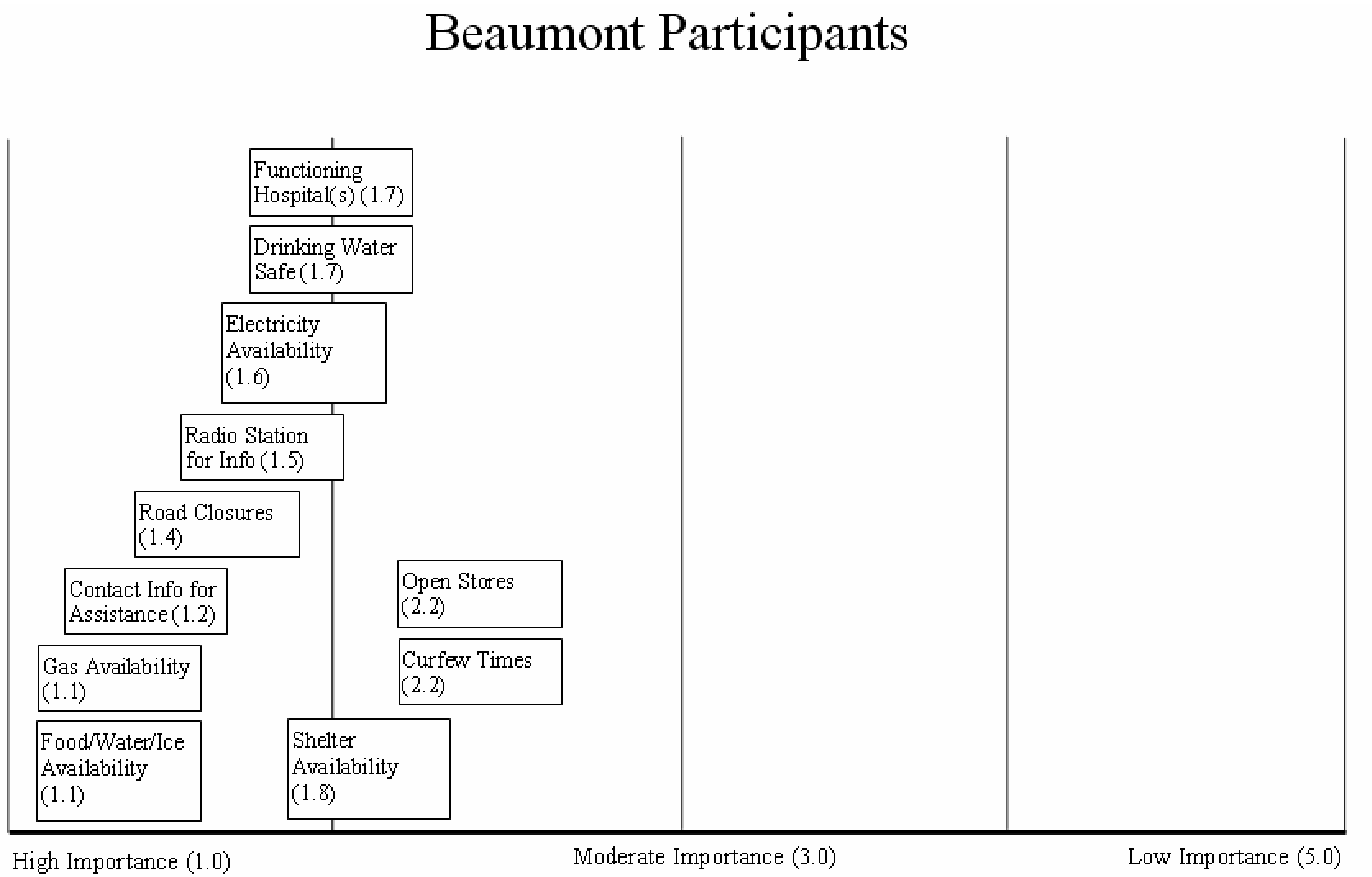


Figure 2-14. Absolute Ratings of the Importance of Information Needed When Returning: Beaumont Participants.

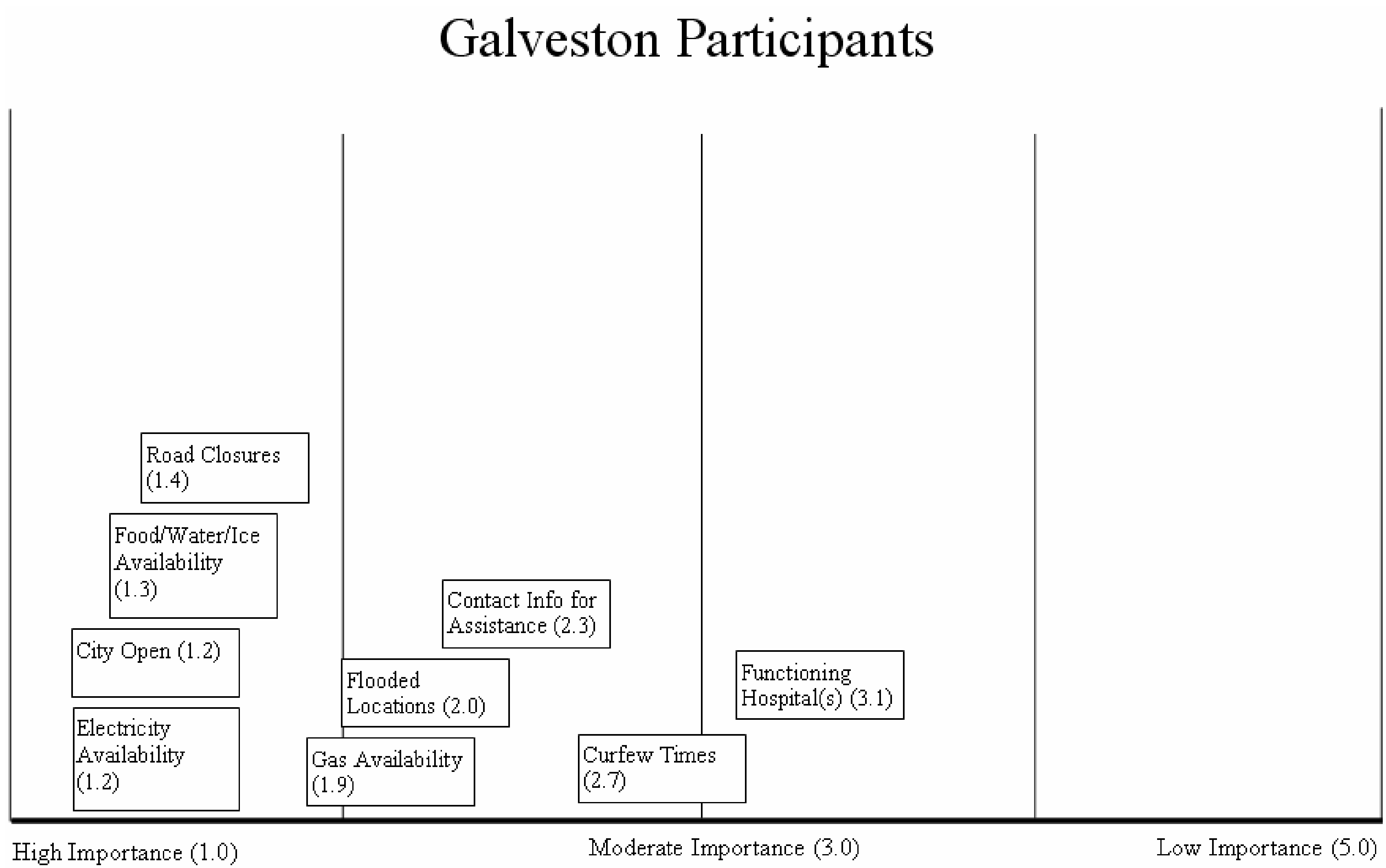


Figure 2-15. Absolute Ratings of the Importance of Information Needed When Returning: Galveston Participants.

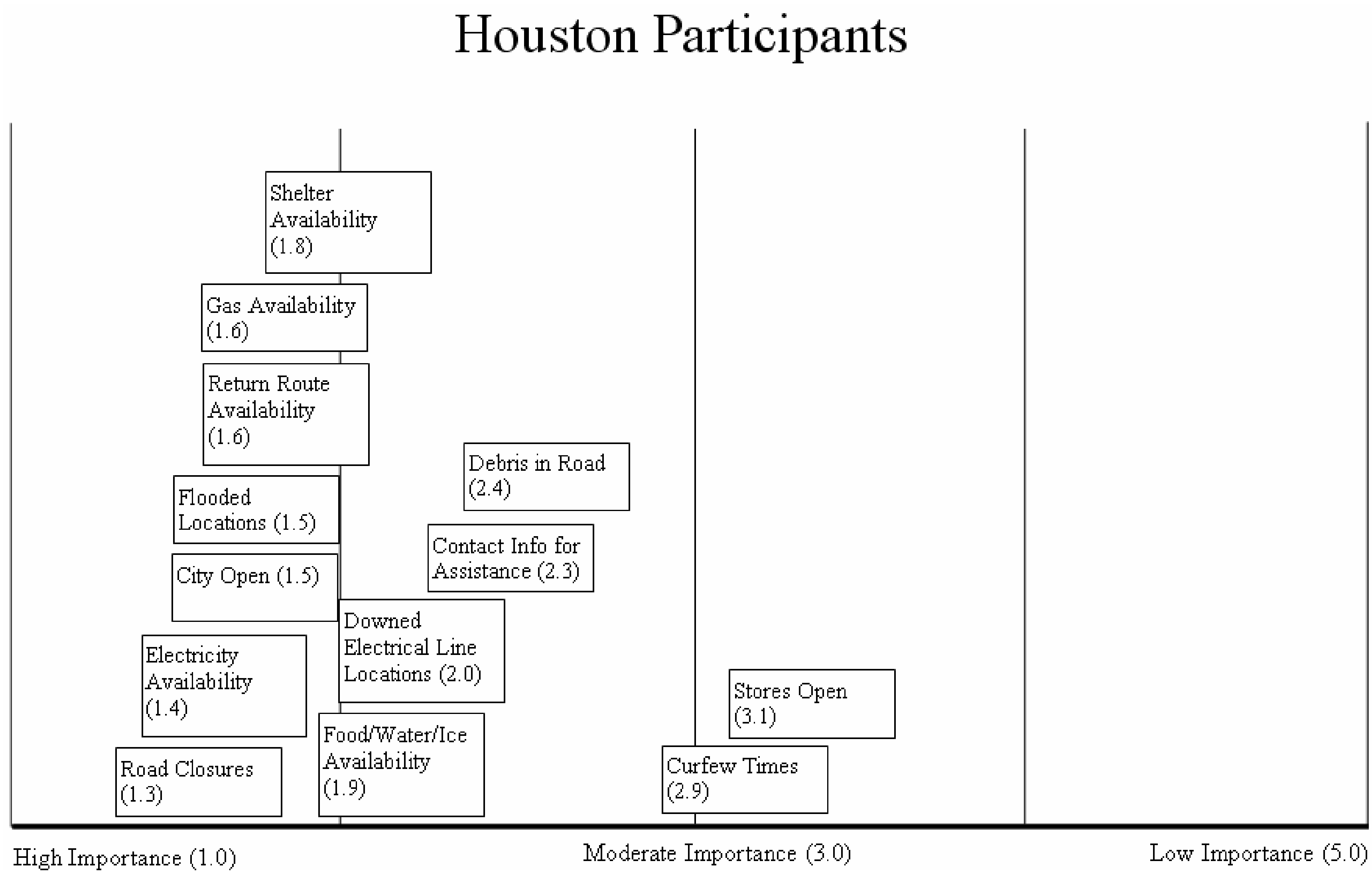


Figure 2-16. Absolute Ratings of the Importance of Information Needed When Returning: Houston Participants.

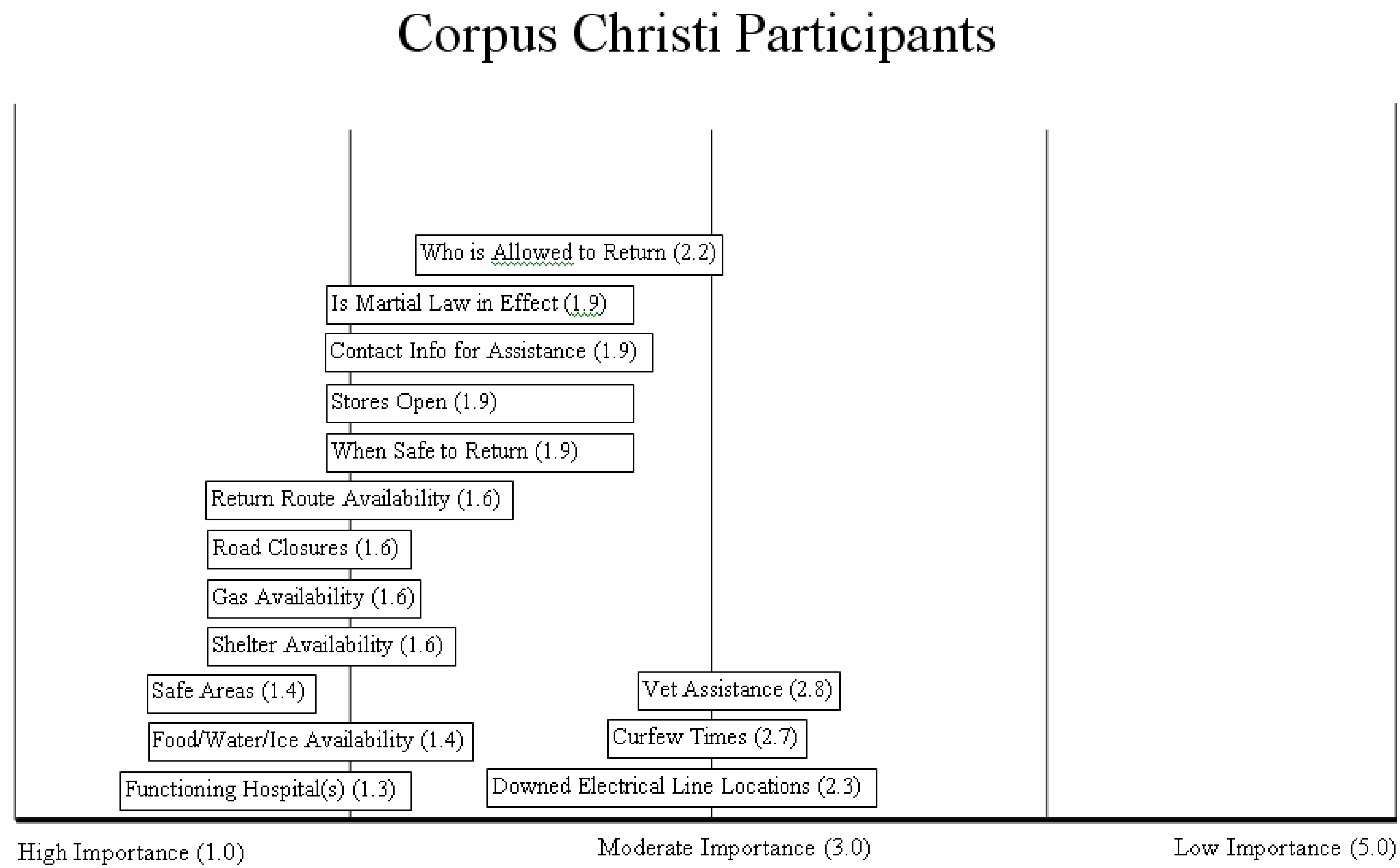


Figure 2-17. Absolute Ratings of the Importance of Information Needed When Returning: Corpus Christi Participants.

Participant-suggested methods of disseminating information to motorists returning after an evacuation included the radio, seen as useful for disseminating all of the above information items, television, DMS, flyers, cellular telephone text messages, telephone hotlines to call, and the Internet. When asked what types of information would be best displayed on the DMS, participants suggested road closures, safe routes to use, locations of flooding, locations where electrical lines were down, curfew times, detours, and functional hospitals. The suggestion for flyers came from Corpus Christi participants, who suggested that all types of needed information could simply be put on a flyer and handed out to motorists as they returned. Corpus Christi participants also liked the notion of having information sent to them on their cell phone, and to have that information tailored to the area where the cell phone is used or where the bill is sent. Galveston participants felt that the Internet would be a good method of disseminating information after an evacuation, providing maps of shelters, indications of which routes were open or closed, which areas were flooded, etc.

IMPLICATIONS FOR LABORATORY STUDIES

In addition to gaining better insights into the opinions and thought processes of motorists during times of hurricane evacuations, another purpose of conducting these focus group studies was to identify issues and traffic control device items that warrant additional evaluation and analysis via full-scale laboratory studies during the next fiscal year. Several such potential items for additional research are listed below:

- Participants expressed a need for better information when HOV lanes are opened to evacuating motorists. Items of primary interest are notification that the normal occupancy restrictions had been suspended, the actual location of entrances and exits to/from the HOV lane (since many of the motorists will not normally be aware of such information), and the actual endpoint of either where the HOV lane will end or where the use of the HOV lane for evacuation traffic will terminate.

- Participants expressed some confusion over signs used to convey when a shoulder is being used for a travel lane. Specifically, the existing sign designating when the shoulder-use lane is terminating may be confusing to drivers. Whereas a similar-type sign under normal operating conditions may function adequately, it does appear that motorists may be less willing to assume that certain behaviors (i.e., to merge back into the travel lanes instead of following the exit) are still allowed. It may be very important to design traffic control devices to explicitly convey what maneuvers are and **are not** allowed at such decision points.

- Well-designed and intuitive advance and guidance signing for contraflow lanes was a key need expressed by group participants. A number of candidate signs and traffic management alternatives were developed through the focus group studies that researchers should consider for evaluation in more formal laboratory studies of driver interpretation and stated response.

- Focus group participants identified a large number of information items needed during a hurricane evacuation and during the return trip. Participants also rated the importance of several of these items fairly high. The information gained should immediately help emergency management officials in hurricane-prone areas to craft an overall information dissemination strategy. For purposes of this research project, however, additional study is needed to determine how messages to convey such information (if so desired by TxDOT) should be designed and displayed on DMS and HAR.

CHAPTER 3. EVACUATION ROUTE SIGNING AND MARKINGS SURVEY

Human factors studies were conducted to determine the most appropriate type and application of hurricane evacuation signing and pavement markings to use in Texas coastal areas. In the first year of the project, focus groups were conducted to determine motorists' comprehension and informational demands of potential signs and markings used in various situations during a hurricane evacuation. The results of the focus group discussion, along with input from the project advisory committee, were used as a basis for the experimental design of the human factors laboratory studies.

STUDY DESIGN

The primary objective of conducting the human factors studies was to determine the most appropriate type and application of hurricane evacuation signing and pavement markings so that the Texas coastal areas would be best prepared to meet the traffic operations and traffic control needs associated with a hurricane evacuation event. The human factors laboratory study was to evaluate, at a minimum, driver understanding, accuracy, and comprehension of candidate signs and pavement markings. The study included both static and dynamic message signs as well as various pavement markings. The laboratory instrument, included in Appendix B, consisted of several sections, covering the following topics:

- overhead signs,
- evacuation route shields,
- shoulder lane sign for use on Farm-to-Market roads,
- open shoulder lane signs,
- closed shoulder lane signs,
- end of shoulder use signs,
- pavement markings,
- contraflow signs, and
- dynamic message sign abbreviations.

The human factors studies were conducted using a laptop computer; however it was not necessary for the participants to have any computer experience. It was decided to display the pictures on the laptop in order to give the participants a more realistic visual approach to the signs.

Upon arrival, subjects were provided with an explanation of the study and asked to read and sign the informed consent document. Facilitators explained to each participant that the survey was not a test, and it would have no impact on their license. They were told to imagine that they encountered these situations while evacuating or returning from an evacuation due to a large hurricane in the Gulf.

In addition to some general overall questions, the subjects were each shown six signs, one marking, and four abbreviations. Some of the signs were presented in specific traffic control techniques used during hurricane evacuation and returning from an evacuation like shoulder usage and contraflow lanes. Other signs and markings were presented to obtain the participants' preferences of different signs or markings that could be used to convey the same meaning. For each sign/marking situation displayed the participant was asked several questions to help determine their understanding of the sign/marking and what action they would take.

Next, the participants were told that the pictures they were about to see were different options that could be used in the same situation that they just viewed. They were asked to rate the different combinations of information on how well they let them know what route they should take to evacuate. The rating was done on a scale from 1 to 5 where 1 indicated that the sign was excellent and 5 indicated terrible. Researchers recorded all responses from the participants on paper. To avoid the occurrence of primacy bias, the order of the sign or pavement marking displayed was randomized, and there were seven versions of the survey.

Location

Similar to the focus group studies, TTI conducted the laboratory studies in areas that are within the hurricane evacuation region in Texas. The locations selected were: Beaumont, Houston, Galveston, and Corpus Christi. Test subjects were approached at random through direct human contact at various Texas Department of Public Safety (DPS) driver licensing stations in the four selected cities.

Demographics

A total of 421 participants were recruited in four selected cities. The only criterion for the participants recruited was that they be over the age of 18 and have a current Texas driver's license. Table 3-1 contains the number of participants recruited by gender, education, and age category. The table shows that the demographics of age, gender, and education level completed were all close to being evenly split. Almost half of the participants were under 39 years of age, and the other half were over 39 (48 percent versus 52 percent), and with respect to education completed, 46 percent of the participants had a high school diploma or less, and 54 percent had some college or more.

Table 3-1. Demographic Sample of Participants.

Age Category	Education Level				Total (%)
	High School Diploma and Less		Some College and More		
	Male (%)	Female (%)	Male (%)	Female (%)	
<25	6	6	5	5	22
25-39	6	7	6	7	26
40-54	7	9	10	9	35
55-64	1	1	4	5	11
65+	1	2	1	2	6
Total	21	25	26	28	100

In addition to obtaining their gender, age category, and last level of education completed; the participants were also asked how long they had been driving, and if they had evacuated due to a hurricane in the last three years? Table 3-2 shows the participants' driving experience, indicating that almost 70 percent of the participants had more that 10 years driving experience. Table 3-3 shows that more participants had evacuated in the last three years from Beaumont and Galveston than from Houston and Corpus Christi. This difference could be contributed to the mandatory evacuation for Beaumont and Galveston for Hurricane Katrina. Overall, there were 56 percent that had evacuated in the past three years and 44 percent that had not.

Table 3-2. Participants' Driving Experience.

Driving Experience	Percent of Participants
< l year	4
1-5 years	15
6-10 years	12
>10 years	69

Table 3-3. Participants That Evacuated in the Last Three Years.

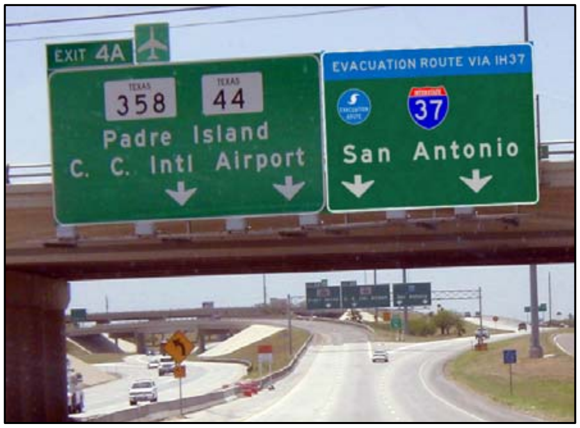
Evacuated in Last Three Years	Percent of Participants
Yes	56
No	44

ANALYSIS

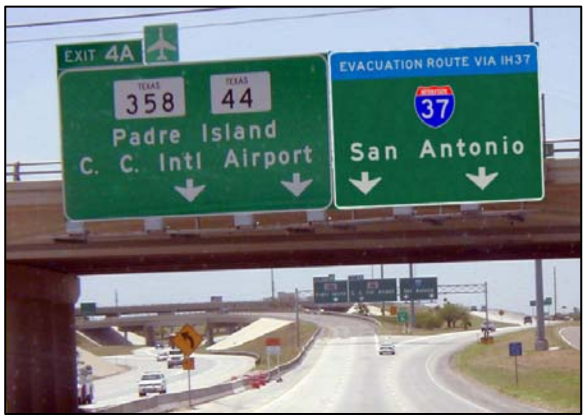
Data analysis was divided into sections according to the different categories of signs and pavement markings that were evaluated in this survey. The initial part of the analysis was to determine participant comprehension of the signs or markings as designating different features of an evacuation route. Researchers used a standard understanding level of 85 percent as the baseline criteria for a sign being within an acceptable comprehension level for use in the field. As part of this analysis, researchers performed confidence interval tests and Bernoulli test of proportions to determine if the identified differences, both from 85 percent and between two comprehension levels, were statistically significant.

Large Overhead Signs

This part of the survey examined three formats for hurricane information inclusion upon a large overhead sign. Figure 3-1 shows the three options studied. Options B and C are based upon current sign formatting found in Texas, while Option A was based upon information gained during a focus group conducted during this project (see Chapter 2). The purpose of this study was to determine how much information motorists need such that they can recognize a designated evacuation route.



A. Text and Symbol



B. Text Only

C. Symbol Only

Figure 3-1. Large Overhead Signs.

Each participant viewed one of the three overhead sign options shown in Figure 3-1. Since there were an odd number of surveys, the number of participants that viewed each sign varied. In this study there were a total of 121 participants that viewed the text and symbol sign, 120 viewed the text only sign, and 180 viewed the symbol only sign.

Researchers asked each participant what information the sign provided to them and what action they would take during an evacuation if they saw the sign. Participants were considered to have correctly interpreted the sign if they could identify that the overhead sign indicated a designated evacuation route. Correct answers consisted of participants indicating they would take the appropriate highway, city, or direction to evacuate.

Comprehension Results

The following tables identify the number (n) of participants who were shown each sign and the percentage who correctly interpreted each sign. Table 3-4 indicates that the majority of the participants (93 percent) interpreted the text and symbol sign as a designated evacuation route. Also, a total of 86 percent correctly interpreted the text only sign. These two comprehension percentages were not statistically different. Therefore, either of these signs was understood at a high enough comprehension level to be appropriate for field use. The symbol only sign was understood at a comprehension level of only 68 percent, which is statistically different than the baseline for this study of 85 percent. It was noted that with the symbol only format of the sign the symbol placard was easy to overlook with all of the other information being provided.

Table 3-4. Percentage Comprehension of Large Overhead Signs.

Large Overhead Sign Options	Percent Correct
Text and Symbol (n=121)	93
Text Only (n=120)	86
Symbol Only (n=180)	68*

*is statistically different from 85 percent

Table 3-5 illustrates what action the participants would take based on the sign they viewed. This table specifically details the responses of participants who interpreted the overhead signs as intended. Researchers found that if participants understood the sign, nearly 95 percent of the participants viewing each option would have taken the intended evacuation route. Additionally, several individuals knew they were not taking the evacuation route, but preferred to go a different direction for personal reasons. Given that these responses were essentially equal, the decision of what signing format to use should be based primarily upon comprehension results.

Table 3-5. Action Taken by Participants.

Large Overhead Sign Options	Percent	
	Correct	Incorrect
Text and Symbol (n=113)	94	6
Text Only (n=155)	95	5
Symbol Only (n=82)	95	5

Next, the participants were asked if the signs provided them with enough information to determine they were on a designated evacuation route, and if so what information had helped them to reach that conclusion. Table 3-6 shows that 84 percent of the participants that viewed the text and symbol sign felt there had been enough information provided in the sign to determine they were on a designated evacuation route. There were 75 percent of the participants who viewed the text only sign and 56 percent that viewed the symbol only sign who felt there was enough information.

Table 3-6. Responses to the Question "Did the Sign Provide You with Enough Information to Determine You Are on a Designated Evacuation Route?"

Large Overhead Sign Options	Percent	
	Yes	No
Text and Symbol (n=121)	84	16
Text Only (n=180)	75	25
Symbol Only (n=120)	56	44

Those participants who felt like the sign had provided enough information to determine that they were on a designated evacuation route were then asked what information helped them make that decision. For all three options the primary responses were: the color of the evacuation placard (blue) or the additional evacuation information (either text or symbol based on what sign they viewed).

Those participants who felt the sign did not provide enough information were asked what additional information they needed. Again, the responses were similar for all three options. The primary responses given as to what other information they needed were that the sign needed to be larger, and the signs needed to indicate where the evacuation route would lead.

Preference

Finally, each participant was shown pictures of each of the three options. Upon viewing each option the participant rated that information on a scale of 1 to 5. Table 3-7 shows the average ratings for each of the sign formats.

Table 3-7. Average Ratings for Overhead Guide Signs.

Large Overhead Sign Options	**Average Rating** (1 – highest; 5 – lowest)
Text and Symbol (n=421)	1.6
Text Only (n=421)	2.4
Symbol Only (n=421)	2.7

In the table above it can be seen that there was a slight preference for the text and symbol sign with an average rating of 1.6. However, the other two signs with text only and symbol only also received a better than average rating of 2.4 and 2.7, respectively. Therefore, there is no clear-cut preference for one particular sign within this grouping.

Recommendations

Based on the results, there are two options that yielded high enough understanding and preference to make them appropriate for field use. These were the text and symbol sign (Figure 3-1(A)) and the text only sign (Figure 3-1(B)). The text and symbol had the best comprehension and was also rated slightly higher. However, the comprehension of this sign was not significantly different from the text only option. Either of these two signs is recommended. Finally, due to the low comprehension of the symbol only sign (Figure 3-1(C)), this format is not suggested for use.

Evacuation Route Shields

The second section of this study evaluated alternate signing for the evacuation route shield. The Manual on Uniform Traffic Control Devices (*1*) evacuation sign (EM-1) was examined along with three other options. These options were a hurricane symbol sign designated in the Standard Highway Sign Designs for Texas (*2*) at EM-1a, EM-1a with a supplemental arrow plaque, and a symbol sign design based on focus group findings. Figure 3-2 shows each of the evacuation route shields studied.

Each participant viewed one of the evacuation route shields to evaluate comprehension. Because there were an odd number of survey formats, the different alternatives were viewed by a different number of participants. The EM-1, EM-1a, and the focus group symbol sign were seen by 121, 120, and 120 individuals, respectively. The EM–1a with supplemental arrow was viewed by 60 participants since it was the same evacuation route shield as in the traditional sign with only the simple addition of an arrow. In addition, the other study shields included arrows and thereby would further evaluate the impact of arrow inclusion with the evacuation route shield. Researchers asked each participant what information the sign provided to them and what action they would take during an evacuation. Correct comprehension was identified as participants who stated that the evacuation route was going north, right, or followed North US 77.

Comprehension Results

Table 3-8 shows the comprehension percentage for each of the sign alternatives evaluated in this section. It can be seen that the EM-1 and EM-1a with supplemental arrow were comprehended by the majority of the participants (91 and 90 percent, respectively). This high level of comprehension would make them appropriate for in-field use. The EM-1a and focus group symbol sign were understood by 84 and 83 percent of the participants, respectively. Although these percentages are lower than the 85 percent baseline, the difference is not statistically significant; therefore, these signs can not be totally disregarded as appropriate for use. Researchers noted that the lower comprehension rate of signs EM-1a and the focus group symbol sign may be attributable to the lack of an arrow for direction on the EM-1a shield and the small size of the arrow in the focus group symbol sign.

A. EM-1

B. EM-1a

C. EM-1a with Supplemental Arrow

D. Focus Group Symbol Sign

Figure 3-2. Alternate Evacuation Shields.

Table 3-8. Percentage Comprehension of Evacuation Route Shields.

Evacuation Route Shield Options	Percent Correct
EM-1 (n=121)	91
EM-1a (n=120)	84
EM-1a with arrow (n=60)	90
Focus group symbol sign (n=120)	83

When the participants were asked what action they would take, the data were divided into those who interpreted the signs as intended, and those that did not. Table 3-9 shows the interpretation of these actions as correctly following the evacuation route or making route decisions that do not follow the designated evacuation route. The table indicates a trend of participants' better understanding evacuation route shields that include arrows. This trend is evident in the fact that only 58 percent of those participants who viewed EM-1a without a supplemental arrow were confused on which direction to take. The other three options all garnered correct actions by greater than 90 percent of the participants. From this perspective, any of these signs would yield acceptable reactions by drivers during an evacuation.

Table 3-9. Action Taken by Participants Who Correctly Interpreted the Sign.

Evacuation Route Shield Options	Percent	
	Correct	Incorrect
EM-1 (n=110)	96	4
EM-1a (n=101)	58	42
EM-1a with arrow (n=55)	98	2
Focus Group Symbol Sign (n=98)	91	9

The participants were then asked if the sign provided them with enough information to determine if they were on a designated evacuation route. Further following the trend that had been set during the comprehension questions, participants felt that those shields with arrows did provide enough information over those with a smaller arrow or no arrow. As shown in Table 3-10, the EM-1a shield with supplemental arrow received the highest number of "yes" responses with 78 percent, the EM-1 had 64 percent, the focus group sign shield that has the smaller arrow received 52 percent, and the remaining shield EM-1 with no arrow had only 33 percent that replied "yes."

Table 3-10. Responses to the Question "Did the Sign Provide You with Enough Information to Determine If You Are on a Designated Evacuation Route?"

Evacuation Route Shield Options	Percent	
	Yes	No
EM-1 (n=121)	64	36
EM-1a (n=120)	33	67
EM-1a with arrow (n=60)	78	22
Focus Group Symbol Sign (n=120)	52	48

Those that felt there was enough information to determine they were on a designated evacuation route were asked what information helped them to make that decision. The top responses included the following:

- evacuation route shield (all options),
- color of the evacuation sign (all options),
- symbol (all options), and
- arrow (all options except EM-1a).

Those participants that responded "no" suggested the following ideas to improve the information provided:

- larger sign, (all options),
- arrows for direction (EM-1a),
- where evacuation route will lead you (all options),
- include symbol (EM-1), and
- include word "Evacuation" (focus group symbol shield).

Preference

As in the previous section, the participants were shown pictures of each of the different options and were asked to rate how well that sign informed them on what route to take when evacuating. The ratings of the different alternatives were consistent with the comprehension results. EM-1a with a supplemental arrow rated the best at 1.8, followed by 2.6 for the EM-1 shield. The focus group symbol sign and EM-1a sign without an arrow both obtained an average rating of approximately 3, as shown in Table 3-11. This further solidifies the fact that arrows are not only better understood, they also provide a higher level of comfort in decision-making for the drivers.

Table 3-11. Average Ratings for Alternate Signs for MUTCD Evacuation Sign (EM-1).

Evacuation Route Shield Options	Percent Correct
EM-1 (n=421)	2.6
EM-1a (n=421)	3.2
EM-1a with arrow (n=421)	1.8
Focus group symbol sign (n=421)	3.0

Recommendations

The comprehension results indicated that any of the alternatives would be acceptable for use in identifying an evacuation route. However, when a motorists' driving decision or action is considered, the use of an arrow (such as in shields EM-1 and EM-1a with supplemental arrow plaque) greatly increased the correct route decisions by motorists. Additionally, EM-1a with the supplemental arrow and EM-1 were preferred by the motorists. Therefore, researchers recommend that either the EM-1 or EM-1a be used as evacuation route shields. However, arrows defining the direction of the evacuation should be provided at all decision points to ensure proper motorist comprehension and choice of turn direction (such as with EM-1a with supplemental arrow plaque).

Shoulder Lane Sign for Farm-to-Market Roads

Only one sign was evaluated within this section, and it is a format that is currently deployed in the Beaumont District. All 421 participants evaluated this sign. Participants viewed the situation in Figure 3-3 and were told to assume that they were evacuating from a particular location on an FM road.

Participants were asked what information the sign was providing and what action they would take. Correct responses consisted of the participants' understanding that the shoulder was available as a travel lane during a hurricane evacuation. An incorrect response was when the participant felt that the shoulder was the only lane included in the evacuation route or that they could not drive on the shoulder.

For this sign, only 64 percent of the participants correctly interpreted that the shoulder could be used as an additional traffic lane during an evacuation. This means that 36 percent of the participants were not able to accurately interpret the sign. Within the incorrect interpretations, the sign misled many of the participants (25 percent) to believe that the shoulder was the only lane that could be used to evacuate.

When asked what action they would take, all of the individuals that comprehended the sign correctly selected an appropriate action. However, the responses from those that did not interpret the sign correctly indicated that there was a great deal of confusion with 83 percent of the participants indicating an incorrect action. Within these responses, participants frequently indicated that they should not cross the solid white line pavement marking, that they believe the road was splitting into two lanes, or that they did not know if the shoulder lane would lead to an evacuation route.

At this point the participants were asked based on the information displayed, if they could drive on the shoulder of this road. Ninety-two percent of all participants felt that they could drive on the shoulder, while 6 percent did not. However, the 92 percent is a bit misleading as it includes those individuals that believed only the shoulder was the evacuation route.

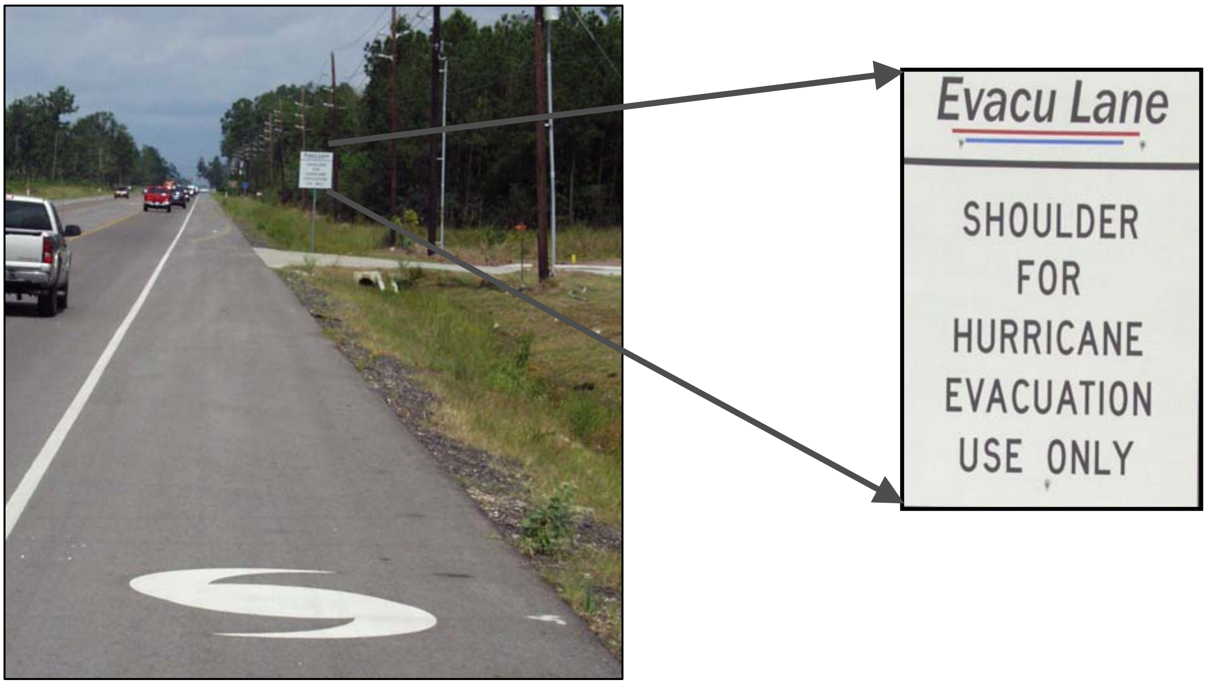


Figure 3-3. Evacuation Shoulder Lane Sign Used on FM Roads.

When the participants who believed they could drive on the shoulder were asked to explain how they came to that conclusion, most of the participants indicated that they had gained that information from the given sign. Other responses included the pavement markings or the sign and pavement markings combined. Next, the participants who stated they could drive on the shoulder were asked if they would use the shoulder lane. Ninety-one percent of the participants stated they would drive on the shoulder during an evacuation. The reasons they indicated consisted of the following:

- to evacuate,
- to evacuate quicker or increase traffic flow,
- sign indicated it was ok, and
- shoulder is the only designated evacuation lane.

Again, the response “the shoulder is the designated evacuation lane” implies that some of the participants were misled in thinking that the shoulder was the only lane you could travel in to evacuate.

Recommendations

Results indicate that the sign was not comprehended at a high enough level to recommend use in the field. It created a high level of confusion for the motorists and in many cases misled the motorist to believe they were required to take the shoulder to evacuate. Researchers believe that the alleviation of the word "Only" on the sign may improve the comprehension level; however, without further research no recommendation can be made at this time. Researchers suggest using one of the shoulder lane open signs in the next section to fulfill the information needs of drivers on FM roads.

Shoulder Lane Open Signs

This section reviews the findings regarding four different shoulder lane open signs. The purpose of this part of the study was to examine alternative signs to determine which sign would best inform motorists that an evacuation shoulder lane (i.e., an "Evaculane") is open for use as a travel lane. Figure 3-4 shows the four signs evaluated.

Each sign was included in one survey (the shoulder lane closed signs in the next section were evaluated in the remaining three of the seven surveys). There were approximately 60 participants that viewed each sign.

A. Diagrammatic Sign

B. "Open" Text Sign

C. Flashing Beacon Sign

D. Diagrammatic Sign with White Panel

Figure 3-4. Shoulder Lane Open Sign Options.

Researchers as in previous sections asked each participant what information the sign gave them and what action would they take in an evacuation. The correct comprehension was when the individual knew they had the option to use the shoulder as a travel lane in an evacuation. An incorrect comprehension was when the participants felt the shoulder was open for emergencies (i.e., vehicle breakdown, parking) or that the shoulder was the only lane to use during an evacuation.

Comprehension Results

Table 3-12 indicates the comprehension percentages for participants viewing each of the shoulder lane open sign options. This analysis indicates that 98 percent of the participants correctly interpreted the diagrammatic sign with a white panel. The diagrammatic sign (Option A) was also understood at a very high level with 90 percent correctly interpreting the information. The remaining two signs were not understood as well with 77 percent for the flashing beacon sign and 62 percent for the "open" text sign. However, the flashing beacon sign comprehension was not statistically different from 85 percent and therefore should not be dismissed from consideration for use.

Table 3-12. Percentage Comprehension of Shoulder Lane Open Signs.

Shoulder Lane Open Sign Options	Percent Correct
Diagrammatic Sign (n=61)	90
"Open" Text Sign (n=60)	62*
Flashing Beacon Sign (n=60)	77
Diagrammatic Sign with White Panel (n=60)	98

*is statistically different from 85 percent

As in the previous sections, when the participants were asked what action they would take, the data were divided into those that interpreted the signs as intended and those that did not. For the participants that correctly interpreted the signs, 100 percent indicated the appropriate action to take (i.e., either to stay in their current lane or use the shoulder). This percentage indicates that the sign recommendations should be based on comprehension rates, as a well understood sign will result in the appropriate actions.

Table 3-13 shows the responses of the participants when asked whether they could or could not drive on the shoulder. The participants all correctly responded that they could drive on the shoulder for the diagrammatic sign with a white panel. Additionally, 97 percent of the diagrammatic sign responses were correct. Again, the remaining two signs (flashing beacon sign and "open" text sign) resulted in confusion in the participant responses, with only 73 percent and 64 percent indicating that they could drive on the shoulder, respectively. Those that correctly stated that they could use the shoulder were then asked how they knew they could drive on the shoulder of this road. The majority responded because of the information provided on the sign.

The reasons participants stated for not feeling they could drive on the shoulder were as follows:

- The shoulder was for emergency stops only.
- It was illegal to drive on the shoulder.
- You could not cross the solid white line.

Table 3-13. Responses to the Question "Can You Drive on the Shoulder of This Road?"

Shoulder Lane Open Sign Options	Percent	
	Yes	No
Diagrammatic Sign (n=61)	97	3
"Open" Text Sign (n=60)	64	36
Flashing Beacon Sign (n=60)	73	27
Diagrammatic Sign with White Panel (n=60)	100	0

Preference

Again, each participant rated all of the options on how well they let drivers know that they could use the shoulder as an evacuation lane. The average rating for each alternative is shown in Table 3-14.

Table 3-14. Average Ratings for Shoulder Lane Open Signs.

Shoulder Lane Open Sign Options	**Average Rating** (1 – highest; 5 – lowest)
Diagrammatic Sign (n=421)	2.0
"Open" Text Sign (n=421)	2.5
Flashing Beacon Sign (n=421)	1.8
Diagrammatic Sign with White Panel (n=421)	1.9

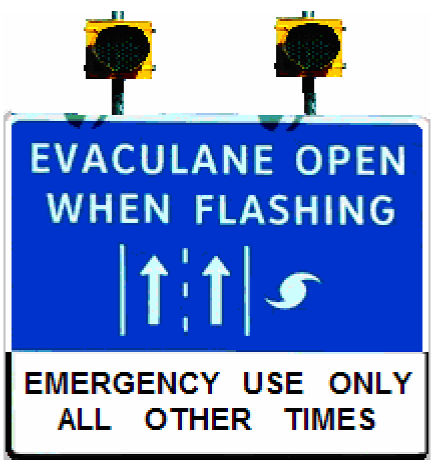
Three of the signs received a good rating of 1.8, 1.9, and 2.0; all of these ratings are essentially equal with regard to participant preference. The best rating of 1.8 was for the flashing beacon sign; however, the comprehension information for this sign was not as high as the diagrammatic options. Researchers believe this rating was influenced by the fact that the sign contained active flashing beacons. During the study administration, it was noted that the participants had a distinct preference for the flashing beacons with regard to their attention-getting effects, even if the understanding of this sign was not as high as other options. The diagrammatic sign with the white panel also had an excellent rating of 1.9. In this case, the rated preference for this sign clearly supports the higher understanding level for this option. This result is also echoed for the diagrammatic sign that was rated 2.0 and had a high level of comprehension. Equating well with the comprehension results, the "open" text sign was rated the lowest as well as having the lowest comprehension levels.

Recommendations

Results indicated that the two diagrammatic signs (with and without the white panel) were understood the best. However, it should be noted that there was not a statistically significant difference from the 85 percent comprehension criterion for the flashing beacon sign. In addition, participants rated this sign the best. Researchers feel that all of the sign options except the "open" text sign have a high enough comprehension level to be considered for use. However, researchers would recommend two alternatives based on comprehension and variety of situations that could be addressed with the alternatives. It is recommended that either the flashing beacon sign or the diagrammatic sign with the white panel be used. For the diagrammatic sign with the white panel, the sign could be fabricated as a flip down sign to be opened when the shoulder evacuation lane is open. During other times, the sign should be flipped up and not visible to approaching traffic. Additionally, when looking at alternatives for use on FM roads, any of these options could be altered for use on roadways with fewer lanes.

Shoulder Lane Closed Signs

Three signs were studied in the shoulder lane closed sign section. Figure 3-5 shows these three signs. Each sign was viewed by 60 participants.



A. Inactive Flashing Beacon Sign

B. Diagrammatic Sign

C. "Closed" Text Sign

Figure 3-5. Shoulder Lane Closed Signs.

As in the previous section, researchers asked each participant what information the sign provided to them and what action they would take in an evacuation. For this section the correct comprehension was the percentage of the participants who felt the shoulder was not open for evacuation at this time, but could be used for emergency purposes. Incorrect comprehension responses were those that felt the shoulder was open for moving traffic.

Comprehension Results

Table 3-15 shows the comprehension percentages for each of the shoulder closed signing alternatives. This table shows that the inactive flashing beacon sign was interpreted correctly by 92 percent of the participants. The comprehension levels of the other two alternatives were significantly lower with 72 percent correctly interpreting the “closed” text sign and 65 percent correct for the diagrammatic sign. Researchers noted that several of the participants were confused by the word “emergency” on the “closed” text sign indicating that emergency parking was available. These participants felt that an evacuation was an emergency so the sign seemed confusing to them.

Table 3-15. Percent Comprehension for Shoulder Lane Closed Signs.

Options	Percent Correct
Inactive Flashing Beacon Sign (n=60)	92
Diagrammatic Sign (n=60)	65
“Closed” Text Sign (n=60)	72

The action of those participants that understood the signs is shown in Table 3-16. The results indicate that all of the participants that viewed the inactive flashing beacon sign and the diagrammatic sign took the correct action. The “closed” text sign had some participants that were confused; again, researchers believe that these individuals felt that an evacuation was an emergency, and as such they should be able to travel on the shoulder lane. However, the majority of the participants (93 percent) did indicate the correct action.

Table 3-16. Action Taken by Participants.

Options	Action	
	Correct	Wrong
Inactive Flashing Beacon Sign (n=55)	100	0
Diagrammatic Sign (n-39)	100	0
“Closed” Text Sign (n=40)	93	7

When each participant was asked if they felt they could drive on the shoulder of this road, the results showed that participants viewing the inactive flashing beacons sign and the “closed” text sign responded correctly 93 and 88 percent of the time, respectively, as shown in Table 3-17. For the diagrammatic sign option, 67 percent of the participants stated that you could not drive on the shoulder, however one-third believed they could use the shoulder as a travel lane. This information further confirms that the diagrammatic sign was causing confusion for motorists.

Table 3-17. Responses to the Question "Can You Drive on the Shoulder of This Road?"

Options	Percent	
	Yes	No
Inactive Flashing Beacon Sign (n=60)	7	93
Diagrammatic Sign (n=60)	33	67
"Closed" Text Sign (n=60)	12	88

Preference

As explained earlier, researchers asked each participant to rate each option to determine which they preferred. All three options in this group were rated at essentially the same level of approximately 2.5, as displayed in Table 3-18. Based on this information, study participants indicated no clear preference. Therefore, all recommendations for sign application will be made based on the comprehension information.

Table 3-18. Average Ratings for Closed Shoulder Lane Signs.

Options	**Average Rating** (1 – highest; 5 – lowest)
Inactive Flashing Beacon Sign (n=421)	2.3
Diagrammatic Sign (n=421)	2.5
"Closed" Text Sign (n=421)	2.6

Recommendations

When looking at the closed signs the inactive flashing beacon sign was understood the best. This sign pair (flashing beacons active and inactive) is recommend for use to inform motorists as to whether the shoulder lane is available for use. However, the other two closed options did not have high enough comprehension levels to recommend their use. Researchers suggest that the equivalent open sign (i.e., diagrammatic sign with white panel) be fabricated as a flip sign so that the message would not be displayed to the motorist during a standard (i.e., shoulder lane closed) condition and that could be flipped open when the shoulder lane was in use for evacuation. This option would limit the confusion by drivers as to when the lane was active or what emergency use indicates on these signs.

End of Shoulder Use Signs

Figure 3-6 shows the three signs that were examined to let motorists know that a shoulder evacuation lane is ending and that they had two action options: to merge back onto the main lanes or exit the highway. The first sign studied is currently being used in the field. The next sign was developed based on the focus group results to address confusion as to whether the exit would lead to an evacuation route. In this case the hurricane symbol was placed in front of each arrow to indicate that it was an evacuation route. The last sign was also developed based on the focus group results to help motorists understand that they had two options to choose from at the end point.

Unfortunately, due to an error in the study design, the single arrow with hurricane symbols sign did not get tested for comprehension. However, it was included in the rating section for this group of signs. The single arrow sign was evaluated by 181 participants, and the double arrow sign was evaluated by 240 participants.

During this portion of the study, the participants were told to assume they were driving on the shoulder during an evacuation when they saw the signs. They were then asked what information the sign gave them and what action they would take. A correct comprehension response for this survey was that the shoulder was going to end, and the driver had two options — either exit the highway or merge back into mainlane traffic, both being evacuation routes.

A. Single Arrow

B. Single Arrow with Hurricane Symbols

C. Double Arrow

Figure 3-6. End of Shoulder Use Signs.

Results

Table 3-19 shows that the double arrow sign was better understood than the current single arrow sign with 80 and 75 percent, respectively. Both of the comprehension percentages are lower than the 85 percent criterion established; however, the difference between the 80 percent comprehension of the double arrow sign and 85 percent is not statistically significant. Additionally, the two comprehension percentages were not statistically different from each other based on a test of proportions. This analysis would indicate that either of these signs could be used at the termination point of a shoulder lane.

Table 3-19. Percent of Comprehension for End of Shoulder Use Signs.

Options	Percent
Single Arrow Sign (n=181)	75*
Double Arrow Sign (n=240)	80

*is statistically different than 85 percent

Table 3-20 shows the actions that participants would take. This analysis includes only those participants that correctly interpreted the given sign to further understand which would be the better alternative. The majority of participants in this group responded with an appropriate action, 95 percent for the single arrow sign and 98 percent for the double arrow sign.

Table 3-20. Action Taken by Participants.

Options	Action (percent)	
	Correct	Wrong
Single Arrow Sign (n=135)	95	5
Double Arrow Sign (n=193)	98	2

When asked if the sign had provided them with enough information to determine what action to take, the responses were split. For both signs the responses were split with half feeling that they needed additional information and half who did not. For both options the majority of those feeling that they needed additional information would have added where the exit would lead or which lanes were evacuation routes.

Preference

As explained previously, due to an error in the study design the single arrow with hurricane symbols sign was not tested in the comprehension section. However, this sign was included in the rating section of the survey. Table 3-21 indicates that average ratings for all three of the alternatives were grouped very closely between 2 and 3. This result would indicate that there is no clear preference for one sign over the other within this group. If any conclusions can be drawn, it is that there was a slightly lower preference for the double arrow sign; however, this is a very small difference.

Table 3-21. Average Ratings for End of Shoulder Use Signs.

Options	**Average Rating** (1 – highest; 5 – lowest)
Single Arrow (n=421)	2.3
Single Arrow with Hurricane Symbols (n=421)	2.1
Double Arrow (n=421)	2.8

Recommendations

The sign with single arrows with hurricane symbols had a slightly higher preference than the other options; however, without a comprehension study researchers cannot recommend its use in the field. The results for the comprehension study of the other two options indicated that both signs were comprehended equally well, and there was no significant difference in the actions people would take. Therefore, both of these options would be acceptable for use.

Pavement Markings

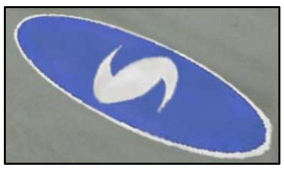
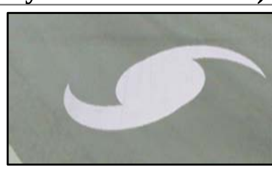
In this section, six different pavement marking symbols were reviewed. These symbols were being evaluated for use on the shoulder of major highways to let motorists know that during an active evacuation a shoulder lane is present that may be used as an extra evacuation lane. All options but one were viewed in one survey (60 participants). It was decided that the top/bottom orientation of the blue elongated symbol would be repeated because it was the only one of the options that was oriented in this direction. Therefore, it was viewed by 120 participants.

The participants viewed one of the pavement markings on the laptop computer and were told to assume they were evacuating when they saw the pavement marking. They were then asked what lanes they felt were available to drive in during the evacuation. To understand the participants' thinking regarding where they could or could not drive, researchers also asked how they knew what lanes were available to drive in and what additional information they would need to know that the shoulder was open as a travel lane during an evacuation.

The correct comprehension is the percent of participants that answer all lanes including the shoulder were available to travel in. Incorrect would be only the shoulder, and other lanes with no shoulder. *Comprehension Results*

Table 3-22 illustrates each pavement marking studied and the responses to the question on what lanes were available to drive in during an evacuation. Percentages for the correct response (all lanes including the shoulder) and two other responses are tabulated.

Table 3-22. Participant Responses to the Question "What Lanes Are Available for You to Drive In?"

Pavement Marking Options	Percent Response		
	All Lanes Including the Shoulder	Shoulder Only	Combination of Lanes without the Shoulder
 **Elongated Blue Symbol (n=60)**	74	12	14
 **Elongated Blue (Shifted Symbol Orientation) (n=120)**	69*	17	14
 **All-White Symbol (n=60)**	52*	30	18
 **Blue Elongated Symbol with Arrow (n=60)**	67*	22	11
 **Blue Elongated Symbol with Blue Rectangle Arrow (n=60)**	70*	23	7
 **All White Symbol with Arrow (n=60)**	73*	17	10

*is statistically different than 85 percent

The table indicates that the elongated blue symbol was comprehended the best with 74 percent. This comprehension level was not statistically different than the 85 percent criterion. However, all of the other options had comprehension levels that were statistically less than this criterion with the all-white symbol having the lowest comprehension of 52 percent.

When asked how they knew which lane(s) they could drive in, the majority of the responses for all three categories were that the symbol or pavement marking on the shoulder showed them where they could drive. There was a small portion from the category that felt that the shoulder was the only evacuation route where the participants stated that this was because that is where the symbol was located. There were no remarks on the color or the difference between the symbols with the arrow or without the arrow as to that being the information used by the participant to determine what lanes were available.

The participants were all asked if they needed any additional information to know that the shoulder was open as a travel lane during an evacuation. The participants for all options suggested additional signing to clarify this point.

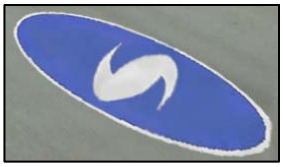
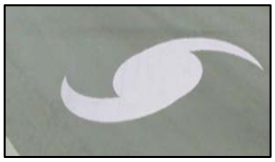
Preference

There was a somewhat different preference regarding color and the addition of arrows when the rating was conducted. Table 3-23 illustrates that the blue elongated symbol with arrow was rated the best with 2.1; however, this rating was closely grouped with the ratings for the elongated blue symbol, elongated blue with shifted symbol orientation, and elongated blue symbol with blue rectangle arrow. All of these ratings were between 2.1 and 2.6. The final two symbols, the all-white symbol with and without an arrow, were rated slightly lower than the blue symbols with ratings of 3.2 and 3.3, respectively. This rating would indicate that motorists do prefer the use of color for these symbols.

Recommendations

When it is necessary to convert the emergency shoulder to a temporary travel lane in an evacuation, researchers suggest using the elongated blue symbol. The study indicated it was comprehended the best as well as having the best preference rating. While the arrows were preferred in the rating, it did not appear to improve the comprehension of the symbol to motorists. However, due to the preference and essentially equal comprehension levels of the elongated blue options with arrows, these options would also be acceptable for use in the field.

Table 3-23. Percent of Hurricane Pavement Marking Average Rating.

Options	**Average Rating** (1 – highest; 5 – lowest)
 **Elongated Blue Symbol (n=421)**	2.2
 **Elongated Blue (Shifted Symbol Orientation) (n=421)**	2.6
 **All-White Symbol (n=421)**	3.3
 **Blue Elongated Symbol with Arrow (n=421)**	2.1
 **Blue Elongated Symbol with Blue Rectangle Arrow (n=421)**	2.5
 **All-White Symbol with Arrow (n=421)**	3.2

Contraflow Lane Signing

Researchers evaluated two signs for the identification of appropriate contraflow signing alternatives. The two sign options are shown in Figure 3-7.

A. Flashing Beacon Sign

B. Diagrammatic Sign

Figure 3-7. Contraflow Signing Options.

For these signs, researchers wanted to evaluate motorists' understanding of the contraflow operations as well as what action motorists would take. Additionally, researchers questioned participants to see if they could identify the distance ahead that was given as part of the sign. This further evaluation helped researchers to identify what information motorists were able to remember from the given signs.

The study design was laid out such that each of the participants saw only one of the two signs for comprehension. Due to the fact there was an odd number of surveys used for this study design, researchers decided to have the final survey evaluate Option A as it was an existing sign and therefore more critical to evaluate driver understanding. This decision resulted in an uneven number of participants evaluating each sign; however, each option did have a significant number of evaluations to be able to draw some strong conclusions regarding their understanding. For Option A, the number of participants evaluating the sign was 241 while Option B had 180 participants evaluating the sign.

Comprehension Results

The first analysis researchers undertook was to determine if participants were able to interpret the intended meaning of the sign, i.e., that the participant identified that the sign provided information regarding an upcoming area of contraflow lane operations. Table 3-24 shows the percentages of understanding for each option.

Table 3-24. Percent Comprehension of Contraflow Signing Options.

Interpretation	Option A: 	Option B: 
Understood Contraflow Operations	37%	47%
Split Traffic	20%	2%
Evacuation Route	23%	21%
Merge Left	1%	14%
Don't Know	3%	2%
Traffic Merging	1%	2%
Continue Ahead	2%	0%
Other	13%	12%

Note: No individual category within "other" contained more than 1 percent of responses.

As illustrated in the table above, the overall comprehension of the signs *as contraflow lane informatio*n was very low for both options. It should be noted that the difference between the two comprehension levels is statistically significant. Looking further at the responses, it cannot automatically be assumed that all of the other responses were misunderstandings. Particularly, the identification of a split in traffic by 20 percent of the participants for Option A was a correct interpretation of upcoming operations; however, it does not recognize that the split to the left would take vehicles into normally oncoming traffic (contraflow) lanes. Similarly, a significant percentage of participants (14 percent) who viewed Option B identified the information provided as they needed to move left. This is again not an incorrect identification of the given information. However, it does not identify all of the available options for traffic or that this is due to a contraflow operation that could be critical to a driver to avoid confusion at the crossover point.

A large percentage of the participants did identify that the sign was giving them information related to an evacuation route (23 and 21 percent, respectively). This identification is correct for the sign, however it alone does not provide researchers with enough information to determine if some or all of these participants recognized that the evacuation route contained contraflow operations.

The second analysis researchers undertook was to determine what action participants would take based on the sign shown. This analysis was first conducted on the responses from participants who were able to identify contraflow in the previous question. Researchers thought targeting these participants would most help decision-making in recognizing the typical reactions of drivers to a contraflow situation. The results for this analysis are provided in Table 3-25.

Table 3-25. Percent of Participants Taking an Action – Participants Understand Contraflow.

Action	Option A: 	Option B: 
Stay on the highway or in their lane	49%	15%
Use contraflow or go left	25%	68%
Select a route	10%	7%
Follow signs or arrows	8%	5%
Don't know	4%	5%
Evacuate	2%	0%
Exit	2%	0%

The above reactions to the sign alternatives both show that the use of contraflow signs would create a split in the stream of traffic if the signs were understood by drivers. However, the different alternatives created greater percentages of people making one choice versus the alternative based on how they were interpreted. For Option A, a greater percentage of participants indicated that they would stay on the original route than for Option B. Researchers attribute this difference to the fact that the first sign had straight ahead arrows that gave drivers a better understanding that this action was still a viable alternative in their travel where the second sign only showed traffic flow arrows moving to the contraflow lane. This use of arrows in Option B greatly increased the percentage of participants who indicated that they would use the contraflow lanes. This result indicates that arrows are a critical component of motorist decision-making when a decision point is approaching.

One interesting point is that when arrows were provided in both directions, a more even split of traffic would be expected given the drivers' actions. This is a very desirable result for a contraflow operation.

When drivers did not understand the signs to mean contraflow, the use of arrows again influenced their driving decisions; perhaps even more strongly than when they did understand the full meaning of the sign. Table 3-26 shows the indicated actions of the participants who did not interpret the signs to mean contraflow.

Table 3-26. Percent of Participants Taking an Action – Participants Do Not Understand Contraflow.

Action	Option A: 	Option B: 
Stay on the highway or in their lane	41%	9%
Use contraflow or go left	14%	67%
Follow signs or suggested path	16%	10%
Select a route	10%	2%
Don't know	7%	3%
Follow traffic	4%	1%
Slow down	1%	4%
Exit	2%	1%
Evacuate	2%	1%
Merge	1%	2%
Other	2%	0%

Note: No individual category within "other" contained more than 1 percent of responses.

Option B shows that the greatest percent of these participants (67 percent) would follow the arrows shown and go to the contraflow lanes. Conversely, in the first option, the participants selected what they thought would be the easiest or most familiar route and indicated that they would stay on their current highway. One additional note that researchers can draw from the information in this table is that the confusion of these participants is illustrated through several of their responses such as follow other traffic, following signs (but not being able to give a specific action or route), slow down, or simply that they did not know what action to take. This category of responses contains 32 percent of the responses for Option A and 19 percent for Option B. This again illustrates that the participants did not understand the concept of the signs. The presence of distinct arrows in Option B did lead to less confusion in deciding upon an action to take.

The final element of the contraflow lane signs that researchers evaluated was driver understanding of the distance that was included for how far it is to the start of the contraflow area. Only approximately 50 percent of the participants were able to tell the exact distance (two miles). In the cases where the participants were not able to correctly identify the distance given, researchers believe that this is a product of information overload for the driver with the given signs and not with the format of the information. Table 3-27 illustrates the responses given by the participants.

Table 3-27. Percent Comprehending Distance Message.

Distance	Option A: 	Option B: 
2 miles	58%	49%
Greater than 2 miles	0%	1%
Range including 2 miles (e.g., 1-2 mi.)	2%	0%
Mile designation, but less than 2	4%	4%
Short distance (ft, yd, or meter)	2%	2%
Near	1%	1%
Don't Know	33%	43%

Researchers evaluated the percent of participants who were able to recall the correct distance and found that although these numbers were 9 percent different, this was not statistically significant. However, researchers would note that the slightly increased value for option A may be attributable to the placement of the distance text on the sign. The inclusion of the distance within the central area of Option A may be slightly more noticeable than when it was placed at the bottom of the sign in Option B.

Preference

Researchers also asked participants to rate each message individually to determine which format they would prefer. For the contraflow messages there was no clear preference for one sign over the other. Both had an average rating of approximately 2 on the scale of 1 to 5.

Recommendations

Based on this information, researchers would recommend that signs being used for contraflow operations have arrows that clearly define all options for route decisions. Additionally, researchers believe that public education regarding the meaning of "contraflow" would greatly increase the effectiveness of this signing. Although many participants could identify that there was an upcoming split or decision point, the terminology was confusing or unfamiliar to them and therefore not as effective as would be possible given a familiar traffic operation.

CHAPTER 4. USE OF DYNAMIC MESSAGE SIGNS PRIOR TO HURRICANE EVENTS

One of the critical elements during a hurricane event is the dissemination of information to the public to ensure that people are able to safely and effectively evacuate or make decisions regarding staying in an area. Dynamic message signs are a critical tool in providing drivers with information both during an active evacuation and prior to the occurrence of a hurricane event.

During this research, investigators were interested in identifying information that could be provided through DMS prior to the time that a hurricane makes landfall. This time period was broken into four different information phases where drivers may desire different types of information to make them feel comfortable with their travel decisions. These stages are:

1. All season or once a hurricane is in the Gulf but still with indeterminate landfall expectations.
2. Prior to a formal hurricane evacuation being called, but a threatened area is determined.
3. Once a formal evacuation has been issued.
4. No longer safe to start to evacuate (within a few hours of expected landfall within the area).

Within each of these categories, researchers have identified different pieces of information that would be appropriate to use to help the public feel comfortable regarding the current situation. In many cases there is overlap between the categories regarding this information; however, there are some distinct needs that are specific to each. The following sections will discuss the information that would be appropriate during each stage and provide some example messages.

The information that was used for the development of the information categorized was derived from previous experience with dynamic message sign design and from the focus groups conducted previously for this project.

STAGE 1: ALL SEASON OR PRIOR TO THREAT

This first category of information would be the most general of all of the different stages. In this case the information is more along the lines of a public service announcement (PSA) message that would provide people with education regarding planning or expected traffic operations that may not be familiar to the public. Messages could contain information regarding the following:

- Determine safe evacuation routes inland.
- Suggest ridesharing options.
- Check vehicle maintenance.
- Fill vehicle gas tank.
- Know your emergency broadcast network.

- Be educated on traffic operations:
    - contraflow lanes,
    - shoulder lanes, and
    - where to get information regarding designated evacuation routes.

This type of information was identified because it provides drivers with ideas of actions they can take long before a hurricane event. Through the provision of this information, TxDOT can facilitate a more efficient evacuation if the time arises because the traveling public will be better informed and prepared. Table 4-1 provides example messages that are applicable to Stage 1. The use of several of these message ideas would allow public officials to select from or program a variety of information for the DMS messages. This variety will minimize the public feeling that there is never new information provided to them and make them more vigilant in watching the DMSs for changing information. Previous research has indicated that drivers would like the messages to be changed daily *(3)*. This variety is a critical component of keeping a positive public opinion regarding the use of DMSs.

In Message 7, there is a placeholder where a phone number should be inserted as appropriate to the area of the evacuation. Thought will need to be given to what agency or group this number should be directed to, as well as the format the number should take. Previous research has shown that the recall of long telephone numbers (i.e., standard 800 numbers) is difficult for drivers. In this research, it was suggested that the use of an acronym for the telephone number would make it easier to recall. Researchers would recommend a number such as 1-800-4-A-ROUTE as an alternative to an all number indicator. This research also evaluated the ability of drivers to recall 511 as a telephone number and found that this was much easier to remember than a longer telephone number. Alternatively, consideration should be given to modifying the current 511 system such that it could provide this information for a given area or county to a caller *(3)*. This information would apply to messages in all stages where a telephone number is indicated.

STAGE 2: PRIOR TO FORMAL EVACUATION

There is a critical informational time for drivers when a hurricane has been forecasted as a possibility for their area, but before it is necessary to call a formal evacuation of the region. Drivers can experience a great deal of anxiety during this time regarding what their actions should be to prepare for a hurricane. During this time researchers feel the following types of information would help to ease the fear by providing them with information that they can act upon or use in their planning process. The following are suggestions for message content during this time.

- Remind people to pack a map of the state and local area in case of evacuation.
- Include information regarding designated evacuation routes.
- Provide ridesharing suggestions.
- Give contact information for Red Cross shelters.
- Provide the emergency broadcast station to use for current weather or evacuation conditions.

Table 4-1. Stage 1 Example Messages.

	Message 1	
Phase 1		Phase 2
HURRICANE SEASON IS HERE		DO YOU KNOW YOUR EVACUATION ROUTE?
	Message 2	
Phase 1		Phase 2
HURRICANE SEASON IS HERE		MAKE AN EVACUATION PLAN
	Message 3	
Phase 1		Phase 2
HURRICANE SEASON IS HERE		PLAN TO RIDESHARE WITH FAMILY OR NEIGHBORS
	Message 4	
Phase 1		Phase 2
HURRICANE SEASON IS HERE		RIDESHARING REDUCES EVACUATION TRAFFIC
	Message 5	
Phase 1		Phase 2
HURRICANE SEASON IS HERE		IS YOUR VEHICLE MAINTENANCE UP TO DATE?
	Message 6	
Phase 1		Phase 2
HURRICANE SEASON IS HERE		YOUR EMERGENCY BROADCAST NETWORK IS XXXX AM
	Message 7	
Phase 1		Phase 2
HURRICANE SEASON IS HERE		EVACUATION ROUTE INFORMATION CALL <phone number>

The essential consideration during this stage is that drivers are not being told to react in a specific way, but are being provided with ideas as to how they can prepare and information they can use later if an evacuation becomes necessary. Table 4-2 provides examples of messages that could be used during this time stage.

Table 4-2. Stage 2 Example Messages.

Phase 1		Phase 2
Message 1		
Phase 1		Phase 2
HURRICANE IN GULF		YOUR EMERGENCY BROADCAST NETWORK IS XXXX AM
Message 2		
Phase 1		Phase 2
HURRICANE IN GULF		PLAN TO RIDESHARE WITH NEIGHBORS OR FAMILY
Message 3		
Phase 1		Phase 2
HURRICANE IN GULF		RIDESHARING REDUCES EVACUATION TRAFFIC
Message 4		
Phase 1		Phase 2
HURRICANE IN GULF		EVACUATION ROUTE INFORMATION CALL <phone number>
Message 5		
Phase 1		Phase 2
HURRICANE IN GULF		REMEMBER TO TAKE MAPS IF EVACUATING
Message 6		
Phase 1		Phase 2
HURRICANE IN GULF		CHECK YOUR EVACUATION SUPPLIES
Message 7		
Phase 1		Phase 2
HURRICANE IN GULF		RED CROSS SHELTER INFORMATION CALL<phone number>
Message 8		
Phase 1		Phase 2
HURRICANE IN GULF		NEED SPECIAL TRAVEL ASSISTANCE? CALL 211

STAGE 3: DURING FORMAL EVACUATION

Once a formal evacuation has been announced for an area, information becomes less general or planning related and more about immediate conditions or sources of critical information to the traveler. However, there may still be a place for limited PSAs as someone is driving through a less congested or altered operations area where they would be surprised to find a blank DMS given the current emergency situation. The information suggestions for this stage include the following:

- Post that a formal evacuation is currently underway.
- Remind drivers to take a map of the state and local area.
- Give contact information for Red Cross shelters.
- Encourage ridesharing.
- Inform drivers of gas availability (if this becomes an issue).
- Provide information regarding shoulder or contraflow lanes (if they are enacted).
- Furnish emergency broadcast station to use for current weather or evacuation conditions.

Table 4-3 provides examples of PSA messages that could be of assistance to drivers during an evacuation situation.

Table 4-3. Stage 3 Example Messages.

	Message 1	
Phase 1		Phase 2
HURRICANE EVACUATION IN PROGRESS		TAKE STATE AND LOCAL MAPS
	Message 2	
Phase 1		Phase 2
HURRICANE EVACUATION IN PROGRESS		RIDESHARE WITH NEIGHBORS OR FAMILY
	Message 3	
Phase 1		Phase 2
HURRICANE EVACUATION IN PROGRESS		RIDESHARING REDUCES EVACUATION TRAFFIC
	Message 4	
Phase 1		Phase 2
HURRICANE EVACUATION IN PROGRESS		FUEL AVAILABLE NEXT EXIT

Table 4-3. Stage 3 Example Messages (continued).

Message 5		
Phase 1		Phase 2
HURRICANE EVACUATION IN PROGRESS		NEXT FUEL AVAILABLE EXIT XXX
Message 6		
Phase 1		Phase 2
HURRICANE EVACUATION IN PROGRESS		NEXT FUEL AVAILABLE XX MILES
Message 7		
Phase 1		Phase 2
HURRICANE EVACUATION IN PROGRESS		RED CROSS SHELTER INFORMATION CALL<phone number>
Message 8		
Phase 1		Phase 2
HURRICANE EVACUATION IN PROGRESS		DO NOT STOP ON SHOULDER

DMS messages related to the closure of roadways or travel lanes, route diversions, travel times, etc., are essential during this stage. These messages should be developed specific for a given situation using existing guidance provided in the *Dynamic Message Sign Message Design and Display Manual* (4). In addition, simplified messages for portable changeable message sign (PCMS) use for general warning and lane closure situations are available in the *Development of a Field Guide for Portable Changeable Message Sign Use in Work Zones* report (5). Given the abundance of guidance already existing for these types of messages, they will not be directly addressed in this report.

STAGE 4: NO LONGER SAFE TO START AN EVACUATION

The final stage that will be reached prior to a hurricane making landfall in an affected area will be when it is no longer safe for remaining citizens to begin an evacuation from the area. During this time, if people are still driving it becomes essential to provide them with information as to how they should react to this situation. The following information is recommended for messages during this time:

- Remind citizens to stay indoors.
- Suggest they return home or to go to the nearest shelter.
- Give contact information for local shelters.
- Warn drivers regarding unsafe conditions.

As with the information in the previous stage, the information in Stage 4 provides drivers with information that will affect their immediate actions. This stage is aimed at improving people's safety once a hurricane becomes an imminent event. Table 4-4 illustrates example messages for this stage.

Table 4-4. Stage 4 Example Messages.

Message 1		
Phase 1		Phase 2
HURRICANE LANDFALL SOON		SEEK SHELTER NOW
Message 2		
Phase 1		Phase 2
HURRICANE LANDFALL SOON		GO TO NEAREST SHELTER
Message 3		
Phase 1		Phase 2
HURRICANE LANDFALL SOON		LOCAL SHELTER INFORMATION CALL <phone number>
Message 4		
Phase 1		Phase 2
EXTREME WIND WARNING		SEEK SHELTER NOW

ABBREVIATIONS

Within the human factors survey described in Chapter 3, researchers evaluated abbreviations to determine driver comprehension of different phrases for use on DMSs during a hurricane evacuation. Researchers included abbreviations as part of the survey design due to the fact that much of real-time information being provided for a hurricane will need to be able to be used on a PCMS. The information capacity of a PCMS is very limited. There are typically three lines on a stage, and each of those lines has eight characters. For this application, researchers wanted to evaluate driver comprehension of specific words or phrases that may be common within evacuation information. The abbreviations evaluated were:

- EVAC TRAF (evacuation traffic),
- EVAC RTE (evacuation route),
- EVAC SHELTER (evacuation shelter),
- TO SHLTR (to shelter),
- FUEL AVAIL (fuel available),
- CONTRA LANE (contraflow lane), and
- CON-FLOW (contraflow lane).

Study Design

The first three of the above abbreviation phrases looked at the use of an abbreviation for the term "evacuation" along with different prompt words. The forms for "traffic" and "route" used in these phrases as prompt words are abbreviations that have previously been evaluated for use on DMSs and had been found to have an acceptable comprehension level (*6*). Within the survey, each participant evaluated one of these three phrases. Additionally, each participant evaluated the abbreviation for "shelter" and the phrase "fuel available" to determine comprehension. The abbreviation for "available" was taken from current TxDOT evacuation management plans. Finally, researchers had participants evaluate one of two abbreviations for "contraflow." The first of these abbreviations had the prompt word lane as a typical application; however, researchers also wanted to evaluate an abbreviation option that would fit upon one line of a PCMS and therefore created the second "contraflow" abbreviation in this study.

Results

Abbreviations are considered acceptable for use on DMS or PCMS when 85 percent or greater of the study participants correctly interpreted the word/phrase abbreviated. This threshold is a common criterion for acceptable driver comprehension of message elements.

Evacuation

The first abbreviation that was considered was for the term "evacuation." Table 4-5 contains the comprehension rates for each of the three phrases used to evaluate this abbreviation.

Table 4-5. Evacuation Abbreviation Comprehension.

Original Phrase	Abbreviation	Comprehension Percentage
Evacuation traffic	EVAC TRAF	98%
Evacuation route	EVAC RTE	87%
Evacuation shelter	EVAC SHELTER	99%

As illustrated in the table above, all of the different formats for the evacuation phrase were understood at greater than 85 percent. Therefore, any of these forms are acceptable for use on DMSs. Additionally, the abbreviation for evacuation seems to be very well understood regardless of the prompt word used with it and therefore would be expected to result in acceptable comprehension levels within other situations or phrases as well. This understanding is illustrated well within the results of the evacuation route phrase. The table above shows the comprehension of the entire phrase; however, the term evacuation alone in this message was understood by 97 percent of the participants (much more in line with the other two phrases). The route portion of this message was the less understood element of the phrase.

Shelter

The second term to be evaluated for abbreviation was "shelter." This phrase was shortened to fit within the space limitations of a single line of a PCMS. Unfortunately, the abbreviation TO SHLTR was understood by only 78 percent of the study participants. Using a confidence interval test, this percentage was found to be statistically different than 85 percent. Therefore, this abbreviation is not acceptable for use.

Fuel Available

One of the primary concerns of motorists during previous evacuations was the availability of fuel at a given exit. Therefore, the current TxDOT evacuation plans have provided for the use of PCMSs where needed to provide information regarding fuel availability. From these plans, researchers found a need to evaluate the abbreviation FUEL AVAIL to ensure that motorists would correctly interpret the intended meaning of the message. For this abbreviation, there was a comprehension rate of 98 percent. This means that the given abbreviation is acceptable for use on DMS messages.

Contraflow

The final term that was evaluated for abbreviation was “contraflow.” Researchers evaluated this term in two different forms, one with a prompt word to try and increase expected comprehension and the second in a format that would fit on a single line of a PCMS (i.e., having eight or fewer characters). Table 4-6 contains the comprehension percentage for each of these abbreviations.

Table 4-6. Contraflow Abbreviation Comprehension.

Original Phrase	Abbreviation	Comprehension Percentage
Contraflow lane	CONTRA LANE	21%
Contraflow	CON-FLOW	22%

The table shows that both of these abbreviations had extremely low comprehension levels and therefore would not be acceptable for use in messages. A very telling finding of the motorists’ interpretation was that the most commonly given response was “don’t know” for both of the abbreviations at 53 and 36 percent, respectively. Researchers believe that much of the misinterpretation of these abbreviations is due to the fact that motorists are not familiar with the term “contraflow” more than an incorrect interpretation of the given abbreviation. As with the contraflow static signing that was evaluated within the survey (Chapter 3), the use of public education regarding this term is needed prior to being able to identify an abbreviation that would be possible for use.

CHAPTER 5. SIGNAL OPERATIONS FOR EVACUATION

DEPARTMENT OF TRANSPORTATION PHONE INTERVIEWS

Researchers directly contacted state traffic operations personnel in each Gulf of Mexico or Atlantic coastal state that regularly experiences hurricanes in order to obtain information regarding signal operations practices during hurricane evacuation events. In the case of the state of Texas, researchers contacted all five coastal districts of the Texas Department of Transportation. Findings from each phone interview are summarized below and an overall summary of different state's practices are found at the very end of this section.

Alabama Department of Transportation

To date there is no unifying state or department of transportation (DOT) policy for how agencies man or operate signalized intersections are manned or operated during hurricane evacuation events. In general, past experience has identified where problems have occurred and staff from local agencies, the state DOT, and law enforcement have developed means to best accommodate evacuation traffic. Typically, local law enforcement assumes manual control of critical intersections (and places signal operations on flash) to move traffic through the many local jurisdictions to reach major state routes. Signals along state routes, such as State Route 59, are typically left in everyday operating mode to maintain a steady flow onto Interstate Highways 10 and 65, which carry the evacuating traffic away from the coast. If complex or route-critical issues emerge they are handled by law enforcement and/or DOT staff because these agencies are able to respond (*7*).

Florida Department of Transportation

Florida DOT went through an assessment and exercise of hurricane evacuation concerns and activities in 1999 and identified critical intersection assignments for state and local law enforcement officers. In each case, the responsible officer assumes manual control of the intersection (either by manual/pushbutton override or flagging) and accommodates evacuation traffic until either the demand has been served or the officer determines the situation is unsafe due to the approaching storm. This situation is complex in terms of administration and decision-making since local agencies/municipalities have administrative responsibilities for the intersections in their jurisdiction. Centralized control may be technically possible, but is unlikely to be practical since these agencies will want to have awareness of what is going on at their intersections before making decisions about their operation. The current method of officer control establishes on-site administration and is immediately dynamic to site and evacuation route needs. Centralized control implies large scale monitoring and preparation which, even if thorough, may not be able to quickly accommodate changes in storm and evacuation patterns (*8*).

Georgia Department of Transportation

Georgia DOT's practices for operation of traffic signals during hurricane evacuation events have been dictated by experience over time. In the early stages of evacuation, especially in situations where there is sufficient advance warning, traffic signals are either put in flash mode or turned off, and law enforcement helps manage critical locations. In later stages of evacuation and/or when warning time is short, signals are placed in flash mode or deactivated and right-of-way is wholly provided for evacuating traffic. In Georgia's experience, many signalized intersections are without power, especially in the later stages of evacuation, and the only practical concern is moving as much traffic inland as quickly as possible. In light of this concern, and the fact that local traffic is minimal or nonexistent during evacuation events, route preference and capacity is wholly dedicated to evacuation (*9*).

Louisiana Department of Transportation and Development

The Louisiana Department of Transportation and Development employs a variety of methods to provide traffic control along evacuation routes with signalized intersections. In more populated areas where there is interconnection between signals, a hurricane timing plan is employed that devotes approximately 90 percent of the signal green time to evacuating traffic. Signals at some minor intersections are put on flash with flashing yellow to the evacuation route, but state staff has noted some driver tendency to stop despite the fact that the condition is yellow flash (i.e., caution rather than stop). Law enforcement is deployed at locations where flash is used but more positive traffic control is necessary.

The state has been experimenting with battery backup on intersections with light emitting diode (LED) indications and using portable generators to provide backup power at some signals. The basic practice for power outage at minor locations is to simply use stop signs on the minor streets or have local law enforcement direct traffic. The US Highway 61 corridor, which parallels Interstate 10 (I-10) from New Orleans to Baton Rouge, is viewed as an emergency responder and supply line when I-10 is placed into contraflow mode for increased evacuation capacity. Some intersections along this route are already remotely monitored and controlled, and more intersections will fall under centralized monitoring and control as the telecommunications system is expanded in the future (*10*).

Mississippi Department of Transportation

Mississippi is using a "stair step" approach in terms of the signals and communities located along US 49 between I-10 in Gulfport and I-20 in Jackson. Prior to Hurricane Ivan (September 2004), there was no organized and centralized approach to how traffic signals along US 49 would be handled to accommodate traffic evacuating Mississippi's coastal areas. Since Ivan and delays that were observed along US 49 during its evacuation effort, the state Department of Transportation (DOT) worked with the local municipalities and law enforcement agencies to provide enforcement officers with a "stop/go" switch for each traffic signal. This control flexibility allows the officer to control when cross- street traffic has right-of-way, but primarily provides through green to US 49 (evacuation) traffic. Since this approach has been taken, the delays observed during the Ivan evacuation have not been experienced with more recent hurricane evacuation efforts (i.e., Rita, Katrina). The state is currently working on a statewide communications system, which may centralize traffic control approaches and technologies in the future (*11*).

North Carolina Department of Transportation

Typical practice for signals in North Carolina during evacuation events varies depending on the control capability at each intersection. Along evacuation routes whose signals are part of a (coordinated) closed system, an evacuation timing plan is put into effect that runs long cycles and devotes the vast majority of green time to evacuation routes. Every attempt is made to maintain progression for increased capacity rather than resorting to yellow/red flash or manual control by law enforcement. At isolated intersections, hurricane timing plans are put into effect if available within the controller; otherwise the intersection is either put on flash and monitored or manually advanced by law enforcement. Where interchanges are found along I-40, which can be placed into contraflow mode for evacuation, interchanges either run an evacuation timing plan or are monitored and controlled by law enforcement. North Carolina is adopting a practice of using metal poles for signalized intersections in coastal areas in order to reduce downed heads and recover more quickly from hurricane events (*12*).

South Carolina Department of Transportation

South Carolina DOT's approach to signals along evacuation routes is to have law enforcement assume control over major intersections and to use either flashing operation or long green times with some monitoring of lower-volume intersections by either local DOT staff or law enforcement. Depending on location, the law enforcement presence may be either local officers or highway patrol. Every effort is made to keep law enforcement "out of the street" to avoid motorists' reactions of slowing down in response to officer presence, though manual control of intersections remains the final method of control if volumes become too high or problems emerge (*13*).

Virginia Department of Transportation

There is currently no statewide policy for how the Virginia DOT operates its signals under evacuation conditions. However, the approach in the southeastern portion of the state (which is most susceptible to hurricanes) is to provide remote monitoring and control of signals along evacuation routes. Video monitoring allows real-time assessment of queuing, and signal timing can be adjusted remotely, as needed, to accommodate heavy (evacuation) movements. At locations where the evacuation route places a large volume where such a volume is not typical (i.e., through a left turn), temporary lane assignment changes are made, and law enforcement is on-site to monitor conditions. Power outages are not a concern during the evacuation stage since there is typically sufficient advance warning. Urbanized areas are monitored more heavily than rural areas, and in some cases safety/service patrols are planned for higher volume evacuation routes. Approximately 30 signals are remotely monitored and controlled in the southeast part of the state during evacuations, and signal timing is oriented toward a "one approach" logic providing green time to evacuating traffic (*14*).

Texas Department of Transportation – Beaumont District

According to the Texas Department of Public Safety's evacuation plan, each signalized intersection's controller cabinet is equipped with an enforcement access panel whereby the intersection can be placed into either a flashing yellow/red mode or a green dwell mode for evacuating traffic. Which mode is used is determined by law enforcement present at the site, and the DPS evacuation plan has agency assignments (among local, county, and DPS enforcement staff) for each intersection along evacuation routes. At select locations law enforcement may assume manual control over the intersection to accommodate a special geometric condition or handle site-specific concerns or queuing (*15*).

Texas Department of Transportation – Corpus Christi District

Along major corridors, the Texas Department of Transportation Corpus Christi District will have law enforcement at major intersections. Intersection coverage is previously arranged among local, county, and state DPS enforcement staff. Typical practice is to use long cycle lengths with long green times for evacuating traffic and, if possible, to have DOT staff on-site to make timing adjustments. If evacuation demand exceeds the capacity of cycling operations, the signals will be turned to flashing operation with yellow for evacuating traffic and red for cross streets. In the urbanized area of Corpus Christi, intersection and interchange operations will be typical peak plans to accommodate high demand, with exceptions for any intersections that need to be manually operated (by law enforcement) to accommodate contraflow plans (*16*).

Texas Department of Transportation – Houston District

The plan for signal control along major routes serving as evacuation routes through the TxDOT Houston District is to have law enforcement manually control the intersections. In this case, law enforcement would be a combination of local (municipal), county sheriff's department, and state DPS officers. In some cases, especially at lower-volume intersections, the intersection may simply be placed on flash with yellow serving evacuating traffic and red for the cross street.

In its development of hurricane evacuation contraflow plans for Interstates and US highways in the Houston District, DOT staff identified several locations where one-way frontage roads (FR) would need to carry opposite-direction traffic. At all such locations law enforcement officers will manually control the interchanges during evacuation events. For frontage road operations in the direction of evacuation, officers will make the decision to operate in yellow/red flash or manually control the interchange. A unique idea suggested to Houston District staff, though one that has not been tested, is to utilize flashing green in place of yellow for evacuating traffic. This idea was intended to improve capacity for evacuation lanes since drivers were often perceived to slow down and hesitate before passing through the intersection along an approach controlled by a flashing yellow indication (*17*).

Texas Department of Transportation – Pharr District

The TxDOT's Pharr District uses a variety of methods for signal operations during evacuations. In general, lower volume and/or more rural signals are either operated with a long cycle time and large proportions of green time devoted to evacuating traffic or placed on flash with yellow flash allowing evacuating traffic the right-of-way. At some locations where this approach may not render the highest capacity for evacuating traffic, such as locations where evacuating traffic must turn, local or state law enforcement may assume (manual) control of those signals. Higher-volume signalized intersections along evacuation routes, especially those in more urbanized areas, are manually controlled by law enforcement.

Though the local communities of Brownsville and Harlingen have jurisdictional responsibility over signals within their communities, the basic approach along the primary evacuation route – US 83 and US 83/US 77 – is to place the diamond interchanges along the freeway (which may be contraflowing during evacuations) into flashing yellow service for westbound (WB) (evacuating) traffic. Once evacuating traffic is west of the Rio Grande Valley's more populated areas, typical practice will be to have US 83 signals run long cycles with the majority of green time for evacuating traffic (*18*).

Texas Department of Transportation – Yoakum District

The Yoakum District's signal approach is in concert with evacuation plans put forth by the local district of the Texas DPS. In essence, signals are placed on flash with yellow flash servicing evacuating traffic. In locations where yellow/red flash is not the default flash mode, an "evacuation switch" has been installed in the controlled cabinet to allow law enforcement to rapidly switch into evacuation flash mode (i.e., yellow flash to evacuating traffic). Depending on location, and again in concordance with DPS's evacuation plan, either DPS troopers or local law enforcement (city or county) will patrol signalized locations along the evacuation routes and will assume manual control if site-specific problems emerge (*19*).

Phone Interview Summary

As is clearly the case in evacuation traffic control situations, researchers found that the primary traffic control concern for state department of transportation personnel was accommodating the heavy demand along evacuation routes. The research team summarized the various states' responses into the following four primary evacuation control methods for signalized intersections:

- flashing operation (almost always yellow/red flash favoring evacuation routes),
- direct control by law enforcement (either manual advance of signal controller or manual control),
- peak direction plan used all day (favoring evacuation demand), and
- maximum cycle of controller (maximum green to evacuation demand).

The most typical practice among the states interviewed was for local (municipal), county (sheriff's department) or state (department of public safety) law enforcement to either assume manual advance control over the traffic signal or to effectively or actually shut down the signal and control traffic by hand. The next most frequent practices were transferring signals to flashing mode – typically to have yellow flash on the evacuation route – or using a special evacuation timing plan. Other than Texas, whose results are found in a separate table, the results for each hurricane-prone coastal state are found in Table 5-1. Review of Table 5-1 reveals that there is a fair amount of consistency in the way states address the bulk traffic concerns of hurricane evacuation using traffic signals. Where available, states utilize improved infrastructure in terms of remote monitoring and remote signal timing plan changes to accommodate evacuation demand.

Table 5-2 contains the traffic signal control practices for TxDOT coastal districts during evacuation events. Again, consistency in practices is noted, and the districts are utilizing a variety of methods to respond to signalized intersection high-demand concerns depending on where their signals are located. Conversion to flashing mode or enforcement officer manual control of signals is typical in smaller communities, remote locations, and where evacuation routes deviate from typical higher-volumes routes. Regular peak period timing plans are used in some locations where an AM or PM peak plan coincides with the route used by evacuating traffic, and evacuation timing plans are used where available and appropriate.

Table 5-1. Current Evacuation Traffic Signal Practice in Coastal US States.

Evacuation Signal Mode of Operation	AL	FL	GA	LA	MS	NC	SC	VA
Flashing (yellow to evacuating traffic)			✓	✓		✓	✓	
Enforcement Manual Control	✓*	✓*	✓*	✓	✓	✓	✓*	
Appropriate Regular Plan	✓							✓
Special Evacuation Plan				✓**		✓	✓	✓**
Maximum Cycle						✓	✓	

* Critical intersections; ** Remote monitoring

Table 5-2. Current Evacuation Traffic Signal Practice in Coastal TxDOT Districts.

Evacuation Signal Mode of Operation	Beaumont	Corpus Christi	Houston	Pharr	Yoakum
Flashing (yellow to evacuating traffic)	✓	✓	✓	✓	✓
Enforcement Manual Control	✓*	✓*	✓*	✓*	✓*
Appropriate Regular Plan		✓			
Special Evacuation Plan	✓	✓	✓	✓	✓
Maximum Cycle		✓		✓	

* Critical intersections

Despite some expectation from the research team that there were "best practices" to be found regarding the operation of traffic signals for evacuation events, researchers actually found that evacuation signal control practices are heavily influenced by past experience and the technology each agency had available. Some agencies, such as the South Carolina DOT, had concerns that motorists tended to slow down for enforcement officers perceived by motorists while other states maintained that the best evacuation operations resulted when law enforcement was present at the roadside. And, while the Texas DOT's Houston District had concerns that motorists tended to hesitate at intersections where flashing yellow was used, many states have flashing yellow as their typical signal control mode along evacuation routes.

Researchers noted from several interviews that one of the benefits of having various signal control options available during hurricane evacuations increased the likelihood that either flashing yellow/red operation, a typical peak timing plan favoring evacuating traffic, or a special plan or long cycle prioritizing evacuating traffic would be able to provide signalized intersection traffic control without requiring law enforcement presence. Thus, at locations where enforcement officers were not otherwise needed due to unusual conditions or historic experience that seemed to necessitate officer presence, the use of traffic signal control freed officers to either provide evacuation support in other areas/ways or assume an oversight and troubleshooting role along evacuation routes.

A final review of high-volume traffic signal operations practices led researchers to conduct a few informal interviews and/or site reviews of signals proximate to major sporting venues. At both major league sporting events and around the Texas World Speedway signal operations and enforcement practices are consistent with those employed for hurricane evacuation and reported herein. Special timing plans are used when available and enforcement officers assume a manual signal controller advance or complete manual operation of intersections perceived to be experiencing unusually high event-related demand. In some cases, enforcement control over the signalized intersection is routine as a result of experience borne out over time.

CHAPTER 6. DATA NEEDS FOR EVACUATION AFTER-ACTION REVIEW

In the aftermath of a hurricane evacuation, there is an opportunity to review the events and learn lessons for future events. Steps toward an effective after-action review include the following:

- Identify transportation system monitoring elements which would allow TxDOT to monitor and evaluate roadway system operational performance for evacuation scenarios as well as for normal traffic days.
- Outline the usefulness of both ITS and non-ITS technologies for data collection.
- Discuss the use of and comparisons between traditional data collection processes (e.g., manual counts, road tube based equipment, and inductive loop systems) and emerging technologies (e.g., video-based and radar-based systems).
- Investigate existing state-of-the-practice technologies in real-time data collection as well as communication, storage, and presentation methods for evacuation routes.
- Prepare a detailed proposed data collection program on hurricane evacuation routes considering primary and secondary routes.

IDENTIFICATION OF TRANSPORTATION MONITORING ELEMENTS

From a traffic engineering perspective, the evacuation of an urban area in anticipation of the expected landfall of a major hurricane requires the cooperation and coordination of regional and statewide agencies in developing a plan to allow for the movement of the highest number of vehicles in the most efficient manner from the area expected to be impacted. Historically in Texas, public shelters were provided in large urban areas such that the distance required for evacuation was minimized; for example, shelters were available in the Houston urban area to accommodate those leaving the coastal regions of Brazoria, Chambers, and Galveston counties. The current plan does not provide for any public shelters in Houston, but rather in cities located several hundred miles from the coast. This plan requires longer travel by evacuees along roadways primarily in the rural regions of the state. While most evacuation plans are designed to provide direction to special needs populations and those needing public shelters, the majority of evacuees have destinations of relatives, friends, or hotel/motel lodging in other cities. As the general population will begin its individual evacuation at different times, it is difficult to accurately predict traffic demands and peaking properties along evacuation routes. In order to assure that the evacuation proceeds as smoothly as possible, current information on traffic conditions is necessary along evacuation routes. The availability of information regarding current traffic demands, travel speeds, and incidents is important for traffic engineers to be able to make informed decisions to facilitate any evacuations.

Prior to making choices on the desired equipment to measure the traffic conditions, it is important to determine the types of data that are necessary to collect the needed traffic information elements as well as how the data are to be utilized by the intended audience. How the data are to be provided to emergency managers is critical in the design of a traffic management system that is geared for evacuation scenarios. Essentially the system should be designed from the desired audience outward to the field devices; the selection of the field devices should be based upon the information needed. If the region has an operating traffic management center, the resources of the center should be used to facilitate dissemination of the traffic information. The following are some examples of specific elements to first consider in terms of data distribution:

- Is the traffic information being made available to the public/media or only emergency and traffic management officials during evacuations?
- What are the capabilities of law enforcement to receive and react to information and guidance from traffic management officials?
    - Do local and statewide law enforcement have Internet access while in the field via smart phones and/or laptop computers while assisting in evacuation traffic control?
    - What is the communication protocol between traffic managers and law enforcement?
    - How receptive is law enforcement to follow traffic management guidance as recommended by traffic engineers?
- Does the region's evacuation plan include contraflow operations on any roadways?
- Is the region an area to be evacuated, a "pass through" area, or a destination of a population of evacuees?
- What are the communication technologies available in the region between field devices and traffic managers; i.e., does it rely on in-ground fiber networks or wireless technology?

Once all of the above items pertaining to the region have been identified and appropriately addressed, the next step is determining the type of data to be collected. In most cases, standard traffic flow information such as traffic volumes, speeds, and occupancy rates will provide sufficient data for traffic managers to monitor traffic operations and to make informed decisions as needed to provide for the most efficient traffic flow. Major contributors to traffic delays during evacuations are incidents such as mechanically disabled vehicles and vehicle crashes which may impede traffic flow. Video surveillance monitoring along the evacuation route is a valuable tool which can be used to assist in identifying and locating such incidents. The video monitoring is also an effective methodology to communicate specific traffic issues to law enforcement and other emergency managers. Although video monitoring is an important element, it is not possible to see the entire route with cameras. An ideal source of information for incident detection along evacuation routes is the evacuating traffic itself. This facet is an often untapped resource of information that can reduce the impacts of incidents on traffic flow by a reduced detection time, minimizing the time that a roadway may be blocked. A tool for allowing the public to provide this information along evacuation routes should be developed for each region. The tool should allow motorists to either call in the information or simply send text messages and/or emails to a designated recipient.

USEFULNESS OF ITS AND NON-ITS TECHNOLOGIES FOR DATA COLLECTION

For the purpose of this document, the difference between "ITS" and "non-ITS" technologies is defined as the presence of real-time communication to the field devices. The "ITS" technologies can be communicated with and are capable of providing the data collected by the device in a real-time mode to a centralized location. While "non-ITS" devices are capable of collecting the same information, these are essentially portable roadside instruments. This type of equipment is generally lower in cost than those with communication capabilities, and there are no recurring costs for the communication bridges which may be required. Generally, the “non-ITS” equipment is ideal for collecting traffic information at locations that do not require a real-time element; such information is useful for after-action review of evacuation response and information on return rates of traffic to a previously evacuated region. In selecting the equipment, one should also consider that a hurricane may damage communication elements as well as electrical power used to operate the field devices. In some cases of devices mounted above the roadway, the data collection element may also be damaged or its alignment altered by high winds. The use of in-pavement devices may be used at some locations to assure that at least some data collection is possible in damaged areas. Field installations of both types of devices (“ITS” and “non-ITS”) should be designed such that even though communication and/or power may be disrupted, data collection and storage can continue; therefore, the devices should be capable of internally storing data and have battery back-up operational capability for several days. This requirement may reduce the types of devices which may be used, but it is critical to have at least one traffic sampling location on each designated evacuation route capable of collecting and storing traffic data without the need for communication and outside electrical power. The portable “non-ITS” devices can operate in areas where electrical power has been disrupted; these devices may be the only methodology to collect data for returning traffic in some areas.

COMPARISONS OF TRADITIONAL DATA COLLECTION PROCESSES VERSUS EMERGING TECHNOLOGIES IN EVACUATION SCENARIOS

Traditional data collection processes may be defined as using roadside type devices such as road tube based counters, in-pavement inductive loop type systems, and manual traffic counts. These technologies have been proven as good methodologies to collect traffic volume data. In an evacuation scenario, it is unlikely that there will be personnel available to complete manual counts for an extended period of time. However, selected spot manual traffic counts may be a good tool for short-term evaluations of critical bottleneck locations along evacuation routes. It is important to consider the safety of any field personnel used for any manual data collection efforts; providing a safe location from which the manual counts is important in that placement should be such that there are minimal impacts to the evacuating traffic. Lastly, the field personnel should be given adequate time to depart to a safe place should they be in the path of severe weather associated with a tropical system.

Road tube based traffic counters are a good tool for collecting evacuation traffic volumes on non-critical evacuation routes. The devices can be safely deployed and will operate without requiring attention from personnel. However, care should be taken to assure that the counter itself will not become submerged should the storm surge or flooding rains impact the area. The road tubes should also be double-secured to the roadway to minimize the possibility that the tubes would not move such that inaccurate data would be collected. Many traffic counters are capable of also collecting traffic speeds and vehicle classification breakdowns as well. As the road tube based counters are portable, an advantage of using these devices on secondary evacuation routes is that the devices can be deployed without having to consider communication and or electrical power requirements.

Traditional inductive loop based devices are normally a part of a network of devices in an urban area; in many cases these are connected to a regional traffic management center. The advantage of the availability of theses devices is that it is not necessary to deploy personnel to initiate data collection during evacuations. However, the loop detector technologies generally require a significant expenditure in ongoing maintenance activities to assure that each will be available during evacuations. In addition, power outages resulting from tropical systems may render the traditional inductive loop systems as non-functioning until power is restored.

The development of emerging technologies that agencies can deploy along the roadside without requiring in-pavement installations has become a valuable tool for traffic management during evacuation scenarios as well as for normal daily traffic operations monitoring and support. The ongoing maintenance of these devices is generally less than with older technologies and many of these roadside mounted devices are capable of collecting a cadre of traffic information measures when compared to either road tube or inductive loop based devices. Many of these devices are capable of using either regular electricity or solar/battery power and can communicate using wireless technologies as well.

The newer technologies are the better option for data collection along evacuation routes in that most are very flexible in terms of the types of data collected, communication, installation options, and maintenance issues. By establishing a program of remotely checking the devices periodically, maintenance needs can be identified in the office environment, and field visits may be minimized. Such a program will better assure that each of the devices is working and available if needed for an evacuation scenario.

EXISTING STATE-OF-THE-PRACTICE TECHNOLOGIES IN REAL-TIME DATA COLLECTION FOR EVACUATION ROUTES

It is important to have a methodology to provide real-time data collected during an evacuation such that the data can be used by the intended audience. The first step in developing the methodology is to determine the audience of the intended traffic information. There are three distinct audience groups as follows:

- operational users such as traffic engineers, law enforcement, and emergency management personnel;
- distributional users including the news media and information service providers; and
- general public for personal use.

Each of these three generalized audiences has different uses and needs for the traffic information. In addition, each of these groups has a need for different levels, formats, and types of traffic data. While traffic engineers may need detailed traffic volume, average speed information and full-motion video, the general public may only need to see speed range information and video snapshots from selected cameras. The news media, for example, desires to have access to full-motion video for re-broadcast as well as more detailed traffic information to provide to its viewers. It is recommended that each region develop a list of data categories that will be supplied to each audience based upon the informational needs of their region. The development of these data needs will also aid in determining the resources required to distribute the information during evacuation scenarios. An “information distribution drill” should be held annually prior to June 1 to help identify any issues which may arise and to provide examples of data to each group in the region.

Distribution of the traffic data to the operational users is ideally handled with any existing internal system within the region. For example, in the Houston region, the resources of Houston TranStar should be used. Although San Antonio is not normally threatened by a hurricane requiring extensive evacuations, should a similar emergency occur, the resources of TransGuide would be utilized for that part of the state. The operational users should use the resources in their region which are available on a daily basis and which the users of the data are already familiar with. If any resources are added just to support hurricane evacuations, it is recommended that updates describing the new information be provided to the operational users of the system. Routine training sessions should be offered to allow the users to become familiar with the updates prior to hurricane season.

The ideal interface to provide the data is the Internet. However, there is not an existing comprehensive system in Texas that combines traffic information from the impacted regions into a single information source. A platform should be developed that can be viewed in both “in-office” and mobile environments. One of the major parts of such a system is the provision of providing the necessary information in a map type format; a major expense for development of map-based displays is the maintenance of the map itself. Using mapping based upon Google Maps is a recommended alternative to developing and maintaining privately developed maps. Such an alternative also allows for quickly adding and removing data point locations as needed throughout the region. The development of a statewide traffic information display system is beneficial in that it would provide for an overview of evacuation traffic operations regardless of which portion of the state is being impacted.

PROPOSED DATA COLLECTION PROGRAM FOR HURRICANE EVACUATION ROUTES

As the general population completes individual preparations for hurricane season, agencies involved in the evacuation process also begin preparations as well. While much of each agency’s preparations in the coastal regions focus on infrastructure preparation as well as logistics of any evacuation, little effort has traditionally been spent upon detailed data collection from a traffic engineering perspective. The evacuation of the southeast Texas coastal regions prior to the anticipated landfall of Hurricane Rita in September 2005 identified the shortfall of evacuation route traffic data within the region. The lack of traffic data prior to the evacuation (for advanced planning purposes), during the evacuation (in “real time” for traffic management support), for the returning trip traffic (to access the proportion of population returning to the region), and data for an “after-action review” have significantly impacted agencies in their abilities to gauge the success of the 2005 evacuation. There is a need to develop a statewide strategy for data collection, data sharing, and traffic impact analysis of evacuation-related traffic.

The state of Texas is divided into six “study areas” or regions for hurricane evacuations. In the event of an evacuation, more than one area is typically impacted, and the population will simultaneously evacuate from adjacent regions. As the designated evacuation routes overlap among the regions, careful planning considering the boundaries of the areas is necessary to assure the most efficient traffic flow. The data collection on the evacuation routes can be divided into three classes to assist in determining a priority of the collection effort as well as equipment deployment. These categories are as follows:

1. Class E-1 – This class is the highest priority of evacuation route data needs. Data collected at these sites should be in at least 15-minute intervals and include traffic volumes, speeds, and occupancies; these sites should be available in "real time" and the data available remotely on a statewide system. General guidance for evacuation routes to be considered as Class E-1 are as follows:

    - Routes that may be used in a contraflow mode of operation during an evacuation. These routes should be instrumented such that both the regular and contraflow directions can be simultaneously monitored. In addition, the equipment should be designed to be able to collect traffic data for the contraflow direction automatically without requiring remote and/or field visits to initiate. Data should be collected along the roadway upstream of the contraflow switch-over to allow traffic engineers to verify that there is sufficient traffic demand to warrant implementation of the contraflow as well as to provide guidance for termination of the reversed roadway operation.
    - All evacuation routes within storm surge areas should have Class E-1 data collection stations spaced at no more than five-mile intervals to measure the movement of the population from the surge area to higher ground.
    - At points where designated evacuation routes merge together into a single route, data stations should be located upstream and downstream of the merge point to allow for remote monitoring of these potential bottleneck locations.
    - Both directions of travel along the evacuation route should be monitored.
    - At critical load points on major routes, consideration should be given to collecting data on entrances to the route to better monitor inputs to the system.

2. Class E-2 – This class represents the second tier of evacuation route data needs. The data should be collected in at least one-hour intervals, and the traffic information should be accessible in "real time." While not necessary, it is desirable to have travel speed information as well. Class E-2 sites should include the following:

    - Data collection stations should be placed on all designated evacuation routes outside of the storm surge area at no more than 15-mile intervals.
    - To better monitor traffic flow near locations where motorists may exit the facility to access fuel and retail establishments, Class E-2 sites should be installed to better provide information to local law enforcement concerning traffic flow at these potential bottlenecks. In addition to collection of data along the evacuation route, consideration should be given to instrumentation of the access to and from the intersecting roadway and the roadway itself.
    - Both directions of travel along the evacuation route should be monitored.

3. Class E-3 – This class represents the lowest priority class of hurricane evacuation route data needs. The routes in the Class E-3 category are not designated as official hurricane

evacuation routes and are generally outside of any storm surge zone. While it is not necessary to have "real-time" data from these sites, the ability to remotely access the data at any time is desirable. In most cases the data for these sites can be collected with portable equipment; however, the agency should understand the risks to personnel and equipment involved in collecting the equipment as a storm approaches. The safety of field personnel should be given the highest priority. Guidance for the Class E-3 sites is as follows:

- Roadways in developing areas should be monitored during an evacuation to aid in determining if traffic volumes in the area are increasing such that the route should be considered for designation as an official evacuation route.
- Access to State designated "comfort and information" stations along designated evacuation routes should be monitored to allow for evaluation of the use and need for individual stations for future evacuations.
- Local and/or municipal streets which serve as feeder routes to evacuation routes may be monitored to assist in surface street level planning for future evacuations.
- Only traffic volume information in one-hour intervals is necessary.
- Traffic data should be collected for both directions of travel while collecting base data. While it would be desirable to have the same data collected during an evacuation, equipment, personnel, and time resources may only allow for collection of the evacuating direction for any evacuation event.

Specific site selection for data collection stations on each of the designated evacuation routes in Texas is beyond the scope of this project. The selection of specific locations for data collections are best determined based upon local knowledge of state and local traffic engineers with input from law enforcement and emergency management personnel. In addition to the collection of data during an evacuation, the Class E-1 and E-2 sites will be collecting data continuously; this data should be made available to all regional transportation agencies for use in day-to-day engineering activities. The data should also be summarized in "non-evacuation" conditions for a typical week during the previous hurricane season; these baseline values can be used to determine the additional traffic demand along each route in an evacuation scenario. This summary should be updated on an annual basis for the Class E-1 and E-2 locations. Baseline data should also be collected at each of the Class E-3 sites as well. As the data at these sites will likely be obtained using portable equipment, equipment deployment prior to an evacuation will allow for field personnel to prepare each site such that the time spent in the field deploying equipment during an evacuation will be minimized. The baseline data should be updated for each of the Class E-3 locations every 24 months; these data should also be collected in the June 1 to November 30 (hurricane season) time period.

While the previous section concentrated on traffic volume information, an important resource to consider is video monitoring of evacuation routes. The ability to visually monitor traffic conditions is a valuable resource to verify the information the field devices are providing. In addition, the ability to provide images of traffic conditions along designated evacuation routes to the media, elected officials, law enforcement, and emergency management personnel is an important information piece to be able to share. The TxDOT Houston District and Houston TranStar have developed and deployed proven systems to collect video snapshots in the field and to make images available on the Internet as well as in devices such as smart phones. This system has been deployed using wireless communication technology which allowed for flexibility in terms of locations of field installations. It is recommended that all of the Class E-1 data stations be equipped with video monitoring cameras. As determined by local knowledge, critical Class E-2 stations should also be equipped with video to provide for better monitoring of conditions at potential bottlenecks. While video monitoring of the Class E-3 sites is not necessary, digital photos of each field location should be obtained for reference purposes.

To provide visual documentation of traffic conditions during an evacuation, it is recommended that a system for archiving snapshot images for the Class E-1 and E-2 video stations should be developed. This system will provide for coordination of the traffic conditions as measured by traffic sensors with a visual perception of the actual field conditions. Such a record is vital in an after-action review and can be a good tool to demonstrate to the general public how traffic traversed along the designated roadways during an evacuation. It is recommended that a system be developed to provide for automatic archiving and reviewing of each snapshot image for each location monitored during an evacuation. The system should archive images at least every 30 minutes and need not be necessarily made available to the general public, but should serve as a tool for traffic management personnel to evaluate evacuation route operations. It is also recommended that the access to any pan, tilt, and zoom controls for individual camera locations be reserved for designated TxDOT personnel to provide for increased consistency in the camera views along the evacuation routes.

CHAPTER 7. BELTWAY 8 EAST (SAM HOUSTON PARKWAY) AS AN EVACUATION ROUTE

The Sam Houston Parkway is a designated hurricane evacuation route around portions of the greater Houston area, including the east side of the metropolitan area. Figure 7-1 shows the current limits of the non-access controlled portion that is the subject of this research.

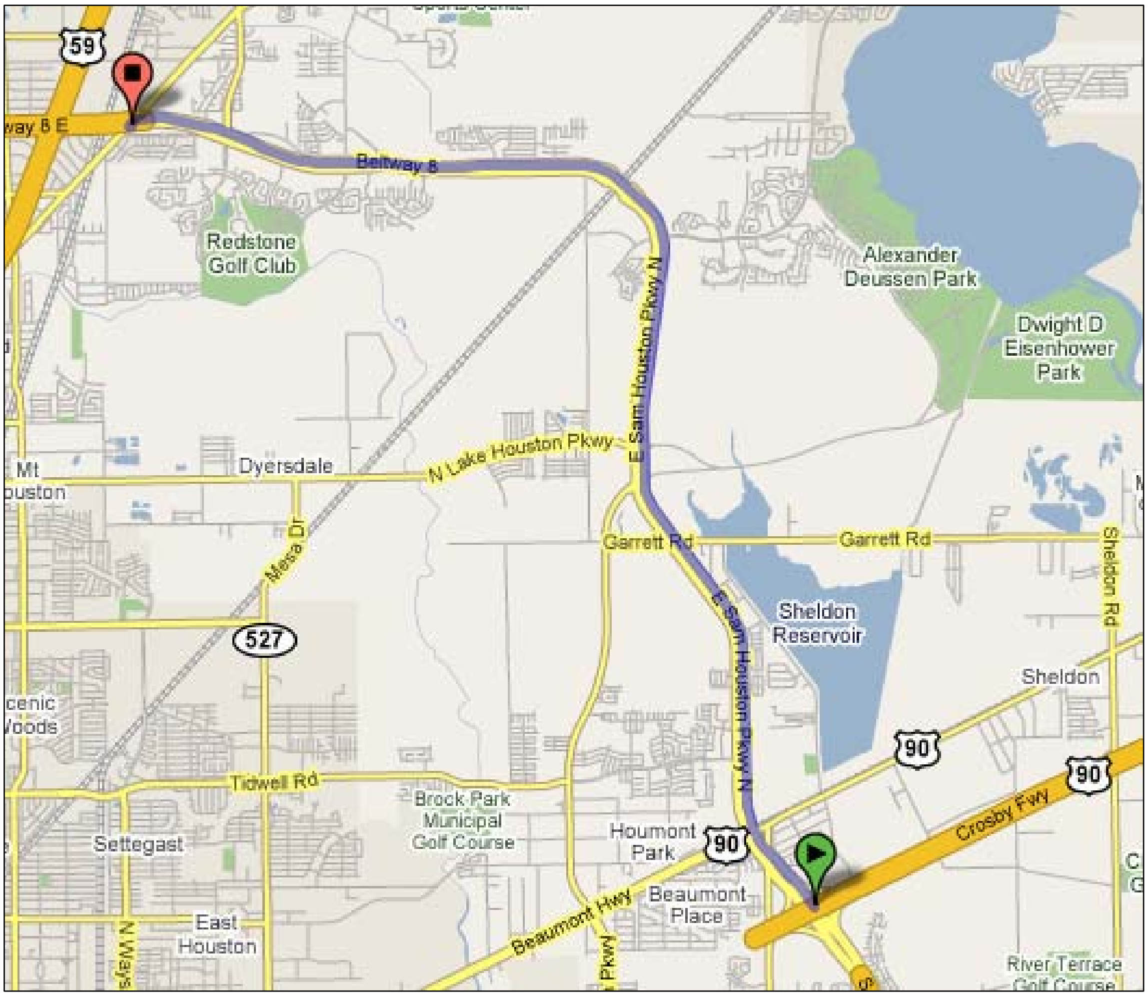


Figure 7-1. Sam Houston Parkway (East Belt) Study Limits.

Some of this portion of the Sam Houston Parkway (also known as Beltway 8) East is within the surge zone for Category 4 and 5 hurricanes, and has been designated within the "Zip-Zone" C according to the Houston area Hurricane Evacuation Route Map (*20*). Beltway 8 East is shown as a "Feeder to the Evacuation" route on this map. Beltway 8 East is also shown as an evacuation route on the DPS's Brazoria/Galveston/Harris County Evacuation Zones Map (*21*). Regardless of which map is referenced, Beltway 8 East is part of the regional evacuation plan, and will be actively managed by DPS during any emergency evacuation.

Currently, a large portion of Beltway 8 East is a non-controlled access highway, controlled at cross-streets with traffic signals. Since Beltway 8 East is a non-controlled access highway, the capacity of this highway is less than other facilities used for evacuation in the region. Researchers initially proposed that traffic analysis models would be used to evaluate the use of this highway as a viable evacuation route. During the time period of this project, the Houston-Galveston Area Council (H-GAC) was creating and calibrating a new CUBE-Voyager (*22*) Evacuation Scenario model (based on the Rita evacuation). The H-GAC model was not available for detailed analysis of Beltway 8 East in time for completion of this project. However, there is some anecdotal information on how the East Belt would operate during an evacuation based on traffic operations during Hurricane Rita.

From I-10 to approximately 1.0 mile north of Wallisville Road, Beltway 8 is an access controlled, six-lane freeway facility, with frontage roads. From 1.0 mile north of Wallisville Road to 0.3 mile east of Old Humble Road (approximately 12.8 miles), Beltway 8 is currently a parkway section, concrete curb and gutter, two-lanes striped, with full width shoulder on right (future through lane when converted to frontage road). Approximately 330 – 350 ft separate the parkway directions. The shoulder/third lane is used for deceleration and acceleration lanes at intersections. Figure 7-2 and Figure 7-3 show the typical lane use configurations for Beltway 8 East, between intersections and at intersection approaches.

The shoulder is converted to a third travel lane west of Mesa Road. A one-lane entry ramp to the North Beltway 8 mainlanes is west of Mesa Road (the Beltway 8 North mainlanes then continue past US 59 to other evacuation routes, I-45 and US 290).

Figure 7-2. Typical Section (Sam Houston Parkway, North of Garrett Road).

Figure 7-3. Typical Intersection Approach (Sam Houston Parkway, Northbound at John Ralston Road).

Significant at-grade intersections within the Parkway section include:

- Split Diamond at US 90 – signalized,
- Diamond Interchange at Tidwell – signalized,
- Diamond Interchange at Little York – stop controlled on Little York,
- Diamond Interchange at Garrett Road – signalized,
- Split Diamond Interchange at C.E. King Parkway (FM 526) – signalized,
- Split Diamond Interchange at North Lake Houston Parkway – stop controlled on North Lake Houston Parkway approaches,
- Diamond Interchange at West Lake Houston Parkway – signalized,
- Diamond Interchange at Lockwood Road – signalized,
- Diamond Interchange at John Ralston Road – signalized,
- Diamond Interchange at Wilson Road – signalized, and
- Diamond Interchange at Mesa Road – signalized.

Other significant intersections are:

- North Beltway 8 FR at Old Humble – signalized,
- North Beltway 8 FR at US 59 – signalized, and
- North Beltway 8 FR at Lee Road – signalized.

A westbound entry ramp to the North Belt mainlanes is located west of Lee Road on the westbound frontage road.

Current Texas DPS Emergency Evacuation Traffic Management Plans *(23)* address traffic control along Beltway 8 East. This plan is summarized in the following paragraphs:

The Harris County Sheriff's Department is assigned to control the following intersections:

- Diamond Interchange at West Lake Houston Parkway – signalized,
- Diamond Interchange at Lockwood Road – signalized,
- Diamond Interchange at John Ralston Road – signalized,
- Diamond Interchange at Wilson Road – signalized,
- Diamond Interchange at Mesa Road – signalized, and
- North Beltway 8 FR at Old Humble – signalized.

These intersections will be placed in flash mode, with flashing yellow on Beltway 8 East and red flash for all other approaches.

Harris County Constable Precinct 3 is assigned to control these intersections:

- Diamond Interchange at Garrett Road – signalized and
- Split Diamond Interchange at C.E. King Parkway (FM 526) – signalized.

These intersections will also be placed in flash mode, with flashing yellow on Beltway 8 East and flashing red for all other approaches.

DPS will control the split diamond at US 90 at Beltway 8, preventing a northbound (NB) to eastbound movement at that at-grade interchange. The interchange will also be placed in flash mode, with flashing yellow on Beltway 8 East and flashing red for all other approaches.

TxDOT will provide assistance by providing Type III Barricades with Road Closed signs to close US 90 eastbound, east of Beltway 8 East.

There is no reference in the 2006 DPS Plan to address manned traffic control or to place TxDOT resources at the following intersections of Beltway 8 East:

- Diamond Interchange at Tidwell – signalized,
- Diamond Interchange at Little York – stop controlled on Little York,
- Split Diamond Interchange at North Lake Houston Parkway – stop controlled on North Lake Houston Parkway approaches,
- North Beltway 8 FR at US 59 – signalized, and
- North Beltway 8 FR at Lee Road – signalized.

Discussions with Mr. Stuart Corder, P.E., Houston District Director of Transportation Operations, indicated that the striped-out shoulder could be used (and likely would be used) for evacuating traffic. The Houston District was examining whether or not to make this a permanent travel lane, but they are considering the impacts of removal of the acceleration and deceleration lanes currently striped out in the right-hand lane. Currently there is no signing that indicates that the striped-out shoulder could be used for evacuating traffic, but it is likely that law enforcement could direct traffic to use the shoulder during evacuations.

The researchers see no operational issues with law enforcement control at the intersections as listed in the 2006 DPS Emergency Evacuation Plan. As shown in Table 5-2, the operations on Beltway 8 East are consistent with signal operations in all other TxDOT districts. However, it is recommended that some clarification be sought about whether law enforcement control will be provided at the intersections of Beltway 8 East at Tidwell, Little York, and North Lake Houston Parkway; and also at North Beltway 8 FR at US 59 and North Beltway 8 FR at Lee Road.

The issues surrounding control of Beltway 8 East during evacuations are reinforced in the discussion of the use of traffic signals for hurricane evacuation routing. The evacuation signal control practice around the Houston area is influenced by the DPS Plan, by past experience, and the traffic signal technology available on hurricane evacuation routes. It is unlikely that computerized traffic modeling can distinguish between yellow flash, green flash, or law enforcement control because driver behavior under those conditions has not been measured, so this research cannot recommend a definitive control strategy that clearly exceeds the various planned control strategies. More important is providing the ability to implement any of the common treatments if, during an event, law enforcement or TxDOT requires operational flexibility.

The implementation of contraflow on non-access controlled facilities such as Beltway 8 East is complicated by numerous access points and the lack of alternate routes for those motorists displaced by the contraflowed facility. It is not recommended that Beltway 8 East employ contraflow during an evacuation, but the option was considered. If contraflow on Beltway 8 was used it would be likely that contraflow would be implemented on the southbound/eastbound sections of parkway from 1.0 mile north of Wallisville Road to US 59. The transition of evacuating traffic from contraflow on the eastbound Beltway 8 Frontage Road would occur at US 59, and proceed to the Beltway 8 North mainlanes via the US 59 split diamond and Lee Road diamond intersections. All approaching traffic to the Beltway would be turned north or west and shoulder use (Evaculane) signing and striping would be required on the shoulders in both directions. Signal operations could be flashed yellow/red or run green on long cycles (+/-5 minutes) on the Parkway approaches and police control would be required at each intersection (each signal at split diamonds/diamonds) and at the stop controlled intersections. This option would be a more intensive manpower and equipment deployment than is currently outlined in the DPS Plan.

Of concern is the current disparity between the DPS evacuation maps (May 2005) (*21*) and those maps currently in circulation from Galveston County/Harris County/City of Houston (May 2007) (*24*). The DPS map (Figure 7-4) shows Beltway 8 East as an evacuation route, while the County/City map shows Beltway 8 East as a "feeder" route (see Figure 7-5). It may not be clear to the public the difference between the two maps, and whether or not they should use Beltway 8 East as a route to access US 59, I-45, or US 290. It is recommended that these maps be brought back to concurrence.

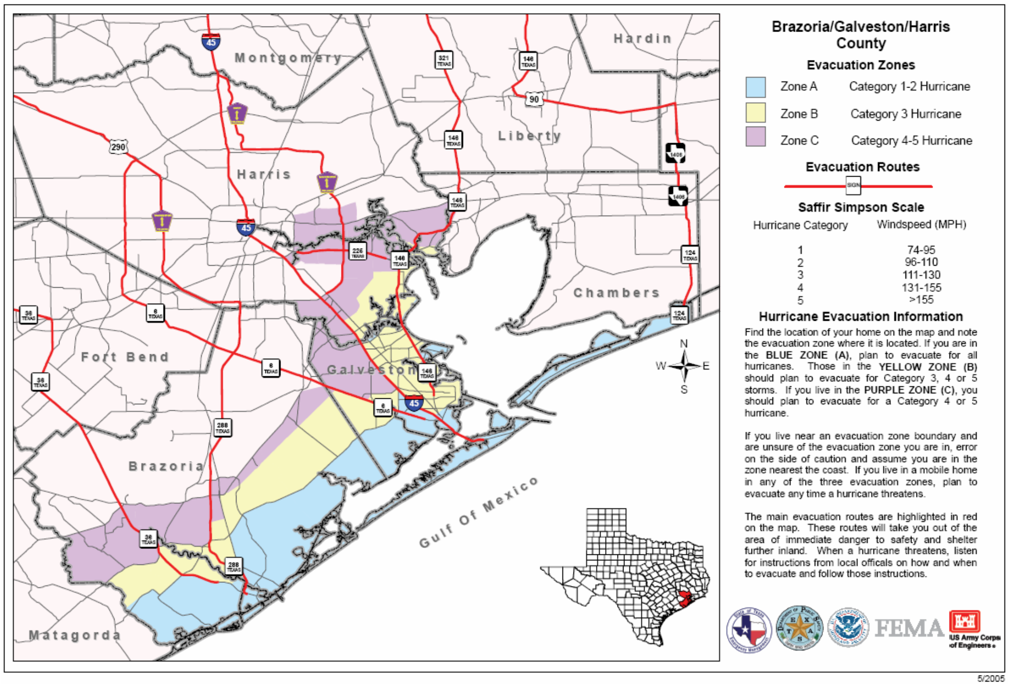


Figure 7-4. Brazoria/Galveston/Harris County Evacuation Map (*21*).

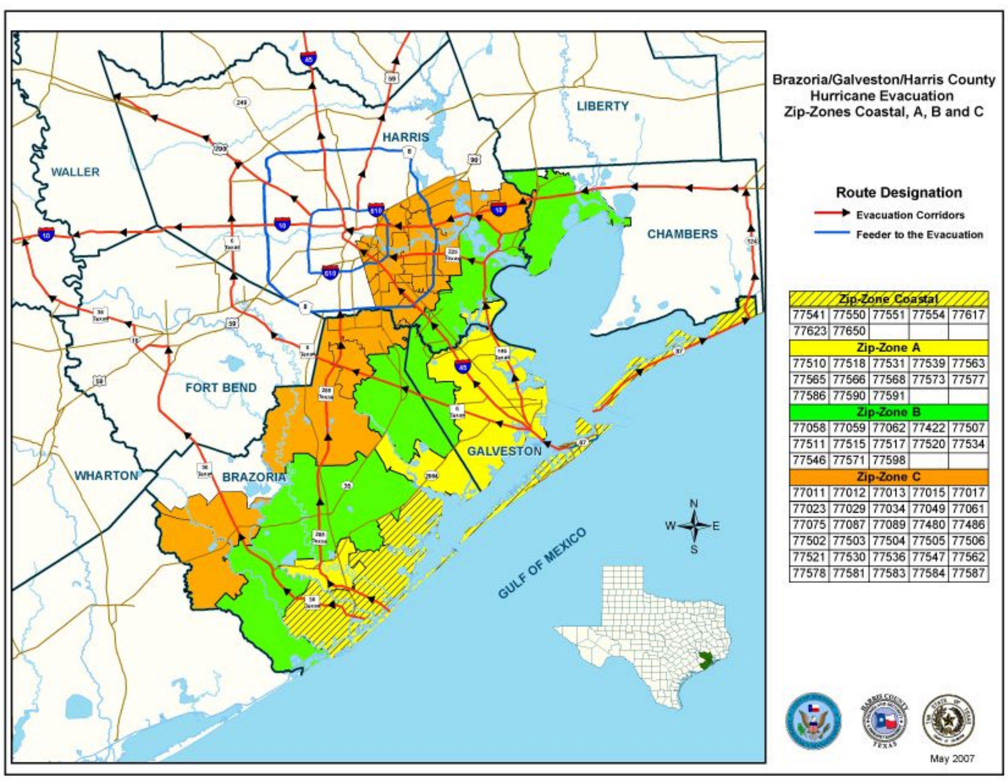


Figure 7-5. Houston/Galveston Area Hurricane Evacuation Zones and Route Map (*24*).

CHAPTER 8. DEPLOYMENT OF ITS TECHNOLOGIES FOR USE IN EVACUATION OPERATIONS

BACKGROUND

Texas has been a leader in the deployment of ITS for transportation management in the urban areas, but in many cases, evacuation routes traverse rural areas of the state where ITS deployment is limited. The objective of this chapter is to provide a brief overview of existing Texas ITS infrastructure and to recommend the strategic use of ITS applications in hurricane evacuation operations that will enhance TxDOT's ability to increase motorist safety and transportation system efficiency during evacuation events. ITS elements that were investigated include the following:

- closed circuit television cameras (CCTV),
- highway advisory radio,
- dynamic message signs,
- traffic counting stations,
- weather information stations, and
- smart-signing (changeable signing or small DMS signs).

Other ITS systems that were investigated include non-traditional information systems that become critical during evacuation events, including fuel availability information and other motorist services information (food, shelter, restrooms, etc.). Existing multi-agency cooperation with development and implementation is also discussed.

In this task, researchers identified and documented current and planned ITS deployments in the TxDOT districts of Houston, Beaumont, Yoakum, and Corpus Christi. Researchers surveyed traffic management centers and traffic engineers from TxDOT district offices to inventory current and planned deployment of ITS field devices and communication technologies. Through the survey, researchers were able to:

- analyze adequacy of current ITS deployment for hurricane evacuation and
- analyze planned ITS deployment for future hurricane evacuation.

SURVEY QUESTIONNAIRE AND PHONE INTERVIEWS

Researchers developed a questionnaire survey to identify existing and planned ITS deployment and communication architecture being deployed at various TxDOT districts. The survey focused on technology options being deployed and planned by districts to handle extreme weather events and mass evacuations. In addition to the ITS deployment, the survey also obtained information on factors, such as existing and planned inventory of ITS devices and applications, which could influence the communication architecture. The questionnaire survey was divided into sections, which are as follows:

- Strategic implementation plan for ITS deployment during hurricane evacuation.
- Inventory of current and planned ITS deployment, including:
  - vehicle sensors,
  - dynamic message signs,
  - lane control signals,
  - ramp meters,
  - closed circuit television cameras,
  - traffic control devices,
  - highway advisory radio,
  - communication setup with other agencies, and
  - communication and monitoring of field vehicles.
- Decision support system and ITS data.

The questionnaire survey and phone conversations were completed with the following traffic management centers (TMCs) and TxDOT districts, as listed in Table 8-1.

Table 8-1. TMCs and TxDOT Districts Contacted for Survey.

Traffic Management Center	TxDOT District	Contact Person
None	Beaumont	Janet Manley
None	Corpus Christi	Ismael Soto
Houston TranStar	Houston	John Gaynor & Carlton Allen
None	Yoakum	Lonnie Gregorczyk

EXISTING ITS DEPLOYMENT AND COMMUNICATION OPTIONS

The survey revealed that Advanced Traffic Management System (ATMS) installations and ITS deployment across the state among traffic management centers are significantly different. Researchers agree that while this diversity highlights the capabilities of ATMS as far as fitting into different communication scenarios, it also identifies a potential weakness. The weakness is that there is little to no consistency in design of the communications environment, which makes it difficult to achieve any degree of statewide uniformity and application. It was obvious from the survey that this lack of consistency adopted by different traffic management centers has created difficulties for supporting various installations, since each traffic management center has been experiencing unique problems.

Smaller TxDOT districts with newer traffic management centers prefer wireless connection to fiber-optic cable due to cost of capital and inadequacy of trained personnel. Wireless communication options may not be suitable for hurricane prone areas due to vulnerability of wireless infrastructure to extreme weather events, which means wireless antennas are susceptible to damage after sustained rain and high wind. This vulnerability could mean the communication infrastructure may not perform at its best for post-hurricane activities.

Different traffic management centers use different communication media and protocol to connect field devices to the traffic management center. Smaller and newer traffic management centers are leaning toward newer communication technology (wireless), while older traffic management centers maintain a combination of fiber, modem, and wireless communication technologies.

Strategic Implementation Plan for ITS Deployment during Hurricane Evacuation

Except for the Houston District, none of the traffic management centers surveyed had developed a long-range ITS plan geared toward hurricane evacuation, as indicated in Table 8-2. Existing long-range plans are in the form of regional ITS architecture, which is more generic in nature and does not include specific plans to manage hurricane evacuation. On the other hand, short-range ITS plans consist of designs to deploy specific field devices for more immediate needs and are developed as part of an individual project. The survey respondents informed researchers that developing a long-range plan is difficult due to dynamic and ever-changing communication media. However, regional ITS architecture can be expanded as a long-range ITS plan to include hurricane evacuation. The national ITS architecture has expanded to include market packages that address evacuation and emergency management.

Table 8-2. Strategic Implementation Plan for ITS Deployment during Hurricane Evacuation.

TxDOT District	Does the district have a strategic ITS implementation plan?	Improvement needs and other issues
Beaumont	No	Not applicable
Corpus Christi	Yes	Integration issues with other agencies.
Houston	Yes	Plan follows updated evacuation plan mandated by the DPS. Also considers previous evacuation situation.
Yoakum	No	Not applicable

It is recommended that TxDOT update its regional architectures to reflect these additions and update, if not create, a comprehensive ITS implementation plan as a preparation to upcoming hurricane seasons. The ITS implementation plan should consist of a detailed description to make the best use of ITS capabilities based on existing and readily available field devices. This plan should include the creation of a concept of operations for ITS use during evacuations, with a focus on center-to-center communications, e.g., between Houston and Austin. The concept of operations should include developing interfaces to provide meaningful information, e.g., traffic volumes in charts and graphs, etc.

Spatial Coverage of ITS Field Devices

An inventory of various ITS field devices was received from the districts, which included the following:

- vehicle sensors,
- dynamic message signs,
- lane control signals,
- ramp meters,

- closed circuit television cameras,
- traffic control devices,
- highway advisory radio,
- communication setup with other agencies, and
- communication and monitoring of field vehicles.

Table 8-3 gives a summary of the current and planned inventory of ITS field deployment for the various districts surveyed.

The Houston District roadway cameras include about 75 rural sites. There are 12 permanent HAR stations and one portable HAR station currently deployed by Houston. There are also a total of 32 HAR signs and 2 static message boards deployed within the coverage area. The Corpus Christi District has no Lane Control Signals (LCS) deployed in its area of operation. The Houston District currently has no LCS deployed in its area of operation. Houston has 160 ramp meter stations across its coverage area. During the recent hurricane evacuation, these devices were used to aid in the evacuation process. The Corpus Christi District has no ramp metering stations currently installed.

Table 8-3. Inventory of Current ITS Deployment.

TxDOT District	Automated Vehicle Identification	Vehicle Sensors	Dynamic Message Signs	Lane Control Signals	Ramp Meters	CCTV	HAR
Beaumont	0	0	7	0	0	Few*	0
Corpus Christi	0	0	22	0	0	25	0
Houston	362	Several	171	0	160	460 Roadway, 25 Non-roadway*	12
Yoakum	0	0	4	0	0	10	0

*Maintained by indicated district

It is recommended that HAR be deployed along major evacuation routes as a means of disseminating relatively lengthy messages during evacuations, as well as for other applications. Newer HAR systems have typed messages as input, which is converted to digital voice messages. TxDOT districts can benefit by installing HAR systems on hurricane evacuation routes.

There are several challenges in the deployment of ITS field devices for hurricane evacuation monitoring and management. One of the most significant is that ITS field devices primarily serve urban areas, while the majority of evacuation route mileage is in rural areas. Several districts have deployed portable ITS devices, particularly HAR and DMS in the past, and continue to do so.

Another challenge of providing wider ITS coverage in rural areas is the cost. Because hurricane evacuations are infrequent events that cover such wide areas, it is difficult to justify their cost solely for hurricane evacuation purposes unless they can incorporate multipurpose functionality for daily traffic monitoring. This challenge is clearly the case in all districts surveyed. Several hurricane evacuation routes in Corpus Christi such as I-37, US 77, and US 181 do not have ITS field devices, as illustrated by Figure 8-1. Similarly, in the Yoakum District portions of I-10 have ITS coverage. However, none of the highways originating from the city of Victoria has ITS field devices, as illustrated by Figure 8-2. As shown in Figure 8-3, the Houston District has the most coverage of ITS field devices in and around the city of Houston and highways leading to the Galveston area. Houston TranStar also maintains several field devices, including CCTVs around the Beaumont area, as shown in Figure 8-4.

It is recommended that TxDOT invest in deployment of ITS field devices along rural hurricane evacuation routes, even though these ITS devices may not be fully justified on the sole basis of daily traffic monitoring purposes.

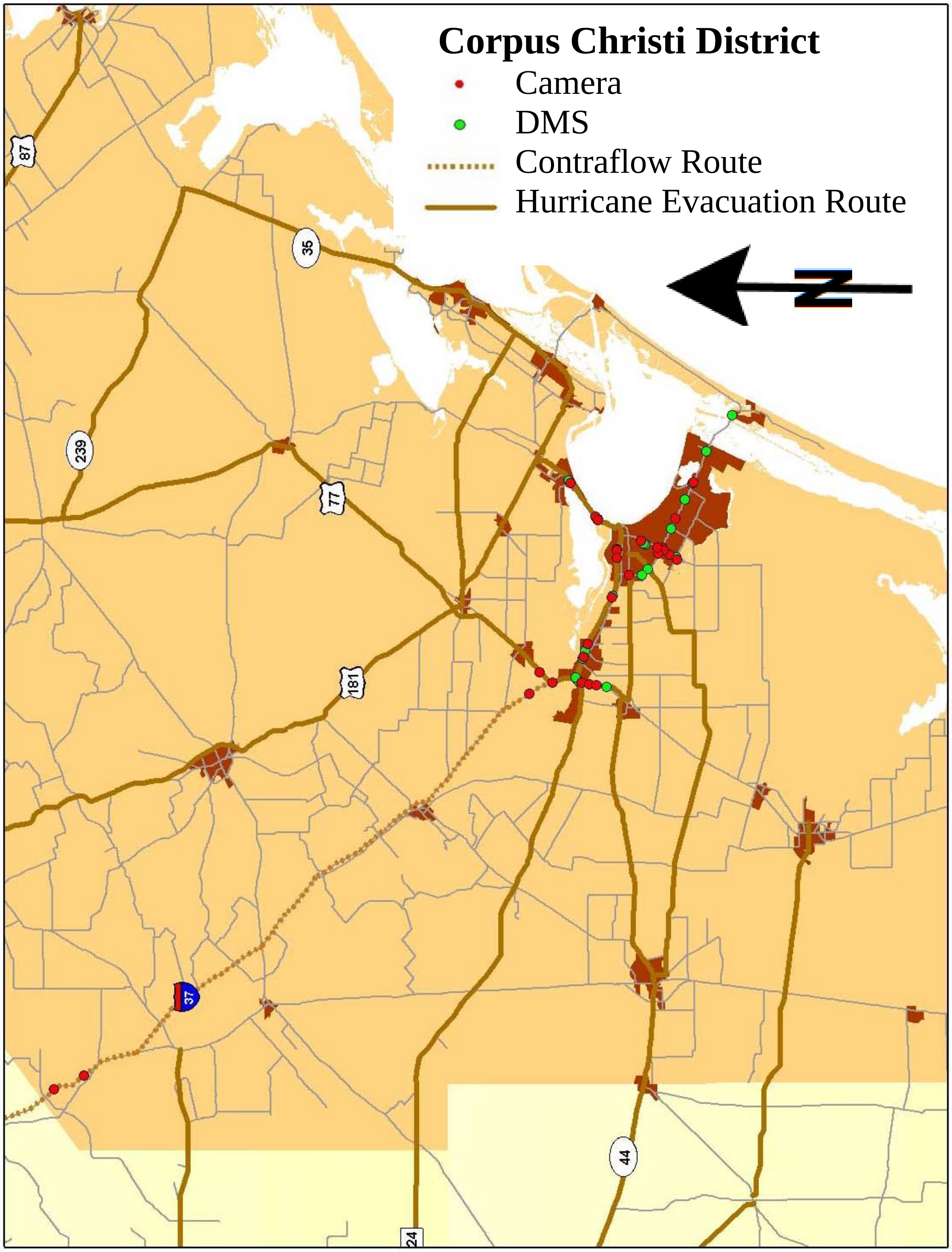


Figure 8-1. ITS Field Devices in Corpus Christi District.

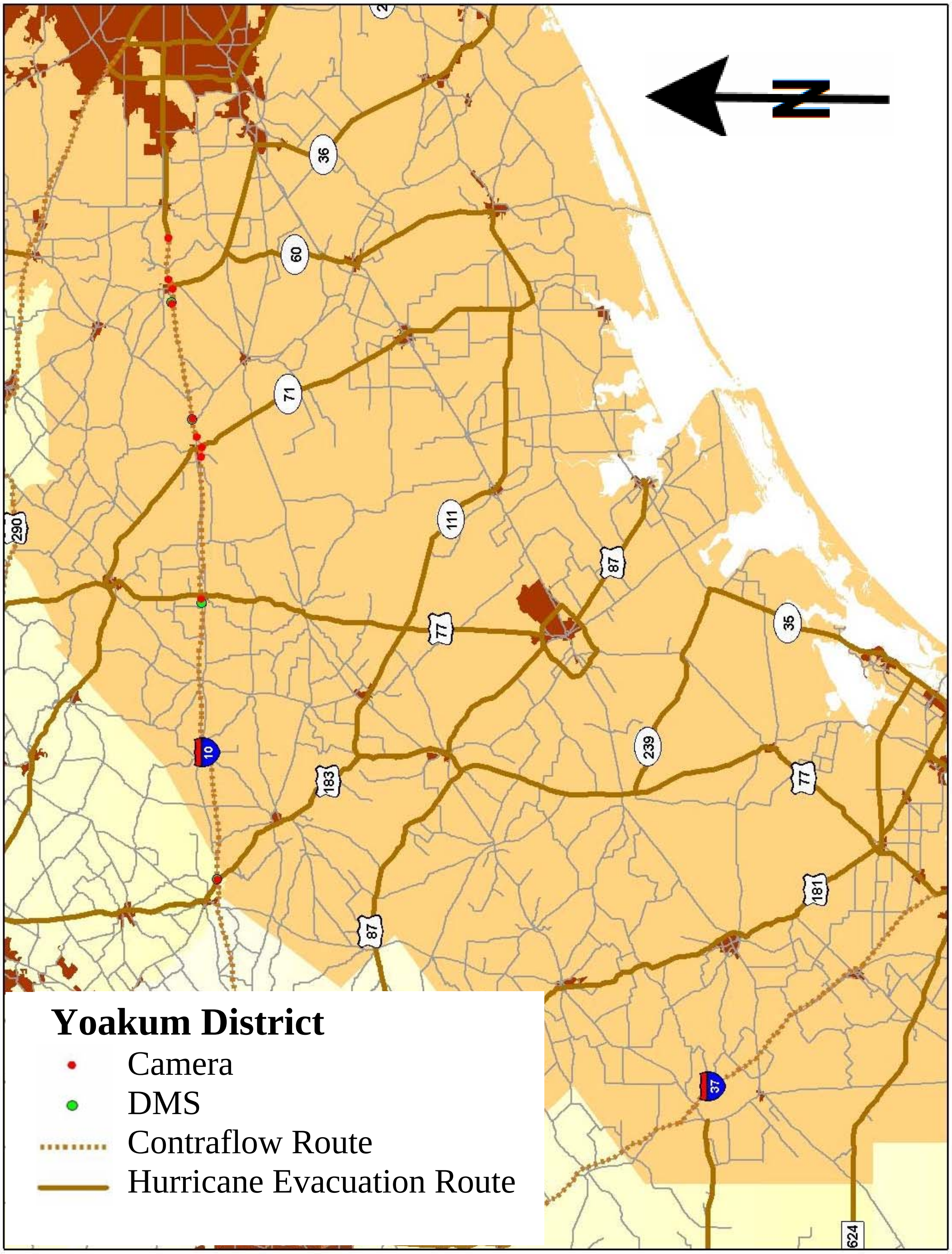


Figure 8-2. ITS Field Devices in Yoakum District.

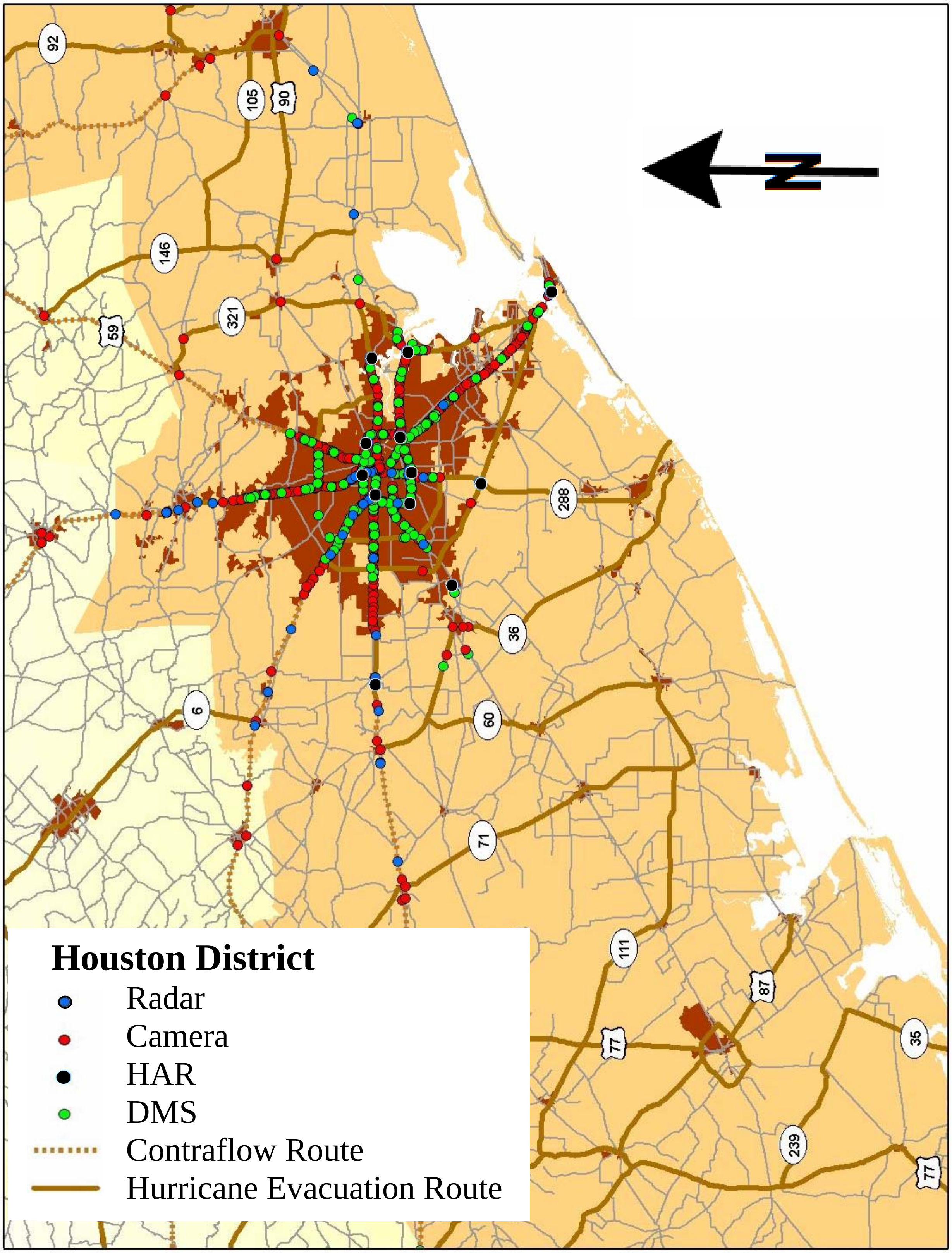


Figure 8-3. ITS Field Devices in Houston District.

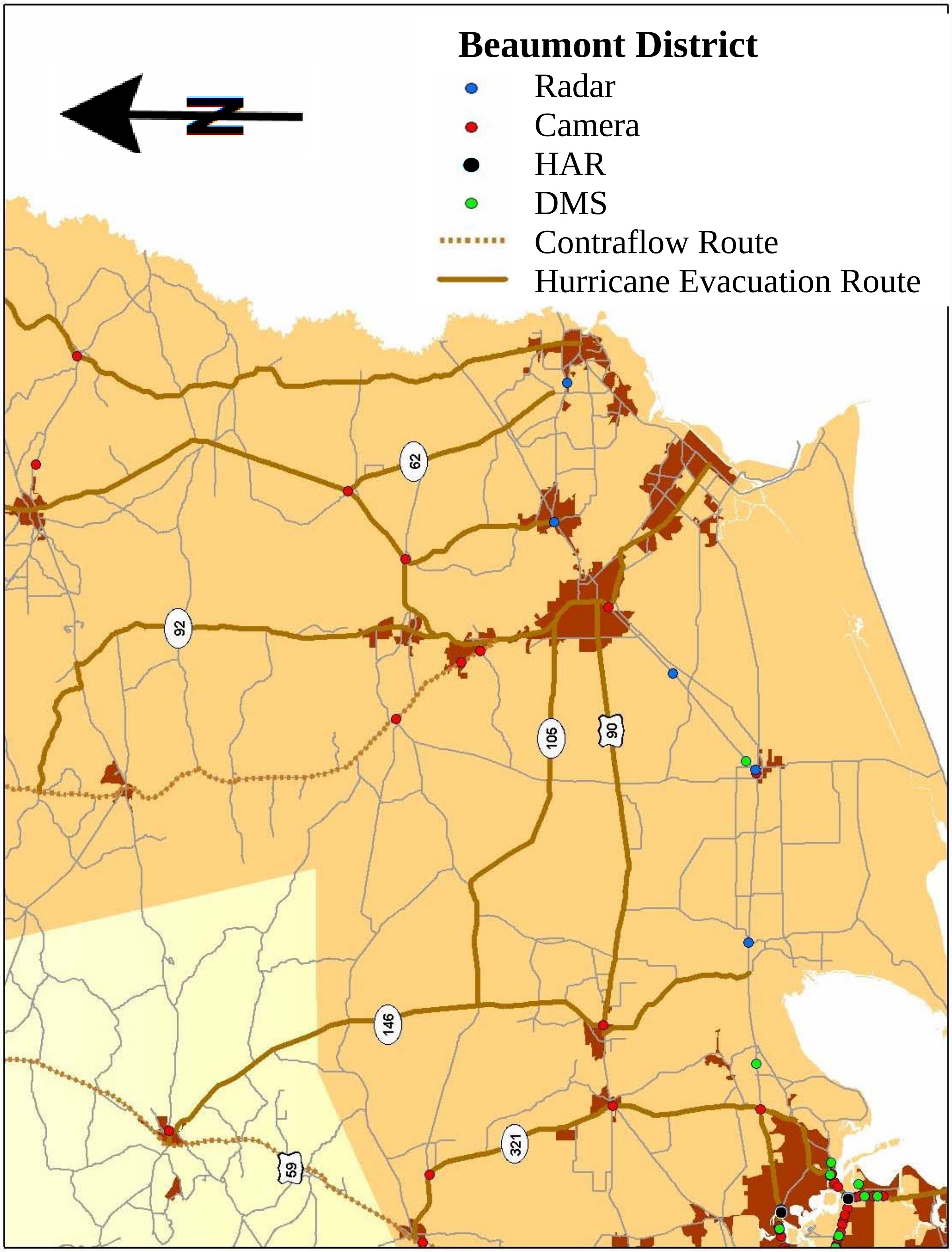


Figure 8-4. ITS Field Devices in Beaumont District.

Vehicle Sensor Data Usage

The real-time data collected from roadway vehicle sensors can also be converted into travel advisory statements that can be disseminated using HAR, strategically located DMS, and locally owned radio stations. Information from roadway vehicle sensors can be used by decision-makers to observe the traffic condition on an evacuation network in real time.

The real-time vehicle sensor will provide indications of queue length at evacuation bottlenecks. In turn, this queue length data can be used to determine where to open shelters during hurricane evacuation. Access to real-time traffic counter data and images from remote roadway surveillance systems will provide that capability to decision-makers. Archived roadway sensor data can be used to calibrate simulation of large-scale evacuation using regional travel demand and dynamic traffic assignment models, e.g., Dynasmart-P, VISSUM. Table 8-4 gives a summary of usage of real-time vehicle sensor data during prior hurricane evacuation in the districts surveyed.

Table 8-4. Evacuation Data from Vehicle Sensors.

TxDOT District	Did your district use data from vehicle sensors during recent hurricane evacuation?	Do you plan to install more vehicle sensors prior to the next hurricane season?	Do you plan to use real-time data to convey traffic information to the motorists?	Do you have traffic flow data on evacuation routes from recent hurricane evacuation?
Beaumont	No	Yes	No	Yes*
Corpus Christi	No	No	No	Yes
Houston	Yes (current travel time and speed for motorists using Internet)	No (Not enough budget)	Yes	Yes
Yoakum	No	Yes	Yes	Yes **

*Gathered by Texas Transportation Institute at several locations.
**Tube count at four locations along SH 71.

It is recommended that TxDOT accelerate the development, support for, and deployment of wireless communications capability for real-time vehicle sensor coverage especially along hurricane evacuation routes, not only to monitor evacuation events, but also to study effectiveness of evacuation strategies, such as contraflow, Evaculanes, and alternate routes by archiving traffic flow data.

In the Report to the Governor on Texas Hurricane Preparedness *(25)*, the Texas Office of Homeland Security stated the following:

"Install a system of real time traffic counters at key points along main evacuation routes to provide information on evacuation traffic flow. (All evacuation areas) Most states that are prone to hurricane disasters, including Florida, have web-based systems that monitor the flow of traffic on evacuation routes. These traffic monitors provide emergency management officials with an understanding of how quickly evacuees are moving to safety, how many households remain at risk, and how to manage the evacuation efficiently. Evacuation areas in Texas must have the same capability to collect and transmit real time data on traffic flow during hurricane evacuations. A network of traffic counters would provide essential data to local emergency operation centers and the State Operations Center. This data will enable the real-time monitoring of the volume and progress of an evacuation along the Texas coast, as well as facilitate traffic management. TxDOT will purchase and install real time traffic counters at critical nodes of the evacuation route system all along the coast. The traffic counters will be linked to local emergency operation centers and to the State Operations Center. TxDOT will seek funding for this project."

Dynamic Message Signs Usage

All four TxDOT districts surveyed used dynamic message signs to convey information to motorists during hurricane evacuation. Table 8-5 gives a summary of DMS usage during prior hurricane evacuation. Except for Houston and Beaumont, no districts in this survey have the capability to provide travel time information through DMS. Providing information about travel time through DMS is much more complex than providing information such as location of nearest gas station or food/shelter locations. Except for the Yoakum District, other districts surveyed provided alternate route information.

Table 8-5. Use of Dynamic Message Signs during Recent Hurricane Evacuation.

TxDOT District	Did your TMC or district use one or more DMS to display the following information during recent hurricane evacuation?				
	Travel time	**Location of nearest gas stations**	**Location of nearest food and shelter**	**Vehicle crashes**	**Alternate routes**
Beaumont	Yes	No	Yes	No	Yes
Corpus Christi	No	No	Yes	Yes	Yes
Houston	Yes	Yes	Yes	Yes	Yes
Yoakum	No*	No	No	No	No

*Dynamic message signs were not working

It is recommended that TxDOT study the accuracy and effectiveness of travel times and alternate route information. Roadway vehicles' sensors have known problems in sending accurate volume and speed data during stop-go conditions, which is typical during a major hurricane evacuation.

Closed Circuit Television Cameras

The Corpus Christi District has already added CCTVs to its previous inventory in anticipation of the next hurricane evacuation season. Houston is continuously expanding its CCTV inventory and recently added hurricane evacuation route cameras to the website. Cameras are being installed on I-10 (Katy Freeway) from the Fort Bend County line to the Brazos River. Cameras are also being installed on Beltway 8 counterclockwise from I-45 (Gulf Freeway) to I-45 (North Freeway). Houston is considering deploying low cost cameras married with cellular modems. Table 8-6 gives a summary of usage of CCTVs during prior hurricane evacuations in the districts surveyed.

CCTV cameras in the Beaumont District are mostly installed and maintained by Houston TranStar. The Yoakum District installed several CCTVs after Hurricane Rita; hence, the district does not yet have experience in using CCTVs during a hurricane evacuation.

Table 8-6. Use of Closed Circuit Television Cameras during Recent Hurricane Evacuation.

TxDOT District	Did your TMC or district use one or more CCTV for the following tasks during recent hurricane evacuation?			
	Observe queue buildup	**Assist PD for visual confirmation**	**Assist PD to implement contraflow lanes**	**Relay screen-shot images over the Internet**
Beaumont	Yes	No	No	Yes*
Corpus Christi	Yes	Yes	No	No
Houston	Yes	Yes	Yes	Yes
Yoakum	No	No	No	No

* Displayed through TranStar website
PD = Police Department

It is recommended that TxDOT expand coverage of CCTV cameras along rural hurricane evacuation sites using wireless technologies or cell phone connections, if installation of fiber is infeasible due to limited budgets and resources.

CCTV cameras have an advantage over loop detection in that they can provide direct visual confirmation of traffic and weather conditions. They can also be used for detecting incidents and verifying their removal. One of the limitations of CCTV is that, unlike the count stations described earlier that can operate on solar power and transfer small volumes of data, CCTV typically requires direct power and communication connections. This requirement is often difficult in remote locations along evacuation routes.

Traffic Control

The survey showed that TxDOT districts have a combination of traffic signals that can be modified manually and centrally. The Corpus Christi District can control all traffic signals on major routes from a central location. The Beaumont and Houston Districts can control some traffic signals from a central location, while the rest of the traffic signals on state roadways have to be altered manually. The Yoakum District currently does not have the capability to control traffic signals from a central location. Table 8-7 gives a summary of usage of traffic signal timing changes as a hurricane evacuation tool during prior hurricane evacuation in the districts surveyed.

Table 8-7. Traffic Control during Recent Hurricane Evacuation.

TxDOT District	Traffic Signal Timing Modification	Type of Traffic Control Network
Beaumont	Some manually altered and some centrally altered	Some traffic signals on state system can be centrally altered, while city does not have any closed loop system
Corpus Christi	Some manually altered and some centrally altered	All traffic signals on major routes can be centrally altered
Houston	Some manually altered and some centrally altered	Some traffic signals on state system and city can be centrally altered
Yoakum	PD can manually alter signals to flashing yellow or red	None of the traffic signals on state system or in the city can be centrally altered

It is recommended that TxDOT integrate state-maintained traffic signals on hurricane evacuation routes into community's closed loop system or a central control. This integration will significantly reduce time and resource requirements to alter signal timing.

Highway Advisory Radio

The Corpus Christi District has no plans for installing HAR stations and/or signs prior to the next hurricane season. The district has established partnerships with local radio stations to convey evacuation information to the public during hurricane evacuation events. The Houston District does not plan to install additional HAR stations prior to the next hurricane season. This decision is mainly due to budget constraints. The Beaumont and Yoakum Districts do not currently have HAR stations deployed. Table 8-8 gives a summary of usage of HAR during prior hurricane evacuation in the districts surveyed.

Table 8-8. Use of Highway Advisory Radio during Recent Hurricane Evacuation.

TxDOT District	Did your TMC or district use HAR to broadcast the following information during recent hurricane evacuation?					
	Travel time	Location of nearest gas stations	Location of nearest food and shelter	Vehicle crashes	Alternate routes	Weather condition
Beaumont	-	-	-	-	-	-
Corpus Christi	-	-	-	-	-	-
Houston	No	No	Yes	Yes	No	Yes
Yoakum	-	-	-	-	-	-

Coordination and Communication with External Agencies

Coordination and communication between TxDOT and external agencies, mostly first responders, are extremely important during hurricane evacuation. In addition to radio communication, districts can share traffic information, such as CCTV video, with first responders and media. Requests by external agencies for the ability to view and/or control CCTV has been growing. However, connections with external agencies raise a number of issues, most importantly network bandwidth and connection medium. While traffic management centers are optimistic about having adequate bandwidth, the concern over availability of the bandwidth might surface in the future. Existing communication between TxDOT and external agencies is listed in Table 8-9.

Table 8-9. Existing Communication with External Agencies.

TxDOT District	Agencies Connected	Purpose	Connection Medium
Beaumont	None	-	-
Corpus Christi	Department of Public Safety	Share video data and control of TxDOT cameras (in process)	Fiber (in process)
Houston	Local Police Dept.	Share video data	ISDN
	Houston Emergency Center	Regional Incident Management System (RIMS)	Internet
	Department of Public Safety	Share video data and control of TxDOT cameras	Fiber
	Other TxDOT districts	Snapshots of Hurricane Evacuation Route cameras	Internet
	Local Media	Share video data (no control)	Leased Fiber
	Joint Operations Center (JOC)	Share video data and control of TxDOT cameras	Video Conferencing
	OEM – Office of Emergency Management	RIMS – Incident management data	Internet
Yoakum	None	-	-

Note:
ISDN = Integrated Services Digital Network

Corpus Christi is currently installing a fiber communication link with the Department of Public Safety to allow DPS pan-tilt-zoom control of TxDOT cameras. The district expects to expand the integration with regional partners, expand ITS field devices into rural areas, and leverage regional Wi-Fi.

The Houston District provided snapshots of Hurricane Evacuation Route (HER) cameras and detector info through the Internet to the Houston Emergency Center (HEC) as well as the general public and also provided incident management data through the Regional Incident Management System to the Office of Emergency Management as well as the Joint Operations Center during major events, emergencies, and/or disasters. RIMS is a secure web-based data management system that integrates information from traffic management and emergency management operations (*26*).

Communication is the key to a successful hurricane evacuation, which requires multi-agency coordination. TxDOT districts with minimal communication capabilities should actively pursue ITS projects to install, deploy, and integrate state and local level communication infrastructure.

Monitoring of Public Transit Vehicles

Corpus Christi has considered using school buses and/or local transit buses for hurricane evacuation. In the past, Houston has considered the use of school buses and/or local transit buses for hurricane evacuation. Although Houston METRO has some Automated Vehicle Location (AVL) capability within its fleet, currently the Houston District does not have the ability to monitor transit vehicles. The Yoakum and Beaumont Districts have plans to use transit and/or school buses during the next hurricane evacuation. However, existing buses do not have automatic vehicle location systems installed. Being able to monitor the location of buses in real time provides the ability to manage the fleet efficiently during hurricane evacuation.

TxDOT should explore the possibility of sharing the capability of monitoring public transit and/or school buses by TMCs. Integrated with TxDOT field vehicles' monitoring capability gives TMCs ability to assist each other's fleet vehicles and resource personnel. By knowing the volume of evacuating vehicles, strategies that are more effective can be developed to cope with the expected shelter demand.

Communication and Monitoring of Field Vehicles

The survey showed that the TxDOT districts have the ability to communicate with TxDOT field personnel during hurricane evacuations through two-way radios and cell phones. In addition, none of the TxDOT districts has the capability to monitor the location of TxDOT field vehicles in real time using a global positioning system (GPS). Real-time monitoring of TxDOT field vehicles during hurricane evacuation will assist TxDOT in managing limited field resources efficiently. Considering the fact that GPS devices and central monitoring systems are relatively inexpensive, benefits during hurricane evacuation will easily outweigh the cost of deploying such a system. Existing communication between TxDOT and field vehicles is listed in Table 8-10.

Table 8-10. Existing Communication with Field Vehicles.

TxDOT District	Communication Medium with TxDOT Field Personnel			GPS Monitoring of TxDOT Field Vehicles	
	Two-way radio	Cell phone	Pager	GPS monitoring	Reasons for not deploying GPS
Beaumont	Yes	Yes	Yes	No	Not considered yet
Corpus Christi	Yes	Yes	No	No	Not considered yet
Houston	Yes	Yes	No	No	-
Yoakum	Yes	Yes	No	No	Not considered yet

The ability to monitor the TxDOT field vehicles, especially for deployment of contraflow lanes, will increase the efficiency of managing the fleet of field vehicles. With GPS-equipped field vehicles, TMC operators can locate field vehicles accurately and allocate resources efficiently.

Decision Support System and ITS Data

A decision support system allows integration of multiple sources of evacuation related information such as remote traffic counters, evacuation route and detour maps, and real-time weather data, preferably in a Geographic Information Systems (GIS) platform. The system can visually illustrate rapidly changing traffic and weather information for managing evacuations. The system could also distribute information over an intranet or Internet and can be used to display and query information by decision-makers to compare evacuation progress with the advancement of storm elements and modify the plan accordingly. ITS data from roadway vehicle sensors continuously feed the system with updated information. The system can be integrated with dynamic traffic modeling tools to create alternate route information, which could be distributed over HAR, DMS, and conventional radio. The survey revealed that TxDOT districts have neither a decision support system nor models to plan hurricane evacuation.

It is recommended that TxDOT develop an integrated decision support system, preferably GIS based, to monitor existing evacuation conditions and assist decision-makers to plan and modify evacuation strategies effectively. TxDOT should also develop hurricane evacuation planning models to predict traffic congestion levels on major corridors along with potential location of shelters.

REGIONAL ITS ARCHITECTURE

Regional ITS architectures of TxDOT districts surveyed in this project have extensive plans for information sharing among the local transportation agencies, including first responders. The plans include almost all the necessary market packages and user services necessary for everyday traffic monitoring as well as evacuation events. However, TxDOT districts face immense challenges to implement proposed information sharing between agencies, which is critical for any major evacuation planning and operation. While plans for information sharing may be adequately robust, the implementation of such plans relies on the successful improvement of the communication infrastructure. Agencies agree that communication and information sharing is crucial for a successful evacuation operation, however, there are also concerns about high infrastructure cost for installation and maintenance.

Regional ITS architectures are developed through extensive stakeholder participation; however, transportation and enforcement agencies tend to implement communication systems on their own without coordinating with the regional ITS architecture and without the participation of potential stakeholders. Hence, TxDOT districts should take every initiative to develop future ITS projects by using the regional architecture as the guiding document. TxDOT districts should maintain, revise, and update regional ITS architecture by involving all stakeholders in the region.

ITS infrastructure allows operational flexibility, which is crucial to manage uncertainties and changes. However, flexible systems require higher level skill sets for operation and maintenance. The survey revealed that smaller and rural districts may not have qualified personnel locally available to implement newer communication infrastructure. Even though regional ITS architecture has prioritized the implementation market packages and user services, priorities may change over time due to the nature of hurricane evacuation events. Hence, stakeholders should revise the architecture to “reprioritize” market packages and user services.

It is recommended that TxDOT districts strictly adopt the regional ITS architecture as a guiding document for future ITS implementation projects. TxDOT districts should maintain and update the architecture while reprioritizing market packages and user services as needed.

CHAPTER 9. RECOMMENDATIONS FOR REDUCING EVACUATION FIELD STAFFING

Large-scale evacuations necessarily require large quantities of resources, including human resources. With these resources often required around the clock for multiple days, the more that can be done to reduce the need for large staffing commitments, the better the evacuation may proceed. In an effort to identify ways to assist in managing the high demand for personnel with the limited availability of personnel, researchers contacted state departments of transportation, state police, and emergency management agencies between Texas and New York to solicit ideas and experiences. These agencies were queried to identify means to 1) supplement field personnel, and 2) employ techniques/technologies to minimize the need for field personnel. This query generated some ideas that are already part of TxDOT's hurricane evacuation plans and others that are not.

RAMP GATES ON CONTRAFLOW LANES

During an emergency contraflow operation, it is critical that contraflow traffic not encounter traffic that is attempting to enter the same lanes while traveling in the normal direction on the normal entrance ramps. Such ramps must be closed, except for those where contraflow traffic is allowed to use them to exit the highway.

At least two states are using railroad crossing-type drop gates for controlling access to freeway ramps for hurricane evacuation contraflow operations. The Georgia Department of Transportation (GDOT) *(27)* has installed two pairs of such gates on 21 ramps on the contraflow side of a 145-mile portion of I-16 between Savannah and Dublin, as pictured in Figure 9-1 and Figure 9-2. Each of these ramps has a gate on each side of the ramp at the beginning and at the ending of the ramp, thereby providing four gates per ramp.

GDOT is expanding its gate program to install the same type of equipment on I-75 and I-95 inland from the Florida state line *(28)*. Georgia State Police continues to staff ramps with gates. These officers manually close the ramp by lowering the gates; then they lock them into place with a key. The officers also are in position there to open the gates in the event of a traffic back-up or to allow contraflow traffic to access fuel stations and facilities.

Georgia installed its first gates after the 1999 Hurricane Floyd. Since that storm, Georgia has not implemented its hurricane evacuation contraflow plan. Consequently, the gates have yet to be tested during an evacuation.

The Virginia Department of Transportation (VDOT) has followed GDOT's lead and installed gates for contraflow ramps on I-64 between Hampton Roads and Richmond *(29)*. However, VDOT installed only one pair of gates on its ramps; these are located at the end nearest the mainlanes. Virginia will block the surface street end of the ramp with law enforcement vehicles. Figure 9-3 illustrates VDOT's gate design.

Figure 9-1. Contraflow Ramp Drop Gate Installation (27).

Figure 9-2. Georgia DOT's Drop Gate for Contraflow Ramps (27).

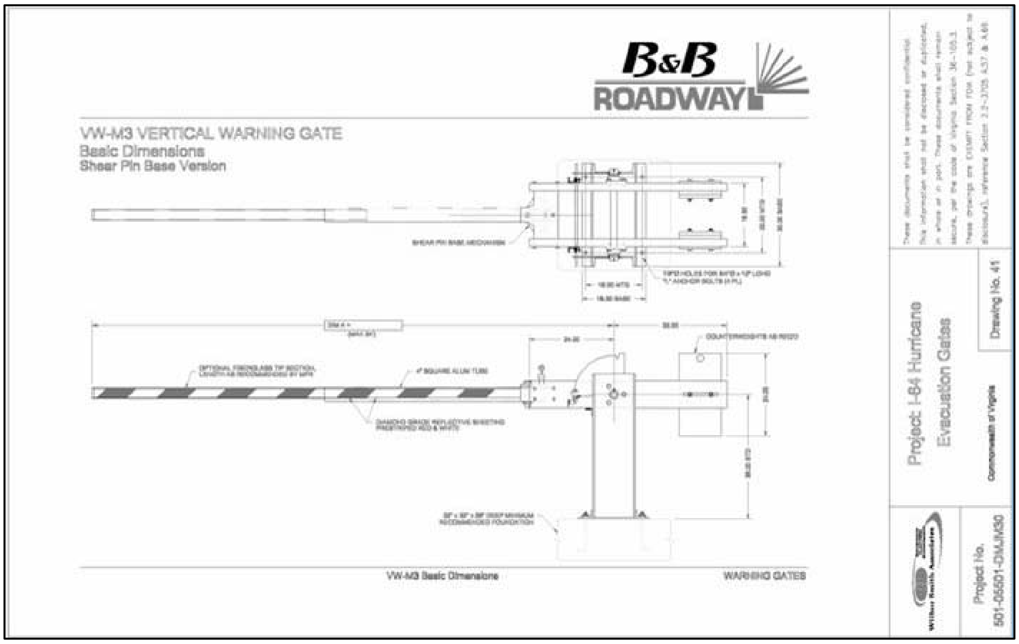


Figure 9-3. Virginia DOT's Planned Contraflow Ramp Gate (*14*).

Alternative Concepts

Watermark Safety Inc. (*30*) is a Texas company that markets a couple of devices that were thought to have applicability to contraflow ramp closure. Their Rollacade product, as shown in Figure 9-4 and Figure 9-5, is a plastic mesh fencing that is manually pulled from a coiled state inside a roadside storage compartment and affixed to a footing attached to the ground on the opposite side of the pavement. This device has not been crash-tested and has not been shown to comply with requirements of NCHRP Report 350 (*31*).

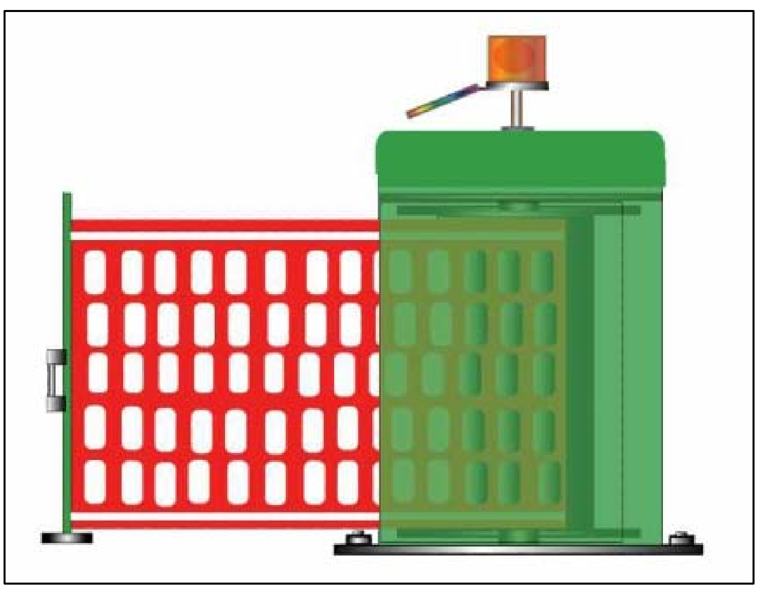


Figure 9-4. Rollacade Access Closure Device (*30*).

Figure 9-5. Fully Deployed Rollacade Fencing *(30)*.

Watermark Safety can also outfit a drop gate, like that shown in Figure 9-6, with communications equipment so that the gate can be opened and closed remotely, as well as provide alarms when the gate is struck. HySecurity *(32)* is a gate manufacturer associated with Watermark Safety. HySecurity's StrongArm is a hydraulic drop gate whose applications are generally not on high-speed facilities. This device has not been shown to comply with NCHRP Report 350 *(31)*.

Figure 9-6. HySecurity's StrongArm Drop Gate *(32)*.

TTI *(33)* conducted crash-testing on a drop gate for the Wyoming Department of Transportation in the 1990s and found it to be NCHRP 350-compliant *(34)*. Figure 9-7 and Figure 9-8 illustrate the Wyoming Road Closure Gate. Wyoming DOT uses these gates in some mountainous areas where they need to manage access to highways.

Figure 9-7. Crash-Testing of Wyoming's Road Closure Gate (*33*).

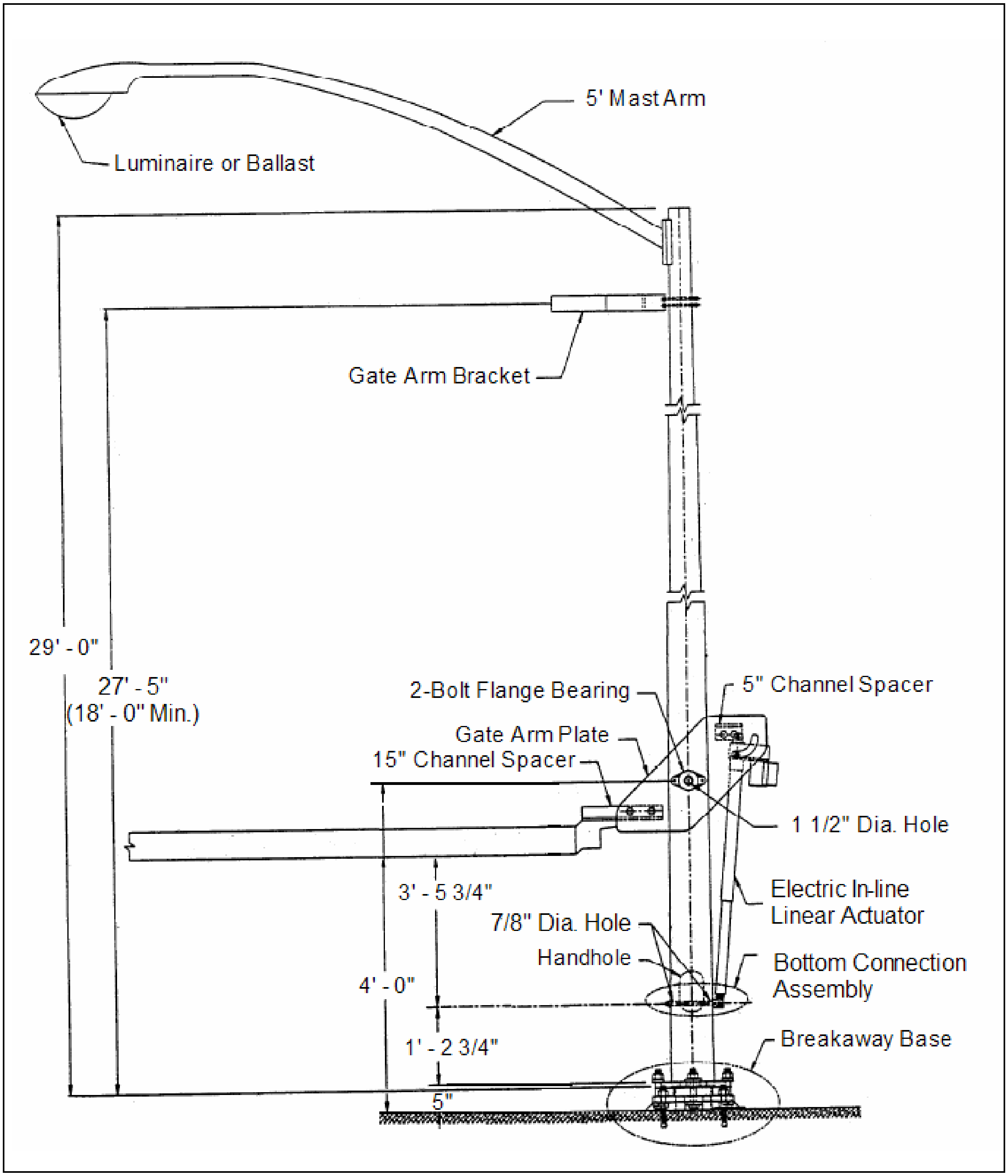


Figure 9-8. Wyoming Road Closure Gate (Adapted from *34*).

Although two states plan to use ramp closure gates in their emergency contraflow plans, neither state has deployed them yet for hurricane evacuation contraflow.

GDOT explained that during an evacuation, the personnel that will be used to facilitate the evacuation are the same personnel that are needed during the aftermath to assist motorists with returning home and to participate in the clean-up activities. Therefore gates were installed to reduce this large demand on public agency staff. However, Georgia and Virginia each plan to post staff at their gates rather than leave the gates and ramps unattended.

Recommendation

If ramps, for which gate installation is being considered, are in areas where the likelihood of their use is increased due to non-hurricane evacuation applications, e.g., common incident management events on high-volume facilities, then there may be merit in investing in ramp gates. However, if there are sufficient TxDOT and/or law enforcement vehicles available to physically block all the necessary ramps during a hurricane evacuation contraflow operation, then the need for ramp closure gates is questionable.

SIGNAL EQUIPMENT

Traffic signals that are equipped with uninterruptible power supplies (UPS) can operate for extended periods of time, e.g., four hours, after the hardwired electrical power system fails. A UPS is useful for any number of scenarios when power goes down, e.g., electrical service pedestal is damaged in a car crash, electrical storm, etc. The usefulness of a UPS is particularly great in the aftermath of a hurricane, when resources are spread very thin. Consequently, the difficult task of allocating limited field staff among the numerous critical tasks immediately after a hurricane can be helped if traffic signals are able to continue operation for a number of hours even when the local electrical power supply is temporarily disabled.

UPS allows the agency to defer the use of manual control, thereby stretching staff resources, if only temporarily. While manual control is superior to a signalized intersection without power, continued cycling operation, via UPS, is preferable.

Where signalized intersections have no power at all, manual control at major intersections facilitates traffic flow. Traffic signals can be equipped with manual switches that allow law enforcement personnel to operate the traffic signal equipment from the roadside, rather than from the middle of the intersection. These controls can reduce law enforcement staffing requirements at major intersections that would otherwise require multiple officers pulling traffic through.

Alabama DOT has begun a policy of installing permanently located generators at major signalized intersections in coastal areas, as part of routine traffic signal designs. Permanently located generators provide the benefit of not having to consume time and labor required to deploy a portable generator. Additionally, because such a generator is more securely situated than a generator chained to a pole, there is less likelihood of it being stolen in the storm’s aftermath when the public’s demand for generators is extremely high.

One state reported a theft problem with portable generators at traffic signals where a thief plugged an electric saw into the generator and then cut the chain that was used to secure the generator to the site; the thief then stole the generator. One remedy for this problem might include developing a lockable cage that is larger than the generator so that a thief could not reach the electrical outlet with the cord of the electric saw. Alternatively, it may be possible for a generator to be designed such that it is not susceptible to this type of theft. Additionally, the use of generators for operating traffic signals in the aftermath of a hurricane can introduce issues of refueling at a time when fuel is likely to be in scarce supply.

Light emitting diode traffic signal indications require significantly less power to operate and thus allow a traffic signal that is operating on a temporary power source to extend the duration of operation.

REMOTE REAL-TIME MONITORING

During evacuation, pre-deployed traffic data collection equipment and wireless network-based cameras allow DOT personnel to know, with certainty, whether labor-intensive evacuation tools, e.g., contraflow, are truly needed. As a means to limit field staffing requirements, remote real-time traffic monitoring provides traffic managers the means to observe traffic conditions at critical locations on evacuation routes. So doing allows them to make decisions about whether to implement contraflow and/or Evaculane operations or not. Real-time monitoring can be particularly useful when conditions motivate the media or political leaders to want to initiate contraflow even though the nature of the threatening storm may not necessitate it.

EMERGENCY CONTRACTS

An obvious method of supplementing in-house traffic operations labor resources is through the pre-storm letting of emergency contracts. In the case of hurricane evacuations and post-storm restoration, emergency contracts can be beneficial in addressing the need for traffic operations field staffing by supplementing the following activities:

- barricade and traffic control device deployment;
- courtesy patrol services;
- towing services;
- repair of signs, signals, ITS field devices, etc.;
- communications systems;
- electrical power generators; and
- supplies for in-house staff, e.g., food, water, ice, shelter, etc.

SIGNING

The use of folding signs along evacuation routes, especially on contraflow lanes and Evaculanes, can provide the static motorist information needed during an evacuation. Because these signs are permanently installed, there is a savings of manpower during the busy pre-storm preparation period. The signs will, of course, require labor resources to open them to be legible when needed; however, the person-hours used for this purpose are less than the requirement for deploying temporary traffic control signs for the same purpose. Additionally, because the folding signs' installations are permanent, and the sign locations have been observed over time by various TxDOT staff members during routine travel within the district, there is less likelihood that the signs are erroneously located than with temporary signs placed on barricades during the more tense days before the storm.

PRE-LOADED BARRICADE TRAILERS

Alabama DOT *(35)* conserves valuable person-hours during the busy pre-storm evacuation period by pre-loading barricade trailers with traffic control devices, e.g., signs, barricades, barrels, cones, etc. These trailers, as illustrated in Figure 9-9, are dedicated to evacuation plan use only and are stored in DOT maintenance facilities throughout affected districts. In addition to the savings of person-hours, this practice ensures the availability of traffic control devices for the evacuation. The trade-off with this practice is in the opportunity cost associated with the investment in equipment and trailers which are used in only rare occasions. Additionally, the dedicated trailers consume space within the maintenance facility. During an evacuation, these negatives will be overcome by the positives. This practice is recommended for TxDOT's consideration.

Figure 9-9. Dedicated Traffic Control Equipment *(35)*.

STAFF MANAGEMENT

During an evacuation, many field tasks are required to ensure efficient traffic operations on all evacuation routes, including contraflow and Evaculane routes. A number of these tasks require various levels of training and expertise. Cross-training in-house staff for some of the tasks that involve lower levels of training can benefit the department during an evacuation as well as during the post-storm recovery. This practice is particularly applicable for cross-training in-house staff whose normal duties are not critical during a time of emergency.

When planning work schedules for an emergency scenario, e.g., evacuation operations as well as post-storm recovery, there can be an inclination to call for "all hands on deck." While it is true that all staff members will need to pull together, it is important to schedule shift rotations so that staff receives sufficient rest between shifts.

It is important to maximize the availability of existing in-house staff as well as critical contractors. To ensure sustained availability of these labor resources the following recommendations are helpful:

- maintaining current contact information for each employee,
- creating a call-down procedure whereby each employee makes contact with a designated member of the staff after the storm, and
- requiring staff and contractors to call in to an out-of-area phone number to report their status after the storm.

OUTSIDE PERSONNEL

Some evacuation operations tasks, e.g., staffing contraflow ramp closures, may require staff from TxDOT and DPS. These available staffing levels may be supplemented by enlisting the assistance of other state agencies. For example, a contraflow ramp closure that would normally be staffed by a TxDOT or DPS employee could be staffed by a peace officer from another state agency, e.g., Department of Corrections, Forest Service, etc.

Redeploying out-of-district TxDOT staff to assist with the evacuation activities is another means of stretching departmental resources during such an emergency.

CHAPTER 10. CONTRAFLOW BROCHURES

During the Hurricane Rita evacuation, Texans were introduced to the first application of contraflow evacuation operations. Although the plans were largely developed during the approach of the threatening storm, and there were, to be sure, opportunities for improvements in the future of such operations, the contraflow operations did contribute to the safe evacuation of many from the Houston area. Thereafter, more thoroughly developed contraflow plans have been produced. To facilitate public understanding of these new contraflow routes, simple two-sided, tri-fold brochures were developed for five contraflow corridors. Appendix C illustrates English and Spanish language versions.

CHAPTER 11. CONTRAFLOW SIMULATION MODELS

GENERAL CHARACTERISTICS

Hurricane evacuation contraflow operations have been planned for several routes in Texas. Selected critical points on many of these routes are the subjects of traffic analyses. The models are not network models, but rather models of specific interchanges. The contraflow routes included in these analyses are listed in Table 11-1. CORSIM traffic modeling software was used to model multiple alternatives. The critical locations were selected during various meetings with Texas Department of Transportation and Department of Public Safety personnel. These locations are described in Table 11-1.

Table 11-1. Modeled Critical Points on Potential Contraflow Routes.

Contraflow Route	Critical Point	Input/Output/Intermediate
I-10	FM 359 (Brookshire)	Input
I-10	SH 36 (Sealy)	Input
I-10	SH 71 (Columbus)	Input
I-10	US 90/US 77 (Schulenburg)	Intermediate
I-10	Loop 1604 (San Antonio)	Output
I-37	Leopard St (Corpus Christi)	Input
I-37	US 77 South (Corpus Christi)	Input
I-37	US 77 North (Corpus Christi)	Input
I-45	FM 1488 (Shenandoah)	Input
I-45	FM 1791 (Huntsville)	Intermediate
I-45	SH 21 (Madisonville)	Intermediate
I-45	US 287 (Ennis)	Output
US 281	I-37 (Three Rivers)	Intermediate
US 290	Mueschke Rd (Cypress)	Input
US 290	SH 36 (Brenham)	Intermediate
US 69	US 59 (Lufkin)	Intermediate

For each model, a capacity of 1400 vehicles per hour was assumed. There is very little data available for establishing the capacity of a lane under mass evacuation conditions. However, this value is compatible with the throughput, under pressurized flow conditions observed on I-10, west of New Orleans, Louisiana, during the evacuation prior to Hurricane Katrina as well as on US 290 at Mueschke Road in Houston during the evacuation prior to Hurricane Rita in 2005. Capacity of contraflow crossover lanes is modeled at 1000 vehicles per hour.

The vehicle mix in all analyses assumes a 10 percent truck component. This value is higher than most roadways and is used to represent an expected high number of vehicles pulling trailers, as evacuees try to save their possessions, e.g., campers, boats, etc.

On controlled-access highways, the input demand at the upstream input point is assumed to exceed the capacity of the highway. At the next downstream point, the input traffic demands for the contraflow and non-contraflow lanes are assumed to be equal to the output generated from the immediately upstream point, e.g., the traffic flow rate departing Brookshire in the I-10 contraflow lanes is used as the input demand at the SH 36 interchange in Sealy. The justification for this is that the contraflow lanes are closed to entering or exiting traffic between these points.

I-10 (Houston to San Antonio)

Input Point at FM 359 in Brookshire, Texas

Westbound I-10 traffic from Houston travels on at least four lanes as far as Katy, Texas. As westbound traffic continues approximately eight miles to Brookshire, Texas, the number of westbound lanes drops to two near the interchange with FM 359. During an evacuation, the effective four westbound lanes can continue from Katy to Brookshire by converting a shoulder into an evacuation lane. To continue providing four moving lanes of evacuating traffic beyond the lane drop in Brookshire, a contraflow operation must begin at this point. The concept is to remove a sufficiently lengthy portion of the existing concrete traffic barrier near the existing lane drop, thereby shifting two westbound lanes across the median into the contraflow lanes and traffic in the remaining two westbound lanes can continue in the two available lanes that continue west from Brookshire toward San Antonio. Figure 11-1 illustrates this location.

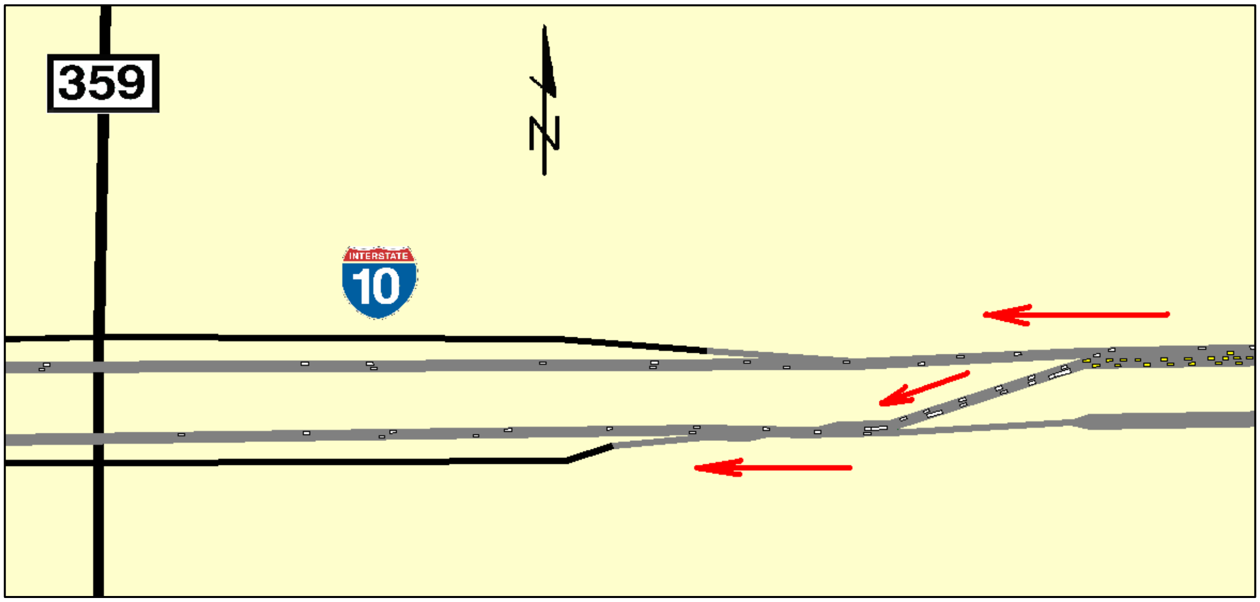


Figure 11-1. I-10 Contraflow Input at Brookshire, Texas.

Table 11-2 indicates the results of a CORSIM analysis of this crossover. The throughput represents the number of vehicles per hour that emerge from this input point. The use of contraflow represents an approximate doubling of the number of vehicles that can proceed west beyond FM 359.

Table 11-2. Vehicular Throughput (vph) on I-10 at Brookshire, Texas.

	Throughput, vph
Normal Westbound Lanes	1628
Contraflow Lanes	1724
Total	3352

Input Point at SH 36 in Sealy, Texas

Approximately 31 miles west of Brookshire on I-10 is the SH 36 interchange in Sealy, Texas. Traffic approaching I-10 from the south on SH 36 is allowed to enter the evacuation lanes on I-10.

Figure 11-2 shows a scenario (Double Entry) in which northbound traffic may enter the contraflow lanes and may cross under I-10 and enter the westbound lanes on the north side of the median. Table 11-3 summarizes the vehicular throughput for this operational concept; it also shows the throughput for a scenario (Single Entry) in which northbound traffic is directed only into the contraflow lanes, but not the normal westbound lanes. The data in the table indicate that the number of vehicles departing Sealy is at its maximum regardless of whether northbound SH 36 traffic enters at one or two points into I-10. Clearly, if there is only one entry into I-10 in Sealy, the long northbound queue is longer than if there are two entries.

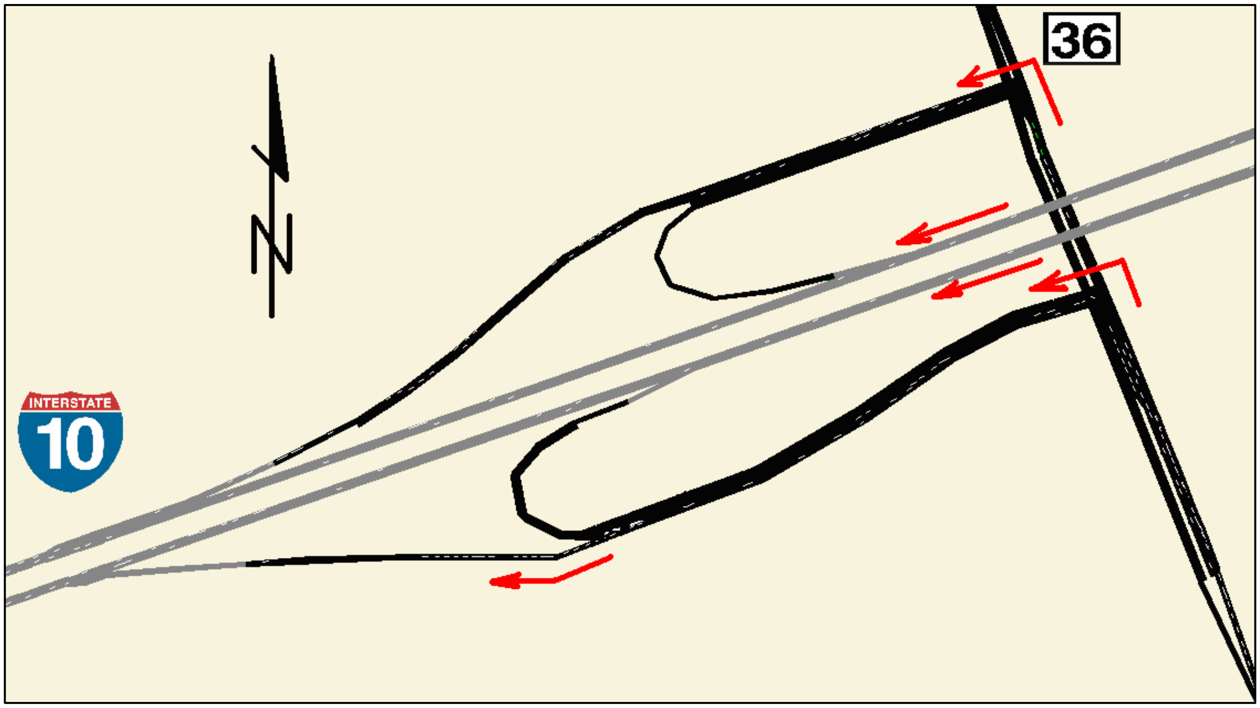


Figure 11-2. I-10 Contraflow Input at SH 36 in Sealy, Texas.

Table 11-3. Vehicular Throughput (vph) on I-10 at SH 36 in Sealy, Texas.

	Throughput, vph	
	Single Entry	**Double Entry**
Normal Westbound Lanes	2602	2643
Contraflow Lanes	2618	2625
Total	5220	5268

Input Point at SH 71 in Columbus, Texas

A third input point on I-10 between Houston and San Antonio is in Columbus, Texas, at SH 71. Similar to the concept for Sealy, there are two scenarios whereby northbound SH 71 traffic may enter the contraflow and may or may not be able to enter the normal westbound lanes. Figure 11-3 shows the option for feeding both sides of I-10. Table 11-4 reflects the results of the CORSIM model for this interchange. As with the Sealy example, the throughput in Columbus is essentially the same regardless of whether one or two ramps are available for accessing I-10.

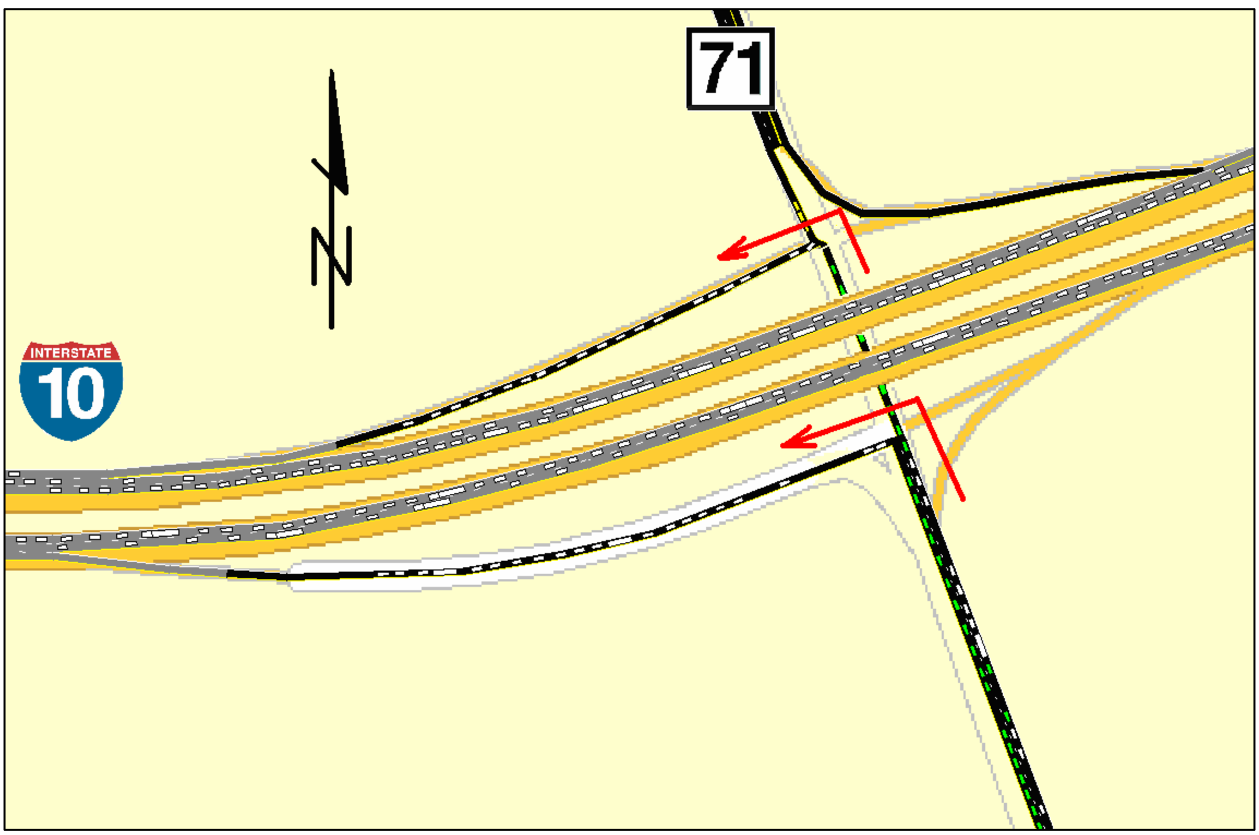


Figure 11-3. I-10 Contraflow Input at SH 71 in Columbus, Texas.

Table 11-4. Vehicular Throughput (vph) on I-10 at SH 71 in Columbus, Texas.

	Throughput, vph	
	Single Entry	**Double Entry**
Normal Westbound Lanes	2599	2662
Contraflow Lanes	2651	2617
Total	5250	5279

Intermediate Point in Schulenburg, Texas

Schulenburg, Texas, has several fuel stations. The plan provides for evacuating traffic to exit I-10 from either side of the median at the US 77 interchange; however, if this interchange congests significantly, evacuating traffic can access Schulenburg via the US 90 interchange east of the city. Traffic from the contraflow and non-contraflow lanes will be allowed to access downtown Schulenburg via westbound US 90, turning north onto US 77 and then back onto the contraflow and non-contraflow lanes at the I-10 interchange with US 77. There are several fuel retail businesses on US 77, north and south of I-10. Figure 11-4 depicts the routing in this area.

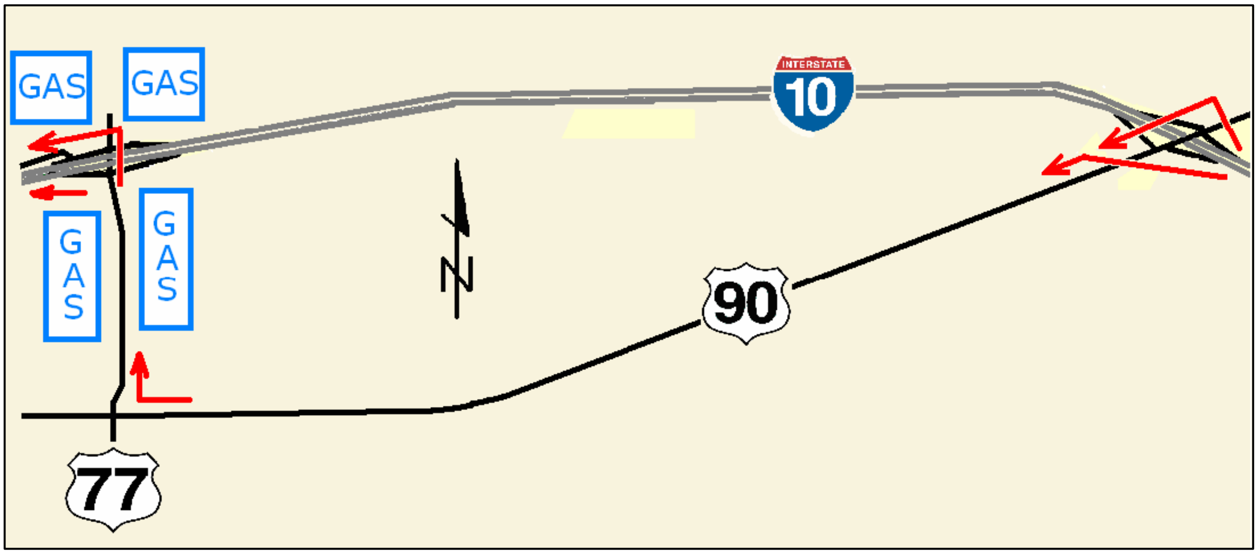


Figure 11-4. I-10 Access to Motorist Services in Schulenburg, Texas.

It is assumed that US 90 will not be carrying full capacity traffic from the east toward Schulenburg. During the 2005 evacuation for Hurricane Rita, there was not a great deal of evacuation traffic on this route in Schulenburg.

Table 11-5 shows the number of vehicles per hour that emerge from the Schulenburg area depending on the percentage of traffic that chooses to leave I-10 for motorist services prior to returning to the freeway. Because the duration of stops that evacuating motorists may make in Schulenburg is unknown and variable, this analysis does not reflect delays created at any gas stations or other retail businesses. The analysis assumes that the number of vehicles per hour that exit I-10 in this community and receive motorist services is the same number that re-enter the freeway. Not surprisingly, as the percentage of vehicles that get off and on I-10 increases, the throughput at the west end decreases. This is largely due to queues on the westbound exit ramp to US 77; as the portion of the exiting vehicles is varied up to 40 percent, this queuing increase constricts the throughput on the normal westbound lanes.

Table 11-5. Vehicular Throughput (vph) on I-10 at US 77 and US 90 in Schulenburg, Texas.

Portion of Exiting Vehicles:	(10%)	(25%)	(40%)
Normal Westbound Lanes	2483	1555	911
Contraflow Lanes	2406	2387	2378
Total	4889	3942	3289

Terminus at Loop 1604 in San Antonio, Texas

TxDOT's plan is to terminate I-10 contraflow at Loop 1604. The existing eastbound entrance ramp will be widened to accommodate two lanes. In contraflow operations, the widened ramp allows both contraflow lanes to exit the freeway. At the frontage road intersection with Loop 1604, left lane traffic will be forced to turn left, and right lane traffic will be forced right. The model assumes that all local traffic will be turned away from this interchange some miles away so that evacuating traffic will be able to flow as freely as possible within the geometric constraints of the route. Figure 11-5 illustrates this interchange and the evacuation traffic flow. Table 11-6 summarizes the throughput at this I-10 contraflow output point.

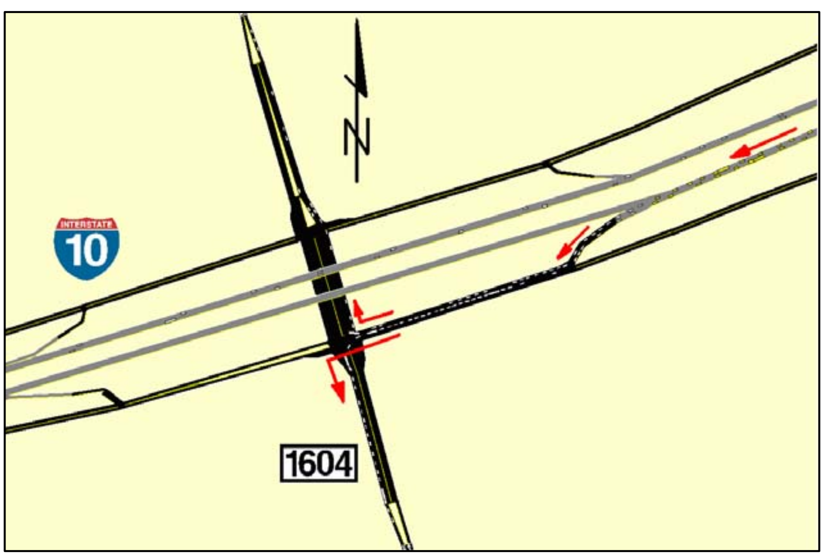


Figure 11-5. I-10 Contraflow Terminus at Loop 1604 in San Antonio, Texas.

Table 11-6. Vehicular Throughput (vph) on I-10 at Loop 1604 in San Antonio, Texas.

	Throughput, vph
Normal Westbound Lanes	2519
Northbound Loop 1604	1006
Southbound Loop 1604	976
Total	4501

I-410 in San Antonio, Texas

Researchers developed a final CORSIM model for I-10 for the I-410 interchange on the east side of San Antonio. This intersection is where all eastbound mainlane traffic is redirected so that there is no eastbound traffic at Loop 1604 to conflict with contraflow traffic. There is no contraflow operation at this interchange. The I-410 interchange will receive the westbound non-contraflow evacuation traffic, which will disperse among the northbound, westbound, and southbound directions. Figure 11-6 and Table 11-7 represent this interchange. As depicted in the figure, the eastbound approach to the interchange experiences significant queues as all traffic must exit.

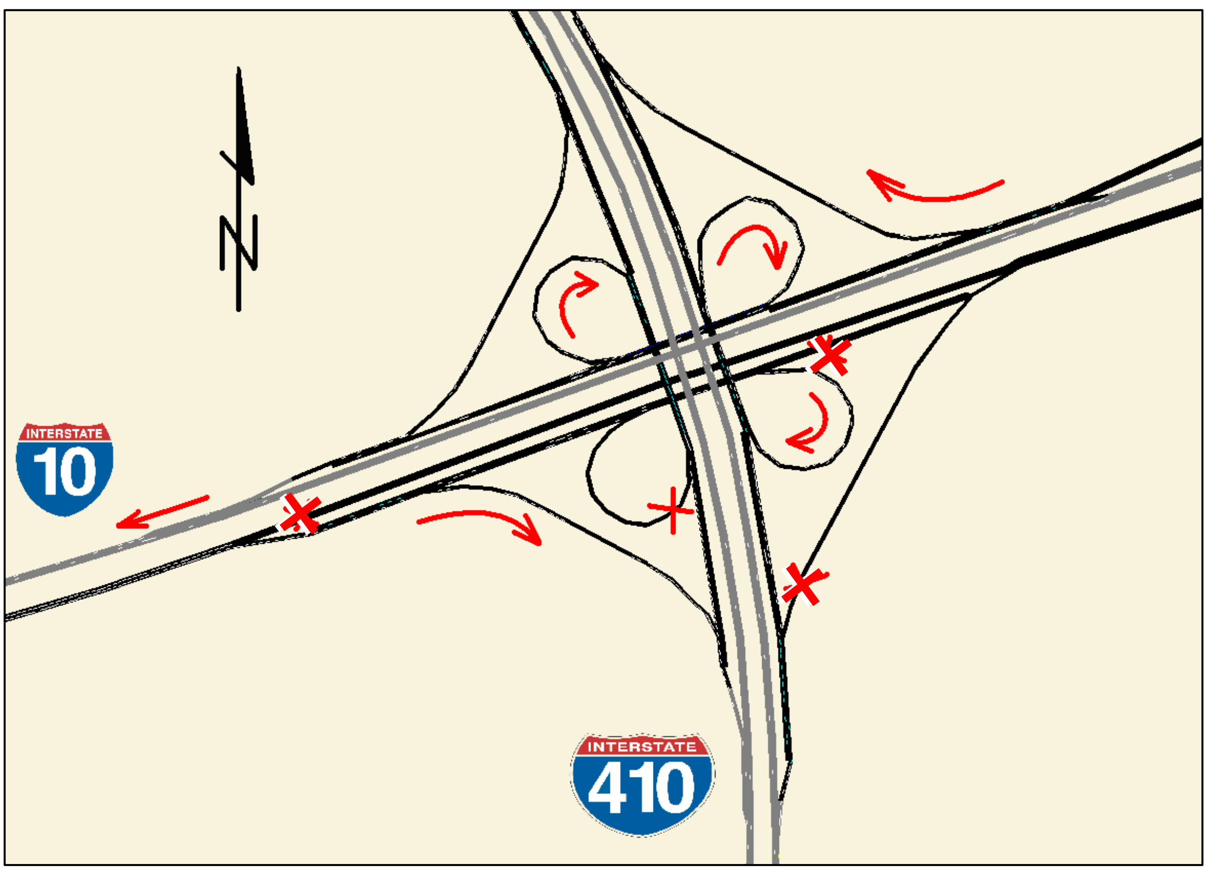


Figure 11-6. I-10 at I-410 in San Antonio, Texas.

Table 11-7. Vehicular Throughput (vph) on I-10 at I-410 in San Antonio, Texas.

	Throughput, vph
Westbound I-10	2664
Northbound I-410	2291
Southbound I-410	2514
Total	7469

I-37 (Corpus Christi)

Contraflow plans have been developed and reported for this corridor in previous years. The analysis herein was aimed at maximizing the throughput on I-37 through the use of contraflow and/or Evaculane operations and the use of multiple input points. In a previous year, TxDOT constructed a contraflow crossover at the US 77 North interchange, as shown in Figure 11-7. Alternatives have been developed to evaluate possible enhancements to the task of loading the contraflow lanes. Additionally, simulation models were developed that included contraflow and Evaculane operation on I-37.

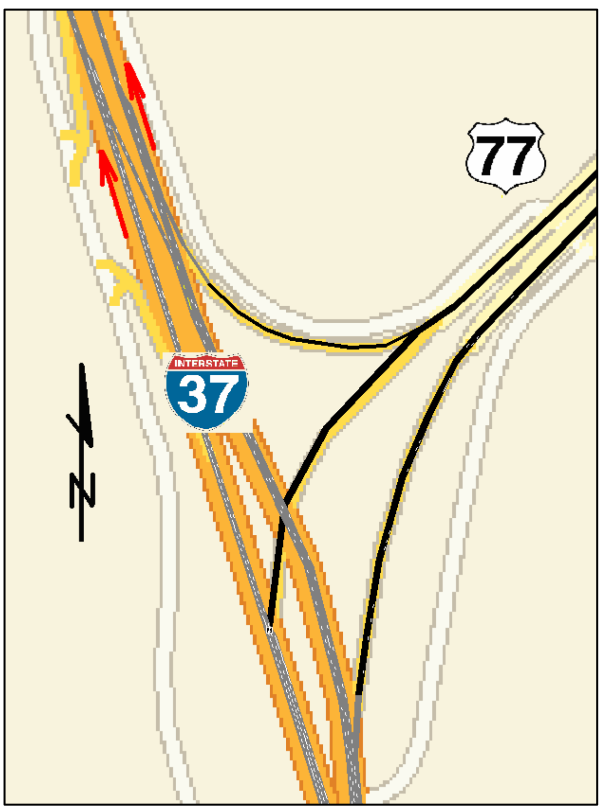


Figure 11-7. I-37 Contraflow Input from US 77 North Interchange.

2006 Contraflow Only Plan

The first model reflects existing geometry, i.e., the only place to feed traffic onto the contraflow side is from the existing crossover, north of the US 77 N interchange, as shown in Figure 11-7. This geometry includes three northbound lanes approaching the two-lane crossover. North of this point, there are two lanes on the northbound side plus two lanes on the contraflow side. This is essentially the 2006 contraflow plan. South of the crossover there are three northbound lanes feeding four lanes. The Evaculane is not included north of the existing crossover. The results of this model show a total throughput of 3775 vph, or 944 vph per lane. This value is less than the theoretical maximum capacity of 1400 vph per lane for evacuation traffic. In this model, the link with the slowest speed operates at 4 mph; 41 percent of the links in the network operate at speeds below 30 mph.

Contraflow + Evaculane

The next alternative is the same as the first with the exception that the Evaculane extends well into the San Antonio District. Of course, this means that the northbound side has three lanes, and the contraflow side has two lanes. This model produces essentially the same throughput (3711 vph) as the first. This is because the link south of the crossover is carrying three lanes (two normal lanes + Evaculane), and it is trying to feed the two-lane crossover to the contraflow and the three northbound lanes. Three lanes cannot feed five lanes in this version any better than in the first alternative. In this model, the link with the slowest speed operates at 4 mph; 39 percent of the links in the network operate at speeds below 30 mph.

In these first two I-37 alternatives, the three lanes south of the crossover are the constraining factor.

2006 Evaculane Only Plan

This alternative involves no contraflow. The I-37 Evaculane begins at SH 358 and extends toward San Antonio, as planned for the 2006 hurricane season. The throughput for this alternative is 3914 vph. This is an average of 1300 vph per lane. In this model, the link with the slowest speed operates at 5 mph; 41 percent of the links in the network operate at speeds below 30 mph.

The models indicate that the Evaculane Only plan produces 4 percent greater throughput (3914 vph) than the Contraflow Only plan (3775 vph), even though the contraflow plan has one lane more than the Evaculane plan. Again, both of these plans are constrained by the three-lane section that feeds them. So why then do they not produce the same throughput, i.e., why the 4 percent difference? Further review of the models indicates that the small difference results from lane changing upstream of the existing crossover. With the contraflow plan, there is a little bit of turbulence in the traffic stream as motorists jockey for position on the approach to the crossover.

Maximum Throughput

The most effective alternatives are those that reach almost 7000 vph, i.e., five lanes with a capacity of 1400 vph each. This result is achieved by the following:

- feeding contraflow from
  - SH 358 using hairpin turn from northbound frontage road, as shown in Figure 11-8;
  - Leopard Street ramp, as shown in Figure 11-9; and
  - circuitous route from northbound US 77/FM 624, via Up River Road bridge, northbound I-37 frontage road, and Sharpsburg Rd; and
- closing the existing crossover at US 77 N.

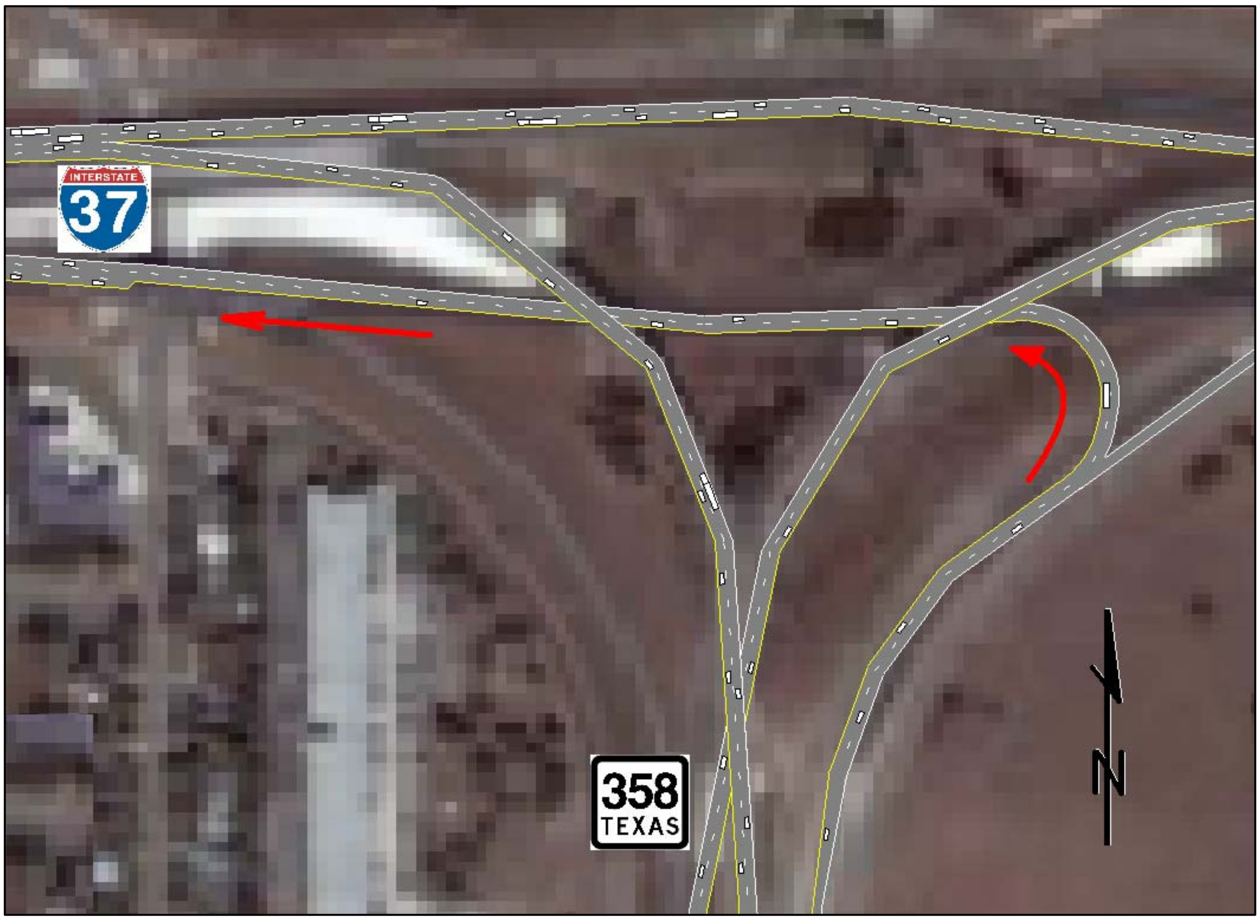


Figure 11-8. Special Contraflow Ramp from SH 358 onto I-37.

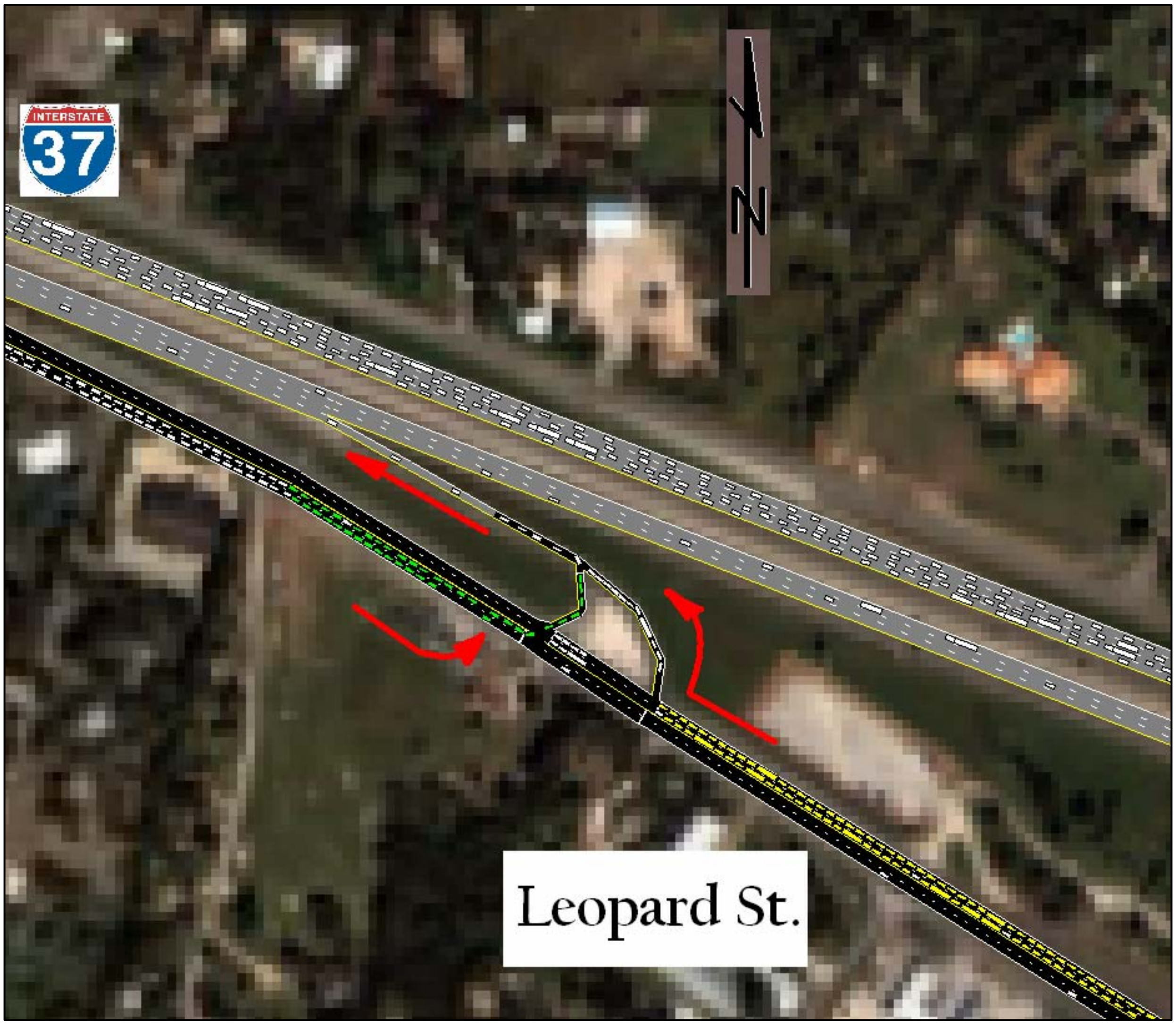


Figure 11-9. I-37 Contraflow Input from Leopard Street.

The results of this alternative include a throughput of 6930 vph, as shown in Table 11-8. The slowest link in this alternative is a 3-mph link on the merge from northbound US 77 onto northbound I-37; 29 percent of the freeway links are traveling at speeds under 30 mph.

Another alternative that produces the same throughput (6930 vph) is using this same geometry, but closing the northbound US 77 connection to northbound I-37. All the northbound US 77 traffic can be directed onto the frontage road to the Up River Road bridge, etc., as described above. Although the throughput is unchanged, the link with the slowest speed is now the northbound I-37 entrance ramp from Sharpsburg Rd. This speed is 10 mph; 17 percent of the freeway links are traveling at speeds below 30 mph.

Table 11-8. Vehicular Throughput (vph) of I-37 Alternatives, Corpus Christi, Texas.

Alternative	Throughput (as measured N. of US 77 N), vph
Contraflow Only (from US 77 North Crossover)	3775
Contraflow (from US 77 North Crossover) + Evaculane	3711
Evaculane Only (beginning from SH 358)	3914
Contraflow fed from - SH 358, - Leopard St, and - US 77 South.	6930

I-45 (Houston toward Dallas)

Input Point at FM 1488 in Shenandoah, Texas

I-45 from Houston carries four northbound lanes toward FM 1488 in Shenandoah, Texas. Due to a construction work zone, from there only two northbound lanes currently extend to the north. As with the Hurricane Rita evacuation, traffic on two of the four lanes can be directed across the median, via removal of a lengthy portion of concrete median barrier, and continue to the north in contraflow lanes toward Dallas. Figure 11-10 illustrates this location.

Table 11-9 indicates the results of a CORSIM analysis of this crossover. The northbound traffic on both sides of the median combine to approximately 4200 vehicles per hour traveling north from this input point.

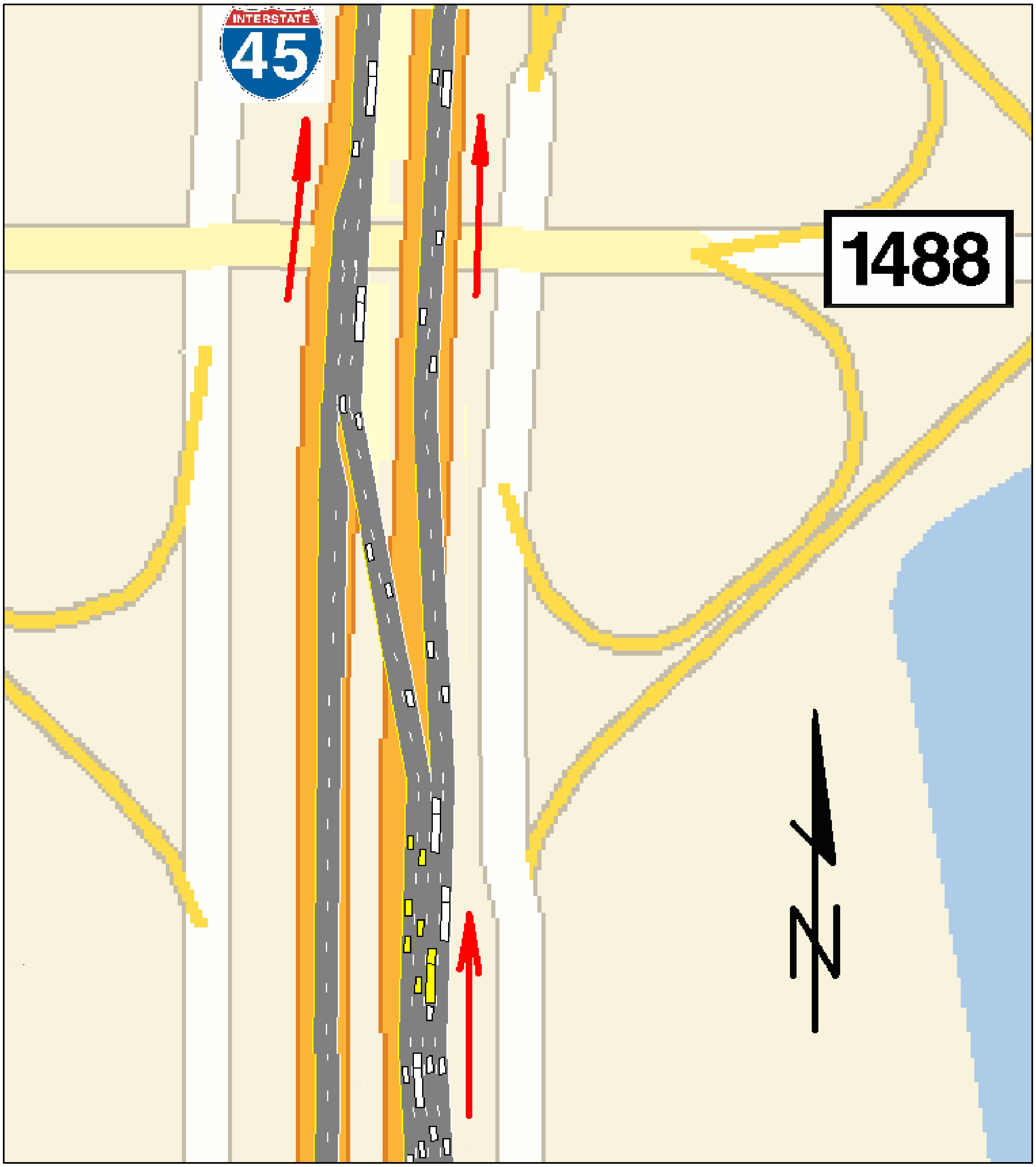


Figure 11-10. I-45 Contraflow Input from FM 1488 in Shenandoah, Texas.

Table 11-9. Vehicular Throughput (vph) on I-45 at FM 1488 in Shenandoah, Texas.

	Throughput, vph
Normal Northbound Lanes	2155
Contraflow Lanes	2058
Total	4213

Intermediate Point at FM 1791 in Huntsville, Texas

The plan for I-45 includes two intermediate points for evacuating traffic to exit and re-enter the freeway to access motorist services. The first of these points is at FM 1791 in Huntsville, Texas, as shown in Figure 11-11. As with the similar function on I-10 at Schulenburg, this analysis assumes that the number of motorists that exit in Huntsville is the same as that which re-enter per hour. Again, with a smaller percentage departing the freeway mainlanes, a greater number of vehicles can move through the interchange per hour, as identified in Table 11-10. However, with a less circuitous route, relative to Schulenburg, the differences are small.

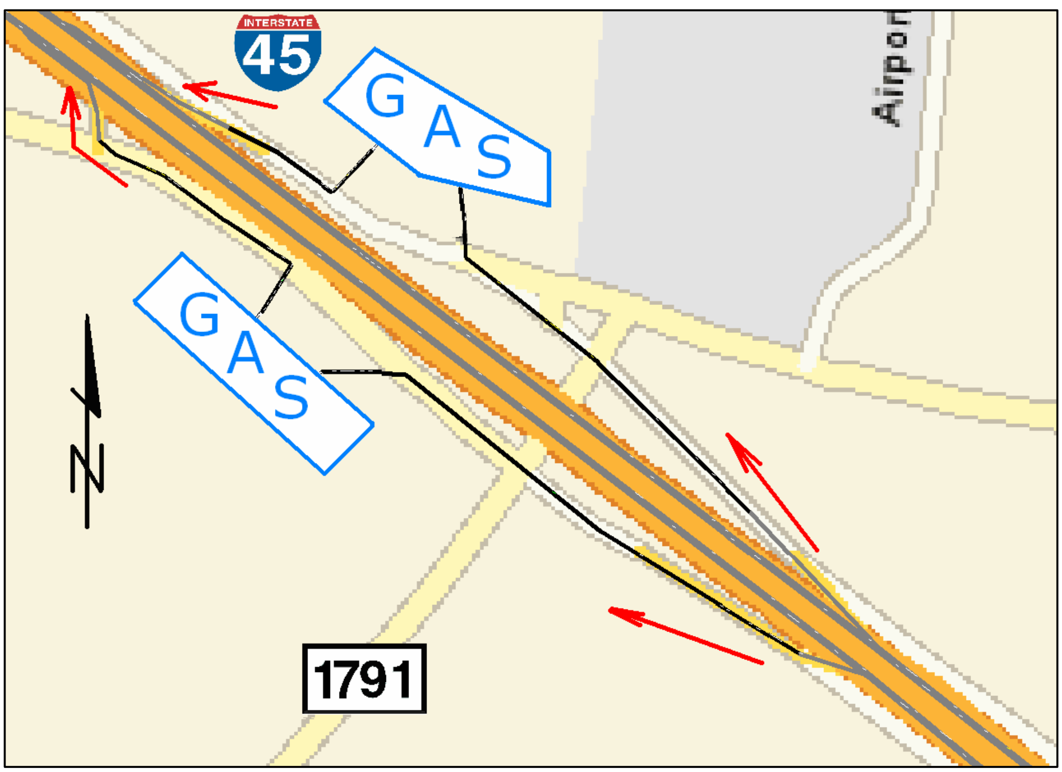


Figure 11-11. I-45 Access to Motorist Services in Huntsville, Texas.

Table 11-10. Vehicular Throughput (vph) on I-45 at FM 1791 in Huntsville, Texas.

Portion of Exiting Vehicles:	**(10%)**	**(25%)**	**(40%)**
Normal Northbound Lanes	2154	2130	2116
Contraflow Lanes	2034	2029	2001
Total	4191	4159	4117

Intermediate Point at SH 21 in Madisonville, Texas

The second location for which the contraflow motorists, as well as those in the normal northbound lanes, can access local retail businesses is at the SH 21 interchange in Madisonville, Texas, as shown in Figure 11-12. The throughput results of the analysis of this location are shown in Table 11-11. To provide adequate storage on the frontage roads for vehicles exiting I-45 at this location, it has been recommended that temporary ramps be constructed approximately two miles south of SH 21, near Boyd Road.

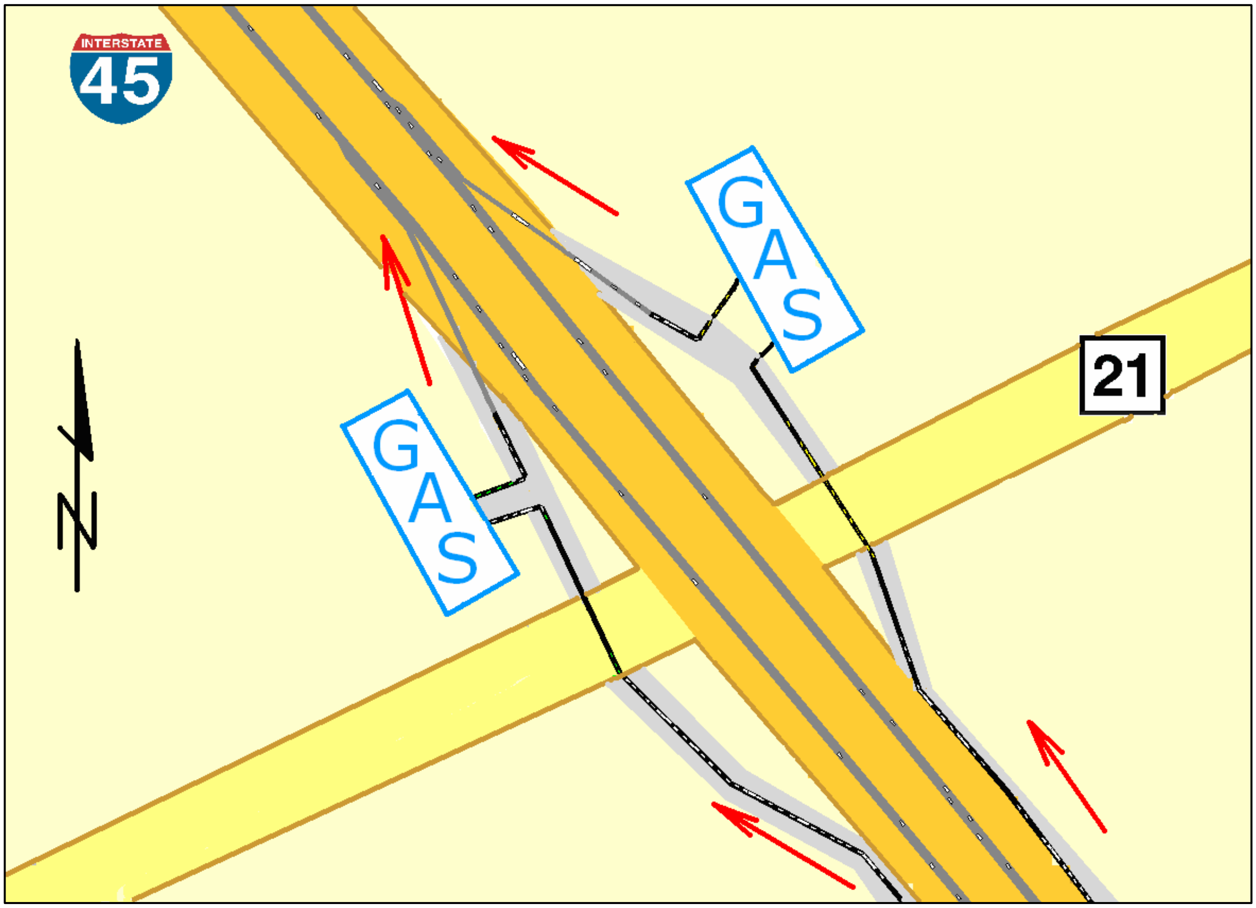


Figure 11-12. I-45 Access to Motorist Services in Madisonville, Texas.

Table 11-11. Vehicular Throughput (vph) on I-45 at SH 21 in Madisonville, Texas.

Portion of Exiting Vehicles:	(10%)	(25%)	(40%)
Normal Northbound Lanes	1969	1903	1796
Contraflow Lanes	1870	1782	1712
Total	3839	3685	3508

Terminus at US 287 near Ennis, Texas

Just south of Ennis, I-45 interchanges with US 287, which connects with the western portion of the Dallas-Fort Worth Metroplex, and can therefore be useful in distributing evacuation traffic. The northbound approach to this interchange includes three lanes on each side of the median, a one-lane exit ramp to westbound US 287, and a ramp from the contraflow lanes to westbound US 287. The traffic that takes this latter ramp later merges via a one-lane contraflow crossover with the traffic that takes the former ramp, as shown in Figure 11-13. Immediately downstream of the US 287 interchange, the remaining contraflow traffic uses another crossover to access the normal northbound lanes and merge with the remaining traffic in the normal northbound lanes. North and west of this location, all evacuation traffic continues without further use of contraflow lanes. Table 11-12 quantifies the hourly volume of evacuating traffic that can depart from this interchange, downstream of the contraflow terminus.

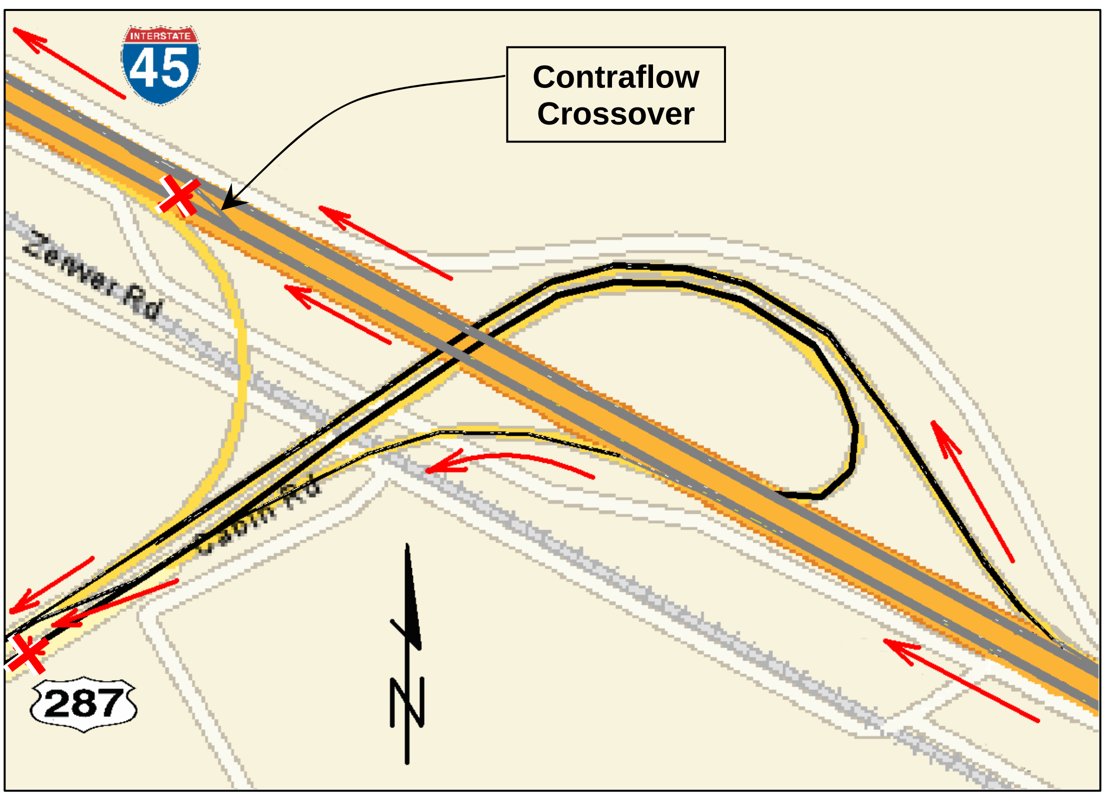


Figure 11-13. I-45 Contraflow Terminus at US 287 in Ennis, Texas.

Table 11-12. Vehicular Throughput (vph) on I-45 at US 287 in Ennis, Texas.

	Throughput, vph
Normal Northbound Lanes	2250
Westbound US 287	1364
Total	3614

US 290 (Houston toward Austin)

Input Point at Mueschke Road in Houston, Texas

Motorists traveling to the west on US 290 in Houston encounter a lane drop near the Mueschke Road interchange. The three westbound lanes merge into two lanes. During an emergency evacuation, traffic can use these three lanes, plus one shoulder, thereby evacuating in four effective lanes. At the lane drop, the contraflow plan can direct two of these four lanes across the median, with the removal of a lengthy portion of concrete traffic barrier, and then operate two westbound normal lanes and two westbound contraflow lanes, as shown in Figure 11-14. This configuration can move approximately 4600 vehicles per hour toward Hempstead, Texas, as shown in Table 11-13.

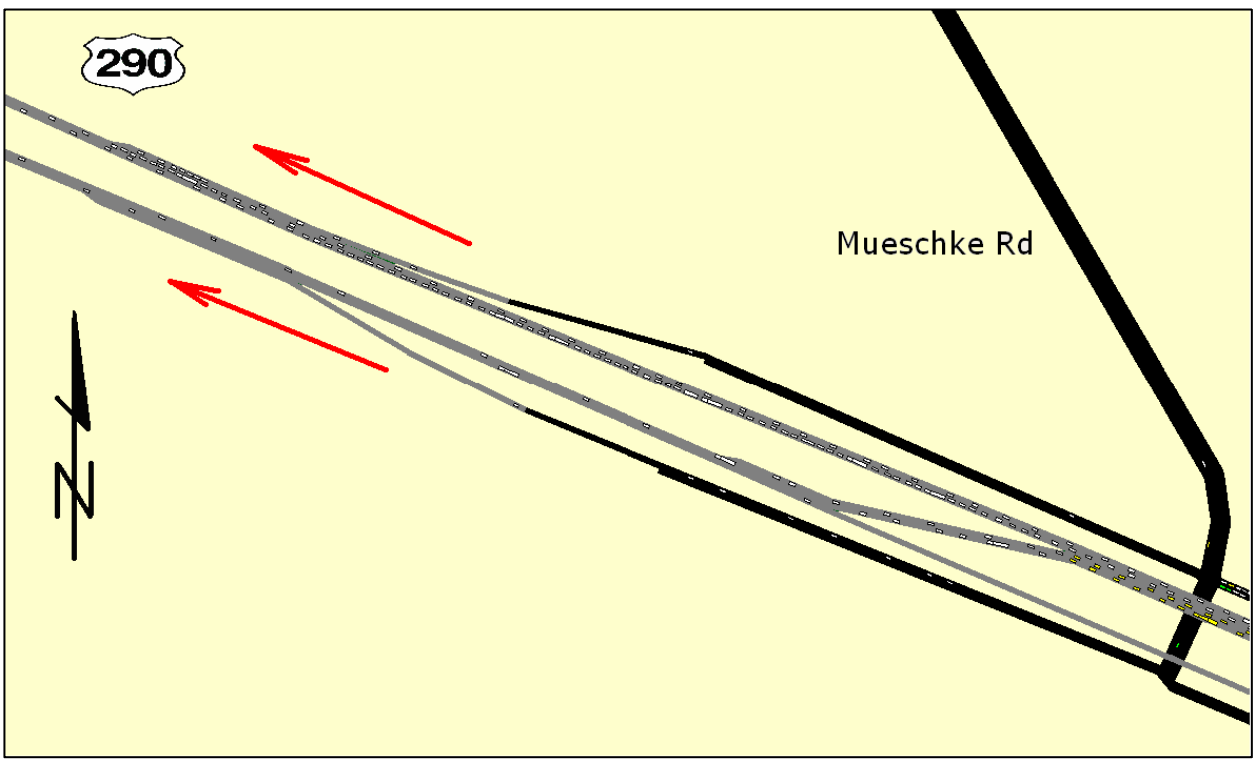


Figure 11-14. Contraflow Crossover on US 290 at Mueschke Road in Houston, Texas.

Table 11-13. Vehicular Throughput (vph) on US 290 at Mueschke Road in Houston, Texas.

	Throughput, vph
Normal Westbound Lanes	2701
Contraflow Lanes	1915
Total	4616

US 290 at SH 36 in Brenham, Texas

US 290, between Mueschke Road and Austin, Texas, has two lanes in each direction, with the notable exception of a short portion in Brenham, Texas. This analysis examines alternatives for processing evacuation traffic at this geometrically constrained location, which was one of the key sites specified in the Governor's Executive Order as in need of "short- and long-term solutions to reduce congestion." The bottleneck is where the two westbound lanes of US 290 are reduced to a single-lane ramp within the partial cloverleaf interchange at SH 36 on the west side of Brenham. The one-lane ramp is located in the northeast quadrant of the interchange.

Brenham Interchange Alternatives

Multiple alternatives for the Brenham interchange are described in Table 11-14. Alternative A reflects existing conditions, as depicted in Figure 11-15. In this alternative, all westbound traffic approaching the interchange from the center of the city, crossing Dixie Street, is forced to turn right onto northbound SH 36, thereby minimizing conflicts with the primary evacuation route. In the figure, this is illustrated by an "X" indicating a road closure.

Table 11-14. Interchange Operational and Geometric Alternatives.

Alternative	Geometry	Evacuating Traffic
A	Existing Geometry	2 lanes (normal side lanes)
B	1 Additional Evacuation Ramp	2 lanes (normal side lanes)
C	Existing Geometry	4 lanes (contraflow)
D	2 Additional Evacuation Ramps	4 lanes (contraflow)
E	1 Additional Evacuation Ramp	2 Westbound + Evaculane
F	2 Additional Evacuation Ramps	2 Westbound + Evaculane

Alternative B provides an additional path for the normal westbound traffic, thereby providing two lanes through the interchange for the two normal side lanes of evacuation traffic; this geometry is shown in Figure 11-16. Under this scenario, both northbound exit ramps will direct traffic into the westbound direction. This alternative will require the construction of an "evacuation ramp" in the southeast quadrant of the interchange. Traffic using this new pavement will travel across the eastbound lanes. Therefore, to minimize conflicts at this intersection, all eastbound traffic approaching the interchange will be directed onto the southbound ramp. Additionally, all westbound traffic coming toward the interchange from the center of the city will be forced to turn right and travel northbound on SH 36. These mandatory turns prohibit ancillary traffic from conflicting with evacuation route traffic, as indicated by the red X's in the figure.

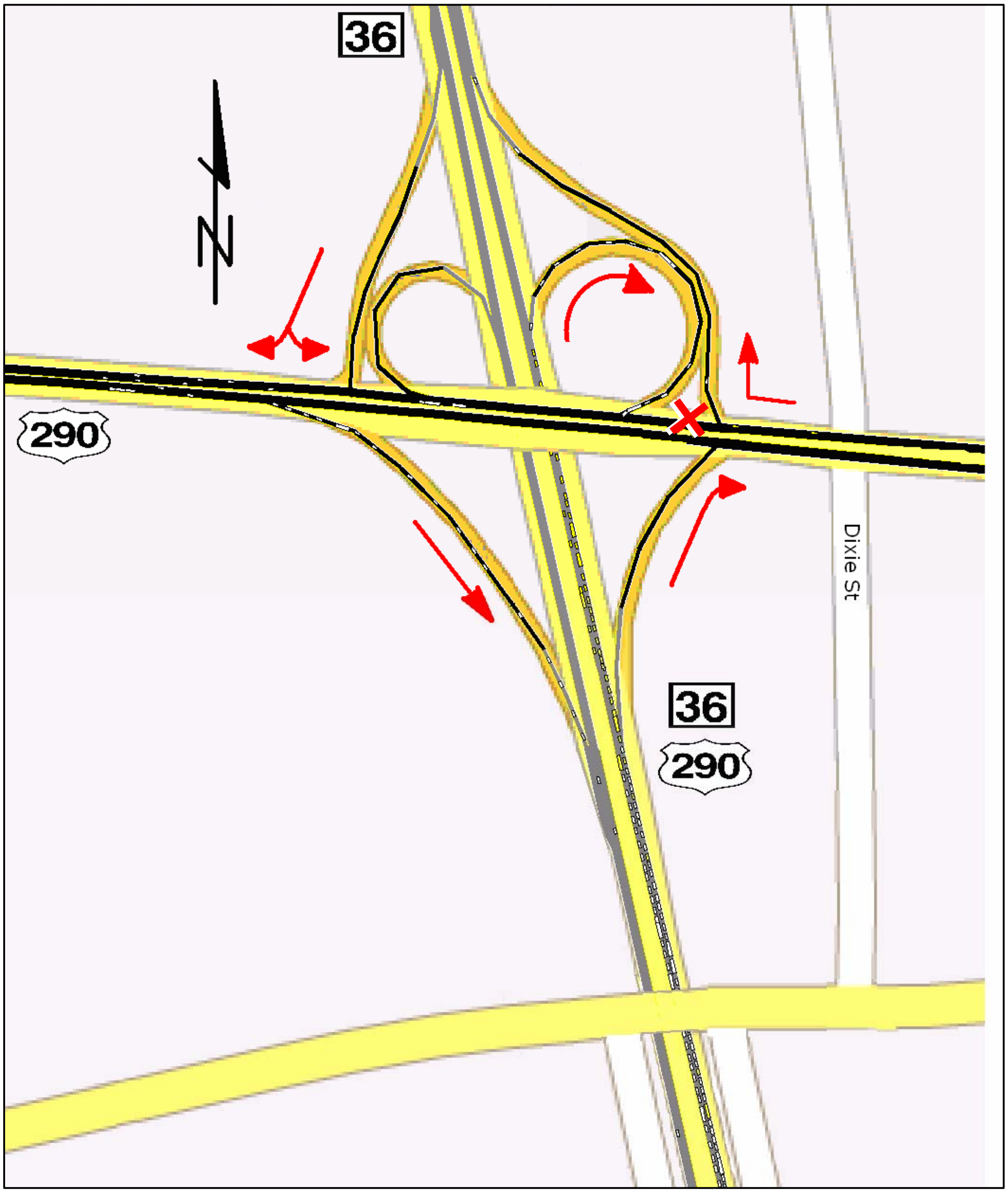


Figure 11-15. Alternative A: Existing Geometry without Contraflow.

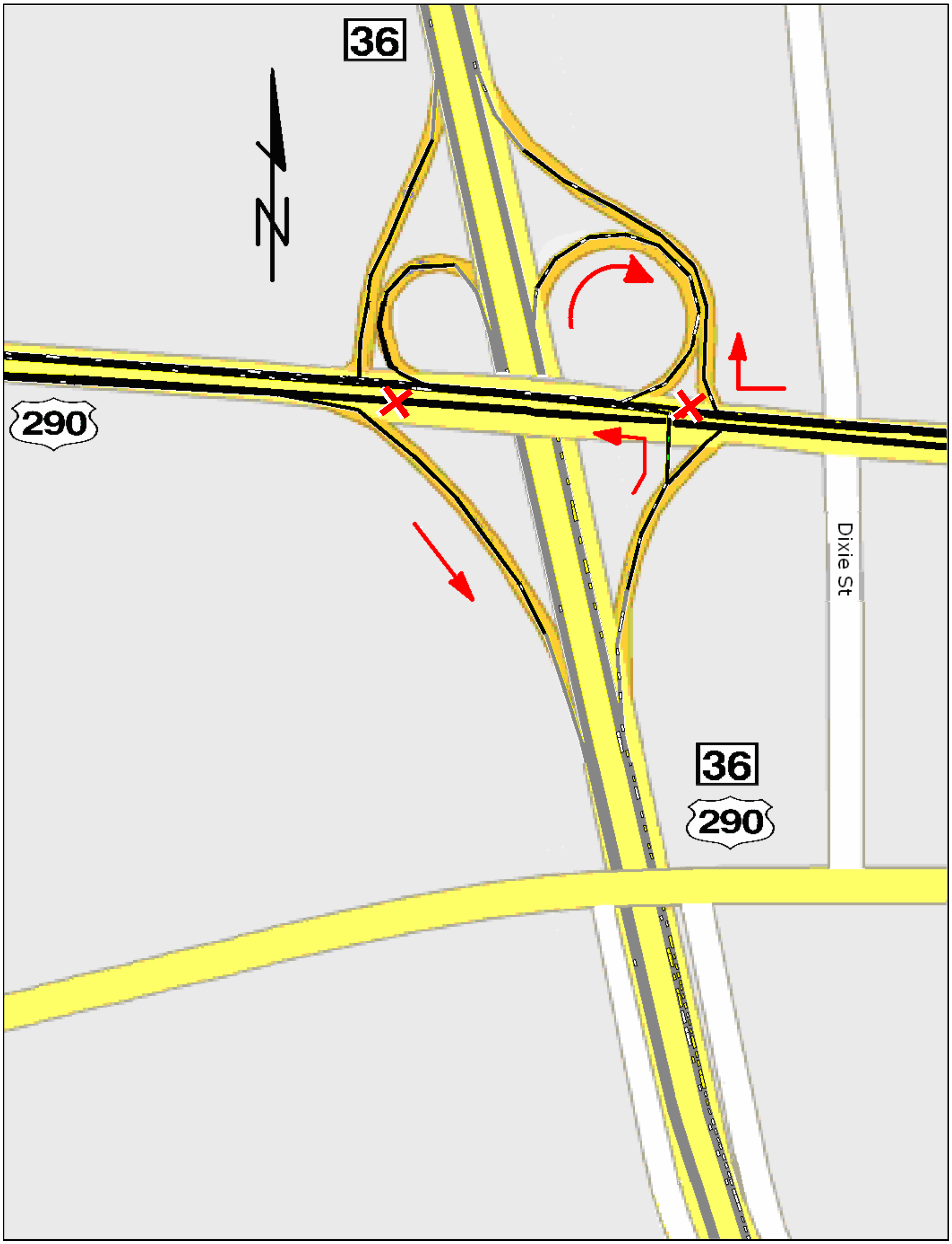


Figure 11-16. Alternative B: One Additional Ramp without Contraflow.

If US 290 is operating in contraflow from the Houston area into Brenham, then this interchange will receive four lanes of traffic from the south. Figure 11-17 depicts Alternative C, which merges both contraflow lanes into the single-lane ramp in the southwest quadrant of the interchange to access westbound lanes; also, both non-contraflow lanes will merge into the single-lane cloverleaf in the northeast quadrant, as is normally done. As with the previously described alternatives, all westbound approach traffic coming from the city of Brenham will be turned right onto northbound SH 36 so they will not conflict with evacuation traffic.

Alternative D, as shown in Figure 11-18, shows contraflow operation using proposed additional ramps in the southeast and northwest quadrants. The "evacuation ramp" in the southeast quadrant is the same as that in Alternative B, except that the northbound traffic that turns left in Alternative D does not cross into the normal westbound lanes on the east-west highway, but rather into the contraflow lanes. More specifically, this left-turning traffic turns into the inside lane on the contraflow side, so that when this traffic arrives at the merge point on the west side of the interchange, it does not conflict with the traffic entering from the south. On the north half of the interchange, a similar separation of entering traffic streams is modeled. That is, traffic using the cloverleaf ramp in the northeast quadrant is directed into the inside westbound lane and traffic using the other cloverleaf ramp is directed into the outside westbound lane. An unintended effect of this alternative is that half of the traffic entering the interchange in a northbound contraflow lane emerges as a non-contraflow vehicle and, conversely, half of the traffic entering the interchange in the normal northbound lanes emerges as a westbound contraflow vehicle.

Alternative E, shown in Figure 11-19, has one evacuation ramp in the northwest quadrant. The contraflow lanes on the west leg merge into one and traffic then follows a one-lane crossover that carries contraflow traffic back to the normal westbound side of the divided highway. In addition, this leg also introduces the use of the shoulder for moving an additional lane of traffic; this is referred to as an Evaculane. The result is that contraflow operations end here, and traffic traveling west from this interchange does so in three lanes: the two normal westbound lanes and the adjacent shoulder (Evaculane).

Alternative F is illustrated in Figure 11-20. It is the same as Alternative E, except that there are two evacuation ramps, as described with Alternative D.

The traffic demand for each alternative is assumed to be larger than the mainlanes of US 290. Therefore, the capacity of these mainlanes meters the flow that enters the interchange. Ultimately, the most meaningful measure of effectiveness in this analysis is the vehicular throughput in the westbound direction, west of the interchange. Mainlane and ramp capacities of 1400 veh/hour and a truck contingent of 10 percent are assumed. This large truck percentage is intended to represent evacuees pulling trailers or boats.

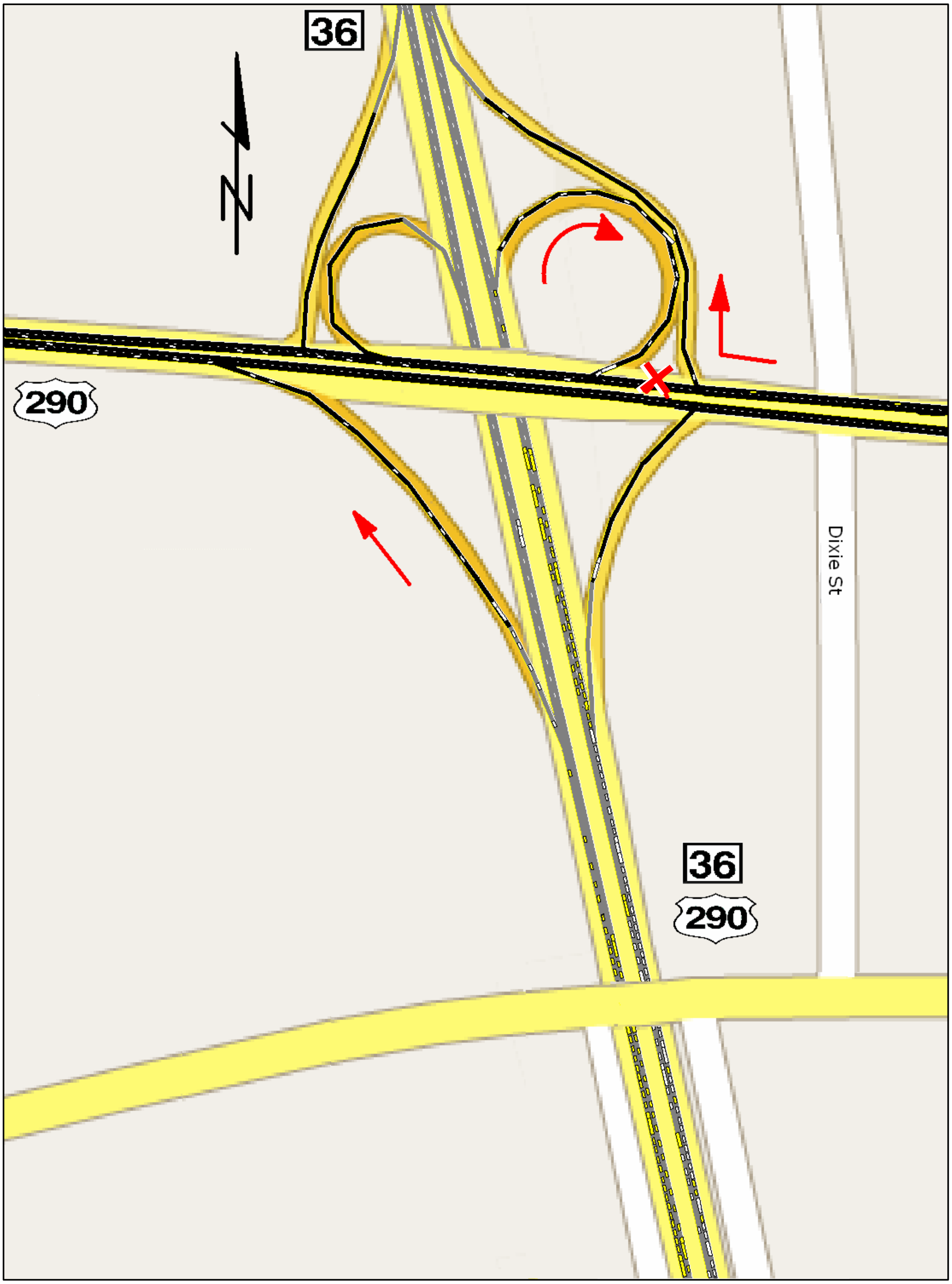


Figure 11-17. Alternative C: Existing Geometry with Contraflow.

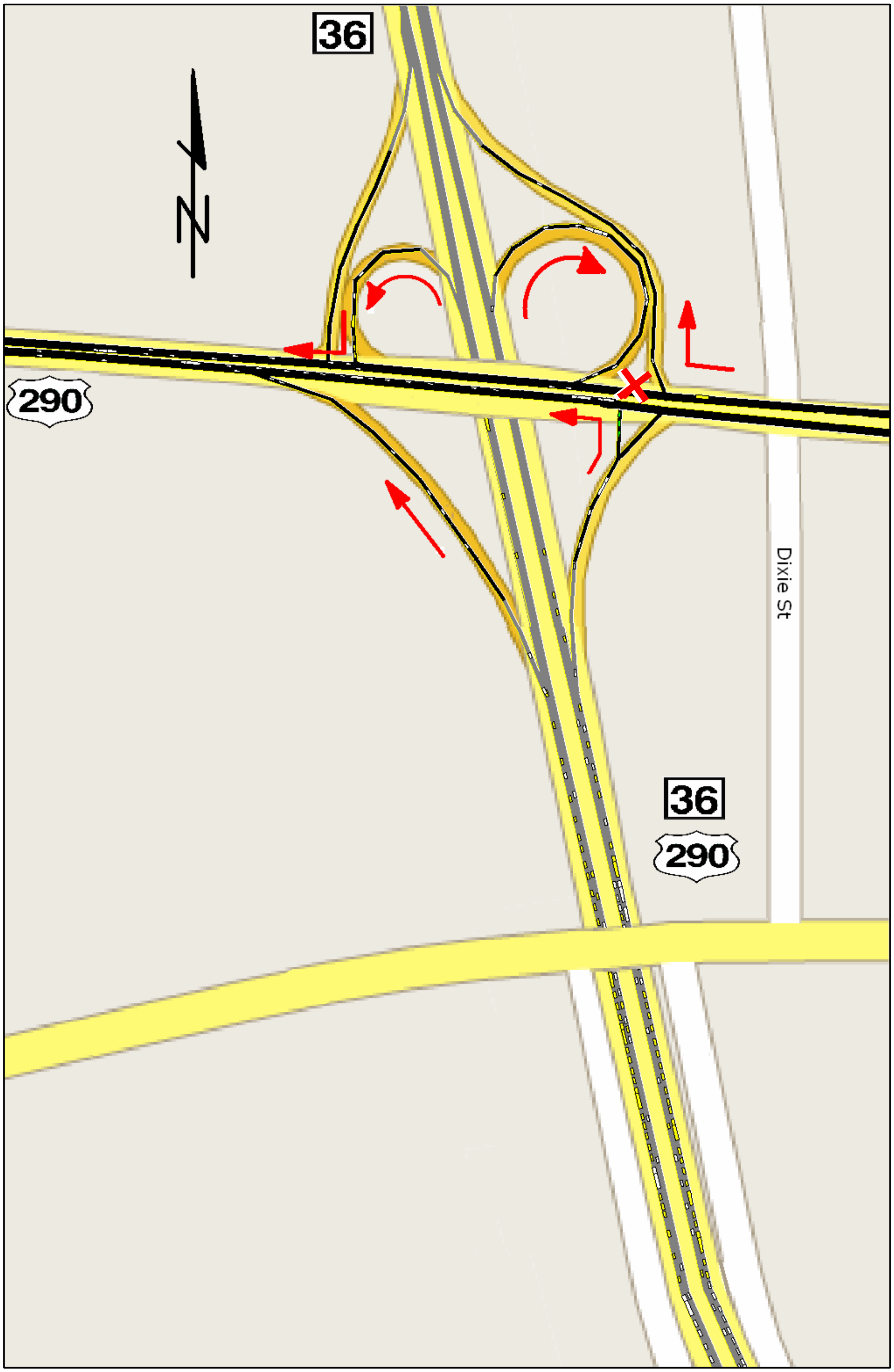


Figure 11-18. Alternative D: Two Additional Ramps with Contraflow.

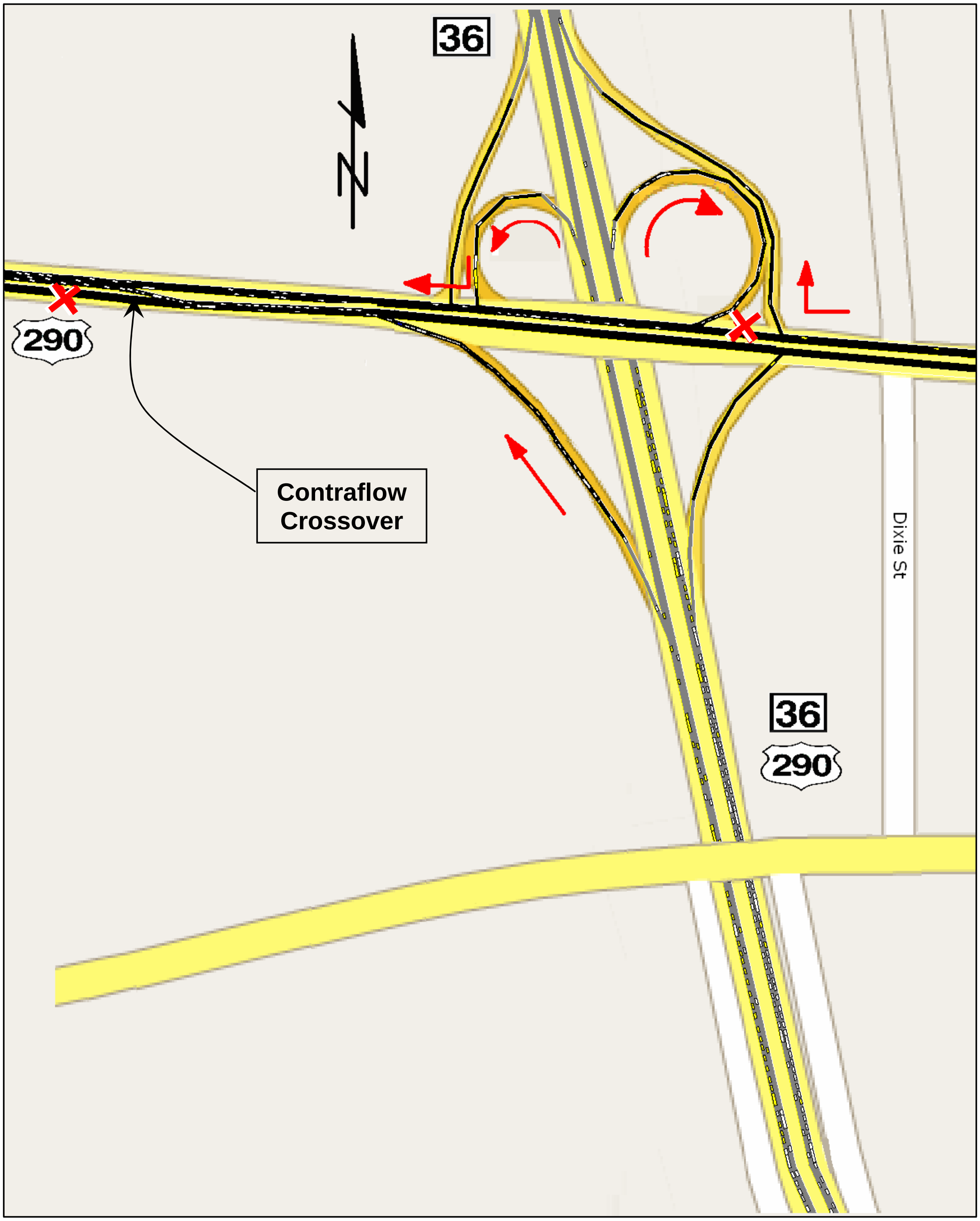


Figure 11-19. Alternative E: One Additional Ramp with Evaculane.

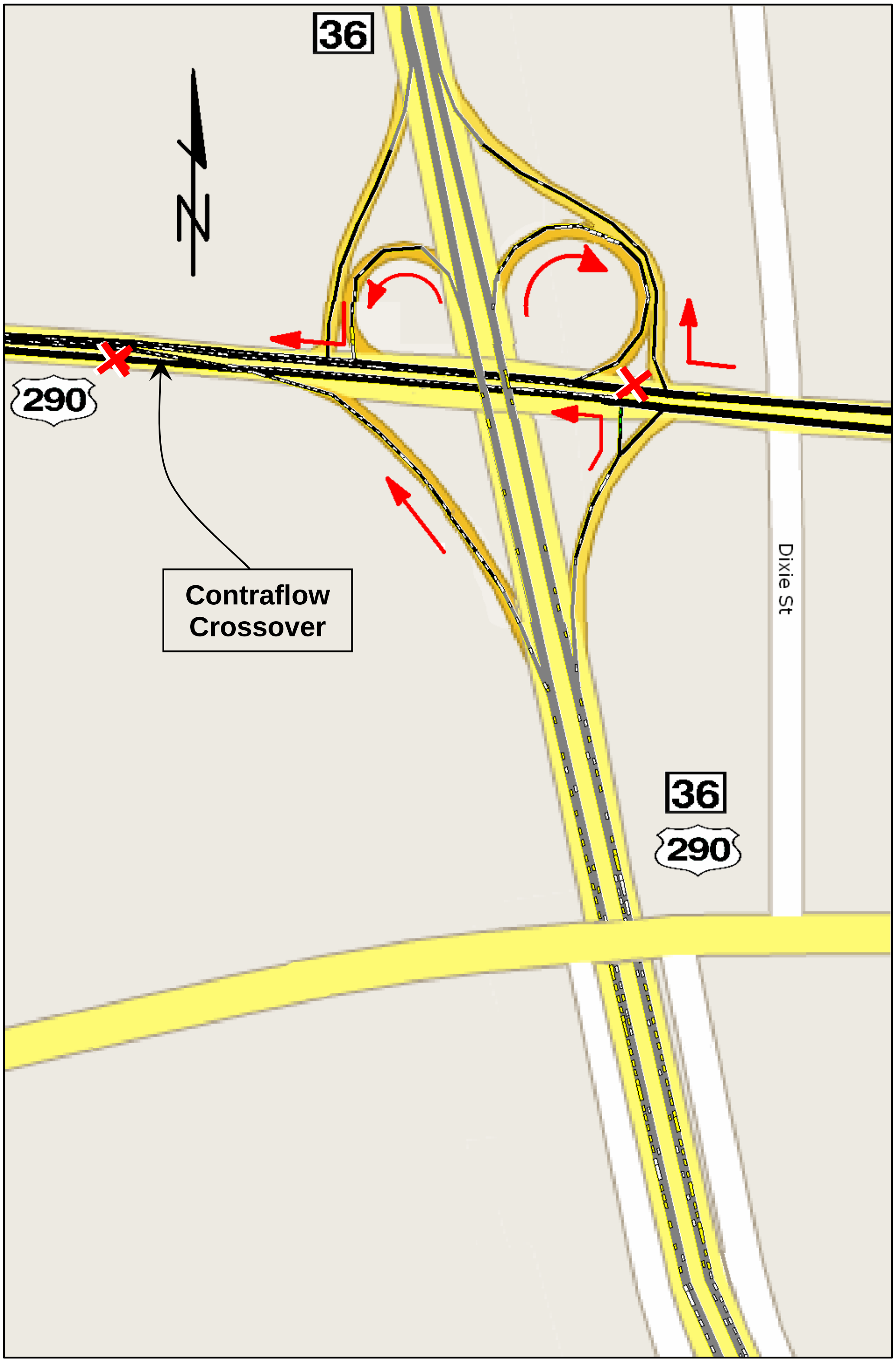


Figure 11-20. Alternative F: Two Additional Ramps with Evaculane.

Traffic Model Simulation

Alternative A: Existing Geometry without Contraflow

The animation of this alternative showed, understandably, that two northbound lanes severely congested as left lane traffic attempted to merge into the right lane immediately upstream of the cloverleaf ramp to westbound US 290. This can be seen in the screen capture in Figure 11-15.

Alternative B: One Additional Ramp without Contraflow

As with Alternative A, there is significant congestion in the interchange, although the throughput upstream of the first exit ramp in this alternative is approximately 60 percent greater than in Alternative A. The model shows the cloverleaf ramp carrying approximately 1300 vph and the "evacuation ramp" carries 1425 vph. This latter path is constrained by the 90-degree turn that is required to access the westbound lanes.

Alternative C: Existing Geometry with Contraflow

This alternative shows congestion on both sides of the freeway's south leg, as four lanes of traffic approach the interchange. On each side of the median, two lanes merge into a one-lane ramp. As shown in Figure 11-17, the head of the queue is a bit upstream of the ramp gore, on both the contraflow side and the normal lane side. This queuing is because an inside lane vehicle has slowed or stopped in an attempt to push its way into the outside lane to access the ramp. From this point back, there are two full lanes of traffic.

Alternative D: Two Additional Ramps with Contraflow

Although all four northbound lanes have a unique path through the interchange, i.e., the number of lanes entering the interchange equals the number of lanes exiting the interchange, there is still significant congestion where the traffic encounters the first exit ramp. On both sides of the median on this south leg of the interchange, the outside lanes operate at a slower speed than the adjacent inside lanes. Again, this congestion is due to the impedance caused by the motorists slowing down to change lanes to get to the outside lane and thereby access the ramp.

Alternative E: One Additional Ramp with Evaculane

With three lanes departing to the west from the crossover on the west leg of this interchange, this alternative flows fairly well inasmuch as there are three paths off of the northbound evacuation route. As indicated in Figure 11-19, the two northbound contraflow lanes each have a dedicated path to the west. Neither lane encounters a merge that has more entering lanes than departing lanes. Consequently the northbound contraflow lanes flow well. The northbound normal lanes have only one exit: the single-lane cloverleaf ramp. This limitation produces congestion where two lanes must merge into one. The traffic flowing on the two cloverleaf ramps each feed one of the two westbound lanes. As described with other alternatives, there is congestion on the northbound contraflow lanes as some inside lane vehicles slow down to access the outside lane en route to the exit ramp even though there is another exit ramp available downstream. This unnecessary merging produces congestion upstream of this first ramp.

Alternative F: Two Additional Ramps with Evaculane

In contrast to Alternative E, the traffic that uses the one-lane crossover on the west leg is fed from two paths: the traffic exiting the northbound lanes via the southeast quadrant and the southwest quadrant. This merging of two lanes into one lane queues back onto the northbound contraflow lanes and the northbound normal lanes. These queues impede traffic accessing the cloverleaf ramps, thereby producing a reduced volume flowing through the interchange, relative to Alternative E.

Table 11-15 summarizes these findings from the CORSIM models. The first column of data shows the hourly flowrate of traffic traveling west from the interchange in the normal westbound lanes of US 290. The second column of data indicates the hourly flowrate of traffic traveling west from the interchange in the contraflow lanes, i.e., the lanes that normally operate in the eastbound direction.

Table 11-15. Westbound Vehicular Throughput, West of Interchange (vph).

Alternative		Normal WB Lanes	Contraflow WB Lanes	Total
A	Non-Contraflow; Existing Geometry	1112	0	1112
B	Non-Contraflow; 1 Additional Ramp	2160	0	2160
C	NB and WB Contraflow; Existing Geometry	1078	1195	2273
D	NB and WB Contraflow; 2 Additional Ramps	1716	2110	3826
E	NB Contraflow; 1 Additional Ramp; WB Evaculane	2840	0	2840
F	NB Contraflow; 2 Additional Ramps; WB Evaculane	2244	0	2244

Contraflow Termination Alternatives

The previous contraflow alternatives are based on the supposition that if contraflow is used to enter the interchange, then contraflow also exists on the west leg, carrying four lanes to the west from the interchange.

Additional scenarios were modeled that address the throughput if contraflow is terminated at this interchange. Table 11-16 lists two alternatives. In each, northbound US 290 traffic approaches the interchange in a contraflow operation, as previously described. However, on the west leg of the interchange, traffic uses a proposed one-lane crossover, beyond which all westbound traffic is in the normal westbound lanes.

Table 11-16. Interchange Contraflow Terminus Alternatives.

Alternative	Geometry
G	Existing Geometry
H	1 Additional Evacuation Ramp

Traffic Model Simulation – Contraflow Terminus

Alternative G: Contraflow Termination with Existing Geometry.

In Alternative G, shown in Figure 11-21, all traffic in the normal northbound lanes is expected to use the existing cloverleaf ramp in the northeast quadrant. All northbound contraflow traffic will merge into a single lane and use the ramp in the southwest quadrant; then this traffic follows a one-lane crossover ramp to merge into the normal westbound lane.

The simulation animation shows congestion at the merge points associated with the ramps connecting northbound traffic to westbound traffic, on both the normal and contraflow sides of the northbound approach to the interchange. Additionally, there is some backup in the crossover on the west leg of the interchange.

Alternative H: Contraflow Termination with One Evacuation Ramp.

Alternative H, illustrated in Figure 11-22, is the same as Alternative G, except that half of the northbound contraflow traffic can continue north to access the cloverleaf in the northwest quadrant and access the westbound lanes via the evacuation ramp discussed in Alternative D, thereby providing contraflow traffic with two paths through the interchange.

This model produced similar merge point congestion on the normal northbound lanes as Alternative G. The contraflow side flows a bit better. However, on the west leg, there is an increased amount of delay where the one-lane crossover merges with the two westbound lanes; this additional delay is because the two westbound lanes are carrying more traffic in Alternative H, relative to Alternative G.

Table 11-17 summarizes these findings from the CORSIM models. The data show the hourly flowrate of traffic traveling west from the interchange in the normal westbound lanes of US 290. There is no traffic operating in contraflow traveling west from the interchange.

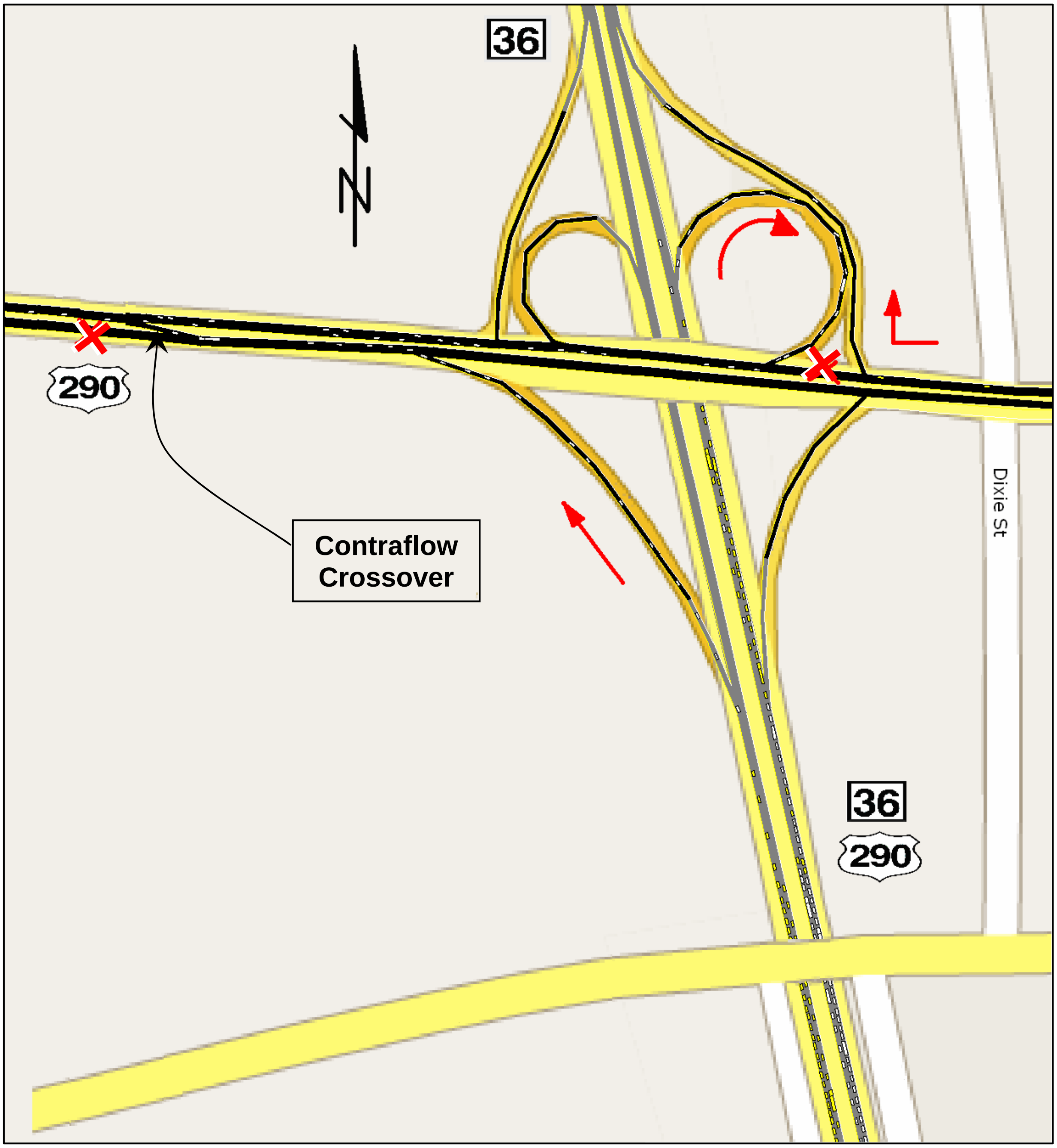


Figure 11-21. Alternative G: Contraflow Terminus – Existing Geometry.

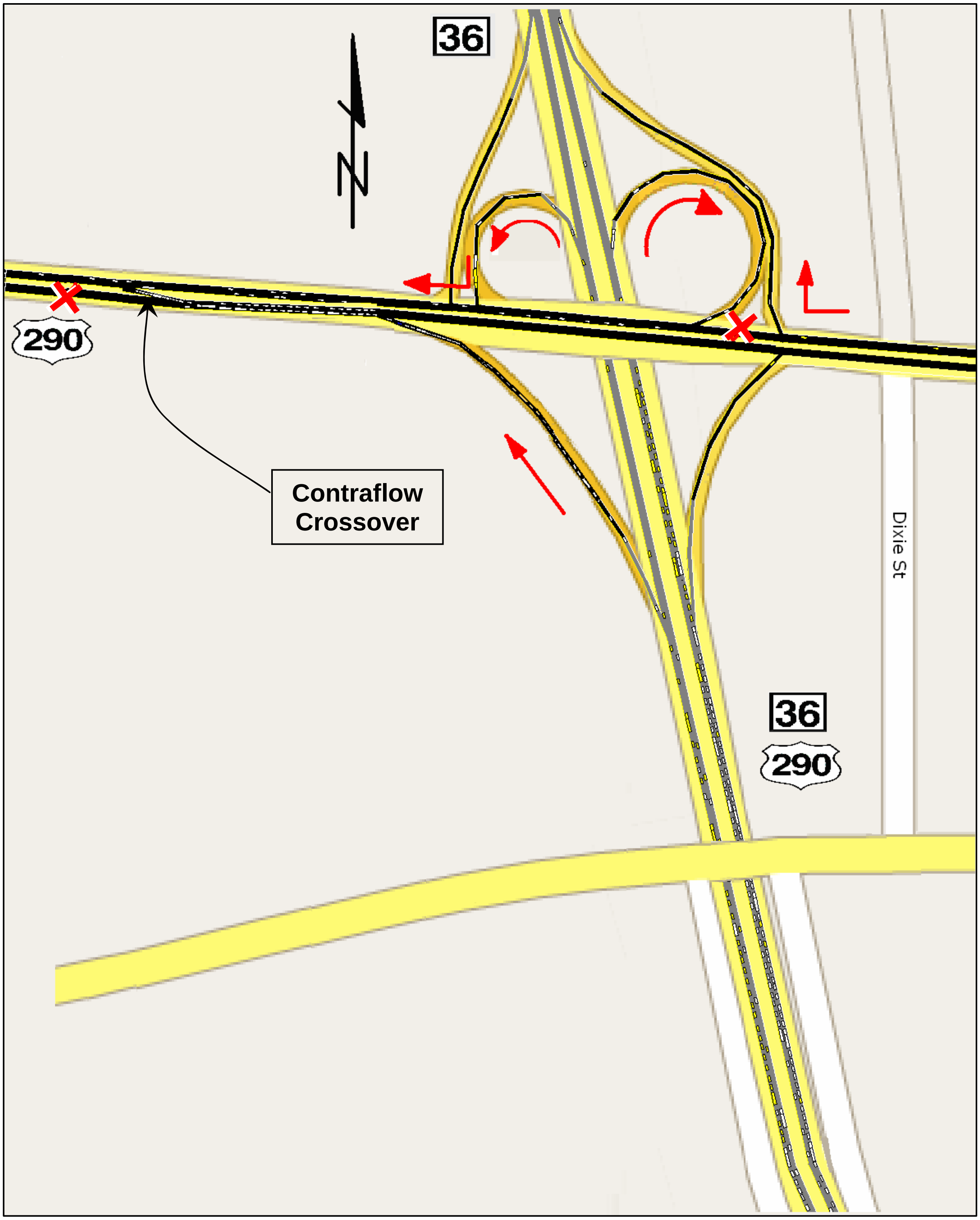


Figure 11-22. Alternative H: Contraflow Terminus – One Additional Ramp.

Table 11-17. Westbound Vehicular Throughput, West of Interchange (vph) Contraflow Terminus.

Alternative:	G	H
	Existing Geometry	1 Additional Ramp
Normal WB Lanes	2171	2320

Summary

The analysis above assumes the demand approaching the interchange from the south is greater than the infrastructure can accommodate. It may be that capacity constrictions upstream of Brenham will meter the flow such that the demand is reduced; however, it is more likely that whatever gaps are created in the US 290 traffic in locations between Houston and Brenham will be filled by traffic entering this evacuation route from intermediate intersections, e.g., the other SH 36 junction due south of the Brenham city center, approximately 2.5 miles upstream of the interchange that is the subject of this analysis.

With the assumption that the traffic demand on the northbound approach to this interchange exceeds the capacity of the mainlanes, as modeled for each stated alternative, the greatest number of vehicles served per hour can be achieved by constructing the two “evacuation ramps” and contraflowing traffic through the interchange.

Ultimately, the best solution is to reconstruct the interchange so that, even during non-emergency operating conditions, there are two lanes in each direction on US 290 through this interchange. Such a solution would serve the motorists well during evacuations as well as during routine use of the highway network in this area.

This analysis is based strictly on the issue of traffic congestion and does not take into account any liability and traffic safety issues that may be quite significant on a non-controlled access highway.

US 83 and US 281 (Rio Grande Valley toward San Antonio)

The Pharr District is developing a contraflow plan for US 77/83, beginning at the southern end of the controlled-access freeway near Los Tomates at the intersection with East Avenue in Brownsville, Texas. Additional input points are planned in the Brownsville area. TxDOT’s consultant is developing the detailed plans for this route. There will be two continuous contraflow lanes on US 83 from Brownsville to Pharr, where the contraflow lanes turn north onto US 281 through Edinburg, Texas. This contraflow plan produces four lanes for evacuating traffic. One scenario merges the two contraflow lanes with the two northbound lanes on the north side of Edinburg near FM 2812; in this scenario, all contraflow operation will occur on controlled-access highways. An alternative scenario continues the contraflow lanes north 150 miles to the US 281 interchange with I-37 near Three Rivers, Texas.

Intermediate Point on US 281 at I-37 near Three Rivers, Texas

This interchange was analyzed to determine the throughput under the scenario in which the US 281 approach from the south is operating in contraflow, i.e., with four lanes carrying northbound traffic. As shown in Table 11-18, the northbound traffic approaching on I-37 is varied to represent three possibilities. All the values in the table represent the flowrate of US 281 traffic that proceeds through the interchange, in contrast to the sum of traffic that emerges on the north end regardless of the origin. In other words, the values do not include any vehicles that originate from Corpus Christi or other communities along the I-37 corridor to the south. The first column with data assumes the approach traffic from the south on I-37 is flowing at capacity. The second column assumes fully loaded lanes on I-37 on both the normal northbound and contraflow approach lanes. The final column with data assumes no traffic is arriving at the interchange from I-37. Data in Table 11-19 include all vehicular throughputs emerging from the interchange regardless of whether the vehicles entered via US 281 or I-37. Table 11-20 and Table 11-21 represent traffic at the same locations as Table 11-18 and Table 11-19, respectively; however the data in the latter two tables are based on no contraflow on US 281 from the Rio Grande Valley. Figure 11-23 represents contraflow on US 281 when I-37 is carrying no traffic from the south.

Table 11-18. US 281 Traffic (vph) Flowing through I-37 Interchange near Three Rivers, Texas (US 281 Operating with Contraflow).

	Capacity Flow on NB I-37 Approach	Capacity Flow on NB I-37 and Contraflow on I-37	No Traffic on NB I-37
Northbound I-37 Lanes	1001	990	1131
Contraflow I-37 Lanes	1197	1054	1191
Total	2198	2044	2322

Table 11-19. Vehicular Throughput (vph) on I-37, North of US 281, near Three Rivers, Texas (US 281 Operating with Contraflow).

	Capacity Flow on NB I-37 Approach	Capacity Flow on NB I-37 and Contraflow on I-37	No Traffic on NB I-37
Northbound I-37 Lanes	2673	2644	1113
Contraflow I-37 Lanes	1172	2635	1162
Total	3845	5279	2275

Table 11-20. US 281 Traffic (vph) Flowing through I-37 Interchange near Three Rivers, Texas (US 281 Not Operating with Contraflow).

	Capacity Flow on NB I-37 Approach	Capacity Flow on NB I-37 and Contraflow on I-37	No Traffic on NB I-37
Northbound I-37 Lanes	994	981	1123
Contraflow I-37 Lanes	0	0	0
Total	994	981	1123

Table 11-21. Vehicular Throughput (vph) on I-37, North of US 281, near Three Rivers, Texas (US 281 Not Operating with Contraflow).

	Capacity Flow on NB I-37 Approach	Capacity Flow on NB I-37 and Contraflow on I-37	No Traffic on NB I-37
Northbound I-37 Lanes	2657	2674	1103
Contraflow I-37 Lanes	0	2614	0
Total	2657	5285	1103

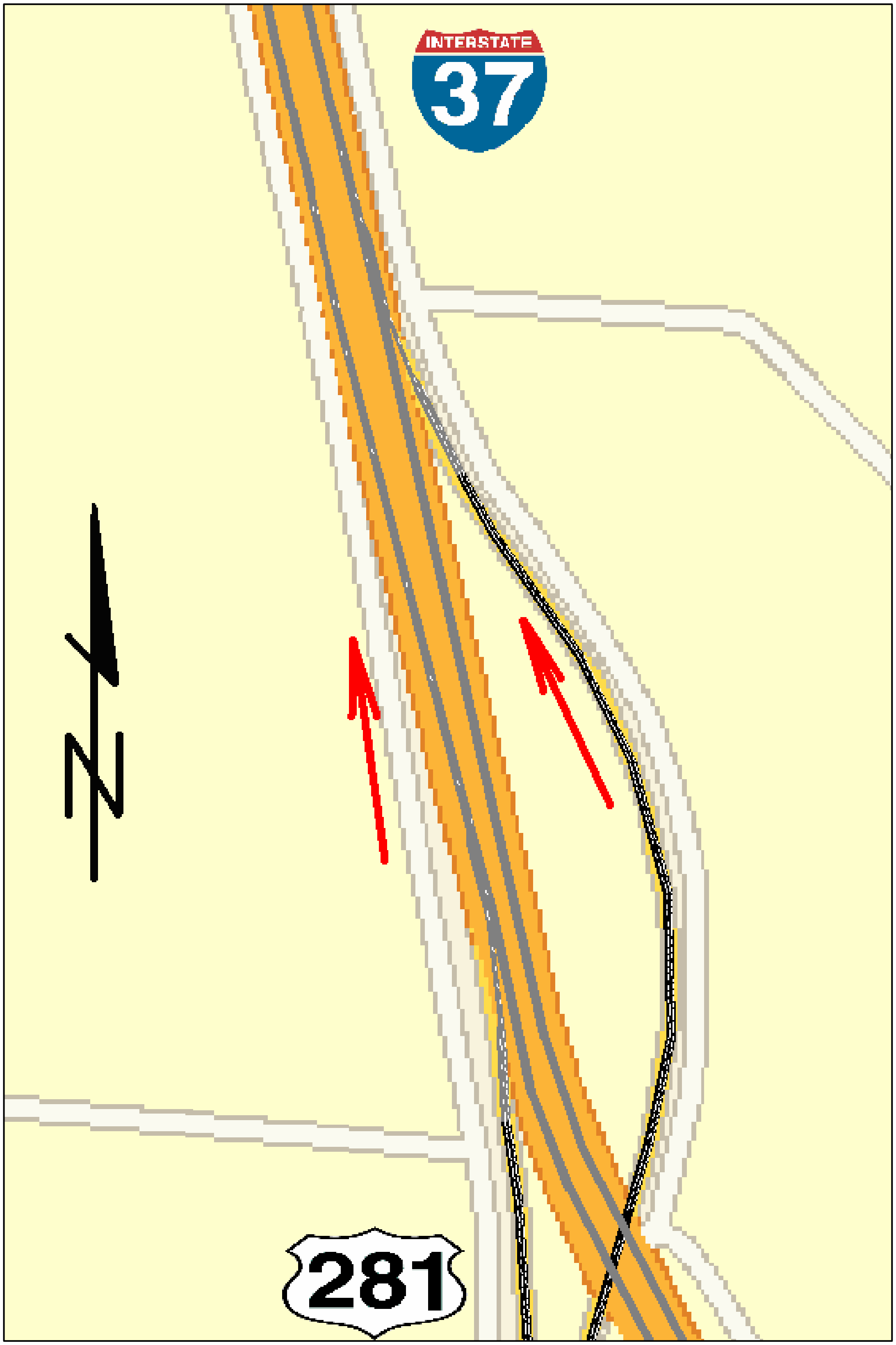


Figure 11-23. Contraflow on US 281 at I-37 near Three Rivers, Texas.

REFERENCES

1. *Manual on Uniform Traffic Control Devices*, Federal Highway Administration, Washington, DC, 2003.

2. *Standard Highway Sign Designs for Texas: A Supplement to Texas Manual on Uniform Traffic Control Devices for Streets and Highways*, Texas Department of Transportation, Austin, Texas, 1980.

3. Ullman, B.R., N.D. Trout, C.L. Dudek, and S.K. Schoeneman. *Amber Alert, Disaster Response and Evacuation, Planned Special Events, Adverse Weather and Environmental Conditions, and Other Messages for Display on Dynamic Message Signs.* Technical Report. 0-4023-4. Texas Transportation Institute, The Texas A&M University System, College Station, Texas, October 2005.

4. Dudek, C.L. and G.L. Ullman. *Dynamic Message Sign Message Design and Display Manual.* Report No. FHWA/TX-04/4023-P3. Texas Transportation Institute, The Texas A&M University System, College Station, Texas, April 2006.

5. Ullman, G.L., C.L. Dudek, and B.R. Ullman. *Development of a Field Guide for Portable Changeable Message Sign Use in Work Zones.* Report No. FHWA/TX-06/4748-2. Texas Transportation Institute, The Texas A&M University System, College Station, Texas, September 2005.

6. Durkop, B.R., and C.L. Dudek. *Texas Driver Understanding of Abbreviations for Dynamic Message Signs.* Report No. FHWA/TX-00/1882-1. Texas Transportation Institute, The Texas A&M University System, College Station, Texas, February 2000.

7. Conner, G., Assistant State Maintenance Engineer, Alabama Department of Transportation. Phone interview, January 2007.

8. Clark, P., Assistant State Traffic Engineer, Florida Department of Transportation. Phone interview, January 2007.

9. Montgomery, K., State Traffic Signal Engineer, Georgia Department of Transportation. Phone interview, January 2007.

10. Fox, D., Assistant Traffic Operations Engineer, District 61, Louisiana Department of Transportation and Development. Phone interview, January 2007.

11. Chapman, B., Emergency Management Coordinator, Mississippi Department of Transportation. Phone interview, January 2007.

12. Provost, J., Division Operations Engineer, North Carolina Department of Transportation. Phone interview, January 2007.

13. Jenkins, D., State Traffic Safety & Systems, South Carolina Department of Transportation. Phone interview, January 2007.

14. Hanshaw, S., Facility Manager, Smart Traffic Center, Virginia Department of Transportation. Phone interview, January 2007.

15. Graves, B., Signal Shop Supervisor, Texas Department of Transportation – Beaumont District. Phone interview, January 2007.

16. Soto, I., Director of Transportation Operations, Texas Department of Transportation – Corpus Christi District. Phone interview, January 2007.

17. Corder, S., Director of Transportation Operations, Texas Department of Transportation – Houston District. Phone interview, January 2007.

18. Leal, J., Director of Transportation Operations, Texas Department of Transportation – Pharr District. Phone interview, January 2007.

19. Jasek, M., Director of Transportation Operations, Texas Department of Transportation – Yoakum District. Phone interview, January 2007.

20. Brazoria/Galveston/Harris County Hurricane Evacuation Zip-Zones Coastal, A, B, and C, http://traffic.houstontranstar.org/weather/hurricane_evac.html, accessed August 2, 2007.

21. Texas Department of Public Safety, Brazoria/Galveston/Harris County Evacuation Zones Map, http://www.txdps.state.tx.us/dem/Hurricanemaps/GalvestonStudyAreaMap.pdf, accessed August 2, 2007.

22. Citilabs website (www.citilabs.com/cube), accessed September 12, 2007.

23. "Emergency Evacuation Traffic Management Plan," Texas Department of Public Safety, Disaster District 2A-Sub 2A. Houston, Texas, 2006, ftp://ftp.txdps.state.tx.us/dem/plan_state/hurr_evac_tmp_2a_s2a.pdf.

24. Office of Emergency Management, City of Houston website, (http://www.houstontx.gov/oem/evac.html), accessed September 27, 2007.

25. *Report to the Governor on Texas Hurricane Preparedness, Texas Office of Homeland Security*, March 17, 2005, http://www.governor.state.tx.us/divisions/press/files/hurricane_preparedness.pdf, accessed August 9, 2007.

26. *Houston TranStar Annual Report – 2004*, Prepared by the Texas Transportation Institute, The Texas A&M University System, Houston, Texas, June 2005.

27. Poole, B., State Maintenance Engineer, "Georgia DOT Hurricane Preparedness and Response 2004," presented at Transpo 2004 Conference. Jacksonville, FL, December 2004.

28. Pitts, E.C., Assistant State Maintenance Engineer, Georgia Department of Transportation, presented at the Contraflow Workshop. Orlando, FL, February 14-15, 2006.

29. Cogburn, P., Transportation Emergency Operations Center Director, Virginia Department of Transportation, presented at the Contraflow Workshop, Orlando, FL, February 14, 2006.

30. Watermark Safety website (http://www.watermarksafety.com), accessed March 25, 2006.

31. Ross, Jr., H.E., D.L. Sicking, R.A. Zimmer, and J.D. Michie. *Recommended Procedures for the Safety Performance Evaluation of Highway Features*. National Cooperative Highway Research Program Report 350, Transportation Research Board, National Research Council. Washington, DC, 1993.

32. HySecurity website (http://www.hy-security.com), accessed March 25, 2006.

33. Mak, K.K., R.P. Bligh, and D.C. Alberson. *Testing and Evaluation of Wyoming Road Closure Gate*. Project No. 472280, RF 93-058. Texas Transportation Institute, The Texas A&M University System, College Station, Texas, January 1997.

34. Poston, J.L., Federal Highway Administration, "Wyoming Road Closure Acceptance Letter," March 24, 1995; website (http://safety.fhwa.dot.gov/roadway_dept/road_hardware/breakaway/pdf/ls-36.pdf), accessed March 25, 2006.

35. Conner, G., Assistant State Maintenance Engineer, Alabama Department of Transportation. "Reverse-Laning I-65 for Hurricane Evacuations," presented at the Contraflow Workshop. Orlando, FL, February 14-15, 2006.

APPENDIX A: FOCUS GROUP GUIDE

Part I - Hurricane Evacuation MUTCD Signing

Show sign A:

1. Did you see this type of sign anywhere when you were evacuating?
   If yes – was it helpful? Explain.

EM-1

If no, did you feel that you were on a designated evacuation route?
If yes, how did you know? Do you think that these signs would have been helpful?

2. Where should these signs be located?

Here are some alternatives for this type of sign that we would like to ask you a few questions about.

A

B

C

3. Do you think that these signs mean the same thing? If no, how are they different?
   If yes, what do they mean?

4. Of the three signs, which sign do you prefer? Why?

5. What would you change or add to improve the sign, if anything?

6. How often do you need to see these signs on a roadway to assure you that you are still on the evacuation route?

7. How far inland (traveling toward your destination) do you feel that these types of signs should be posted?

Part II - Traffic Control Techniques to Increase Traffic Flow during Hurricane Evacuations

HOV lanes (relevant primarily in Houston)

1. Did you use the HOV lanes to evacuate? Why/why not?

   If yes, did you have enough information provided on the signs/pavement markings to guide you onto the HOV lanes? If no, what other information would have been helpful?

2. Did you feel there was enough information available to decide if you could use the HOV lanes to evacuate?

   If yes, what information was useful to you? If no, what other information would you need to let you know that the HOV lanes were available for evacuation traffic?

3. Did you expect that the HOV lanes were being used for evacuation traffic or strictly for rush hour commuter traffic? Why/why not?

Shoulder Lanes (relevant primarily in Corpus Christi)

We are now going to show you three different signs.

A

B

C

1. Do you know the meaning of these signs? Can you tell me what each sign means?

2. Did you use the shoulder during the evacuation process? If yes, did you have any problems or difficulty?

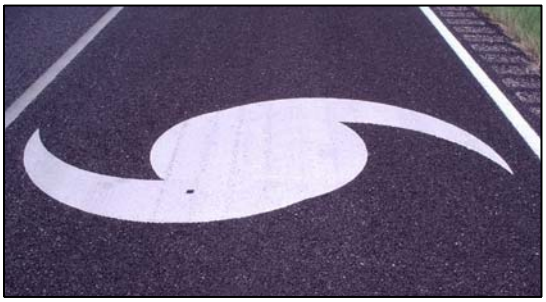
3. Are any of these signs confusing or hard to understand? If yes, what would you change or add to improve it?

4. Do you feel that the shoulder lane should be used for evacuation traffic? Why/why not?

5. If you were approaching the area where the shoulder is being opened for evacuation traffic, what information on signs or markings would you need?

6. While traveling on the shoulder what information would you need, if any?

7. As you reach the end of the shoulder lane that is being used for evacuation, what information would you now need, if any?



8. Have any of you seen this pavement marking? Can you tell me what it means?

9. Do you feel that this is helpful or confusing if placed on the shoulder where it is possible to use the shoulder as a lane during an evacuation? Why?

10. Are there any other places where you feel that this pavement marking should be located?

11. What other types of pavement markings, if any, do you think would be helpful when evacuating or returning?

Contraflow Lanes

1. When you were evacuating for the hurricane, did you use a contraflow lane?
   a. If yes – what problems (if any) did you encounter? How could road signs or pavement markings have helped?
   b. If no – did you choose not to use the contraflow lane, or was one not available?
      If chose not to use – Why?

Most of you know that contraflow is using the lanes in the opposite direction; however, there is a lot of traffic control involved in providing this operation. One significant point is that once you are on a contraflow lane, most or all of the entrances and exits will be closed for safety reasons. Assuming this situation:

2. Did you have enough guidance through signs and markings:
   a. to get onto the contraflow lane?
   b. to provide necessary information while traveling on the lane?
   c. about exiting the contraflow lane?

   If no – what other information did you need? Where should this information be provided?

3. Currently, there is no standard contraflow sign. What suggestions do you have on the development of such a sign? (pass out scratch paper for participants to draw ideas for signs)
   a. Are there specific colors that should be used?
   b. Should this sign include a special "contraflow" symbol? If yes – what would that symbol look like?

4. Are there any specific pavement markings that you think could be used to help with contraflow operations? *(pass out scratch paper as needed to draw ideas)*
   a. Is there anything specific needed at ramps to let you know if that ramp can be used to exit/enter the highway when in contraflow operation?

Signal Operations

Video clip or simulated clip of a ***flashing red*** *traffic signal. Try to have no cars stopped in the lane/direction of travel perspective.* Often there are problems with signals during or after a hurricane evacuation. We are going to show you a short video of a traffic signal and then ask you some questions about what you would do.

1. If you saw this operation on a traffic signal, what would you do?

   a. If Stop – Do you think that you must stop for this light?
   b. If continue/use caution – Do you think that the other directions have to stop?
   c. What helped you to make the decision about how to react to this light?
   d. Is there anything you would add at this signal or in the area (signs, pavement markings, etc.) during this type of situation that would help you to understand how you should react?

Video clip or simulated clip of a ***flashing yellow*** *traffic signal.* We are going to show you another clip.

2. If you saw this type of situation on a traffic signal, what would you do?

   a. If Stop – Do you think that you must stop for this light?
   b. If continue/use caution – Do you think that the other directions have to stop?
   c. What helped you to make the decision about how to react to this light?
   d. Is there anything you would add at this signal or in the area (signs, pavement markings, etc.) during this type of situation that would help you to understand how you should react?

Video clip or simulated clip of ***non-functioning*** *traffic signal.* We are going to show you another clip.

3. If you saw this type of situation on a traffic signal, what would you do?

   a. If Stop – Do you think that you must stop for this light?
   b. If continue/use caution – Do you think that the other directions have to stop?

c. What helped you to make the decision about how to react to this light?
d. Is there anything you would add at this signal or in the area (signs, pavement markings, etc.) during this type of situation that would help you to understand how you should react?

Part III - Motorist Information Needs

We are going to talk now about different information you need when you are evacuating before a hurricane.

1. If an **evacuation** of the area was required, what type of information do you think you would need while you are traveling on the road?

2. Now we want you to rank how important each of these different types of information are for you to have. Next we need you individually to rate how important each piece of information is using a scale from 1 to 5 where 1 is – Most Important and 5 is – Least Important.

3. How would you prefer to get information regarding evacuation? Next we want you to think about how each of these different pieces of information should be presented to a driver. *Go down the list of information pieces and ask where they would like to get this information.*

We are going to change your situation now. I want you to think of the time when you are **returning** to your home following a hurricane.

1. What type of information do you think you would need while you are traveling on the road to return following the hurricane?

2. Now we want you to rank how important each of these different types of information are for you to have. Next we need you individually to rate how important each piece of information is using a scale from 1 to 5 where 1 is – Most Important and 5 is – Least Important.

3. Next we want you to think about how each of these different pieces of information should be presented to a driver. *Using list from above go down the list of information pieces and ask where they would like to get this information.*

APPENDIX B: SIGNS AND MARKINGS SURVEY INSTRUMENT

Project 0-4962 ***Subject #:*** _______
Date: __________________ ***Researcher:*** ______

SURVEY 1

Hurricane Evacuation Signs and Markings

This survey is being conducted by the Texas Transportation Institute (TTI), which is part of The Texas A&M University System (TAMUS). It is sponsored by the Texas Department of Transportation. The purpose of the survey is to help determine drivers' understanding and comprehension of various signs and pavement markings to be used during hurricane evacuation and returning from a hurricane evacuation. Please circle answers below.

Driving: **Less than 1 year** **1-5 yrs.** **6-10 yrs.** **More than 10 yrs**.

Evacuated in last three years: **Yes** **No**

Age Group: **18-25** **25-39** **40-54** **55-64** **65+**

Education: **No HS Diploma** **HS/GED** **Tech School** **Some College** **College Degree**

Gender: **Male** **Female**

Now before we begin, for all questions that I will ask, I want you to assume that you are evacuating from Beaumont due to a large hurricane in the Gulf of Mexico.

Section 1 - Overhead Guide Signs

Option 1: Evacuation Route via US 287 and hurricane symbol placard

1. Assume you are evacuating due to a hurricane. What information did the sign provide to you?

____
____
____
____

2. Based on the information provided in this sign, what action would you take (if any)? ______

____
____
____

3. Did the sign provide you with enough information to determine if you are on a designated evacuation route? **Yes** **No**

If yes: What information helped you make that decision? ________________________________

____
____
____

If no: What additional information would you need that would let you know you were on a designated evacuation route? ____
____
____
____

RATE Section 1: The pictures you are about to see are different options that could be used in the same situation you just viewed. Please rate the different combinations of information on how well they let you know what route you should take to evacuate, with 1 doing an excellent job in informing you and 5 doing a terrible job.

Option 1 - Evacuation Route via US287 and Hurricane Symbol Placard
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Option 2: (With text on blue header but without symbol)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Option 3: (Symbol only - shield)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Section 2 - Testing Alternate Signing for MUTCD Evacuation Sign (EM-1)

Option 1: MUTCD

Assume that you are evacuating due to a hurricane and you see the following sign.

1. What information did the sign provide to you? ______________________________
____
____
____

2. Based on the information provided in the sign, what action would you take (if any)? ________
____
____
____

3. Did the sign provide you with enough information to determine if you are on a designated evacuation route? **Yes** **No**

If yes: What information helped you make that decision? ______________________
____
____
____

If no: What additional information would you need that would let you know you were on a designated evacuation route? ____
____
____
____

RATE Section 2: The pictures you are about to see are different options that could be used in the same situation you just viewed. Please rate the different combinations of information on how well they let you know what route you should take to evacuate, with 1 doing an excellent job and 5 doing a terrible job.

Option 1: (MUTCD)
1 – Excellent   2 – Good   3 – OK   4 – Bad   5 – Terrible

Option 2: (Traditional symbol [no arrow])
1 – Excellent   2 – Good   3 – OK   4 – Bad   5 – Terrible

Option 3: (Traditional symbol sign w/supplemental plaque for arrow)
1 – Excellent   2 – Good   3 – OK   4 – Bad   5 – Terrible

Option 4: (FG sign symbol with arrow in eye of symbol)
1 – Excellent   2 – Good   3 – OK   4 – Bad   5 – Terrible

Section 3 - Shoulder Use Signs:

Part 1 – FM Road Shoulder Lane Sign: Assume that you are evacuating on a FM (Farm to Market) road and that you see this sign.

The sign that grew larger is just to help you read the message on the smaller sign in the back.

1. What information did the sign provide to you? ______________________________
____
____
____

2. Based on the information provided in the sign, what action would you take (if any)? ________
____
____
____

3. Based on the information in the picture, can you drive on the shoulder of this road? **Yes No**
How did you know? ____
____
____

If yes, would you use the shoulder lane? **Yes** **No**
Why or why not? ____
____
____

Part 2 – In use and not active shoulder lane signs:

Option 1: Corpus Christi original active sign

Assume that you are evacuating on a major evacuation route and that you see the following sign.

1. What information did the sign provide to you? ________________________________
____
____
____

2. Based on the information provided in the sign, what action would you take (if any)? _______
____
____
____

3. Based on the information in the picture, can you drive on the shoulder of this road? **Yes** **No**
How did you know? ____
____
____
____

If yes, would you use the shoulder lane? **Yes** **No**
Why or why not? ____
____
____

RATE Section 3 – Part 2: The pictures you are about to see are different options that could be used in the same situation you just viewed. Please rate the different combinations of information on how well they let you know if the shoulder lane is available for travel use during a hurricane evacuation, with 1 doing an excellent job and 5 doing a terrible job.

Option 1: (CC original active sign)
1 – Excellent **2 – Good** **3 – OK** **4 – Bad** **5 – Terrible**

Option 2: (New Corpus Christi Open Sign)
1 – Excellent **2 – Good** **3 – OK** **4 – Bad** **5 – Terrible**

Option 3: (Houston sign with beacons on)
1 – Excellent **2 – Good** **3 – OK** **4 – Bad** **5 – Terrible**

Option 4: (Corpus Christi sign with removable panel in white with blue text)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Option 5: (Houston No flashing)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Option 6: (CC original not active)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Option 7: (CC redesigned - closed)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Part 3 - End of Lane Signs

Assume that you are still evacuating on a major evacuation route. However, this time you are driving on a shoulder evacuation lane and you see the following signs.

Option 1: Current sign from CC

1. What information did the sign provide to you? ____
____
____

2. Based on the information provided in the sign, what action would you take (if any)? ________
____
____

3. Is there other information you would need to determine what action you would take? **Yes No**
If yes, what? ____
____
____

RATE Section 3 – Part 3: The pictures you are about to see are different options that could be used in the same situation you just viewed. Please rate the different combinations of information on how well they let you know that the shoulder lane is going to end and you have the option to either exit or continue on the highway, with 1 doing an excellent job and 5 doing a terrible job.

Option 1: (Current Sign from Beaumont)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Option 2: (Focus group – double headed arrow)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Option 3: (Add symbols to original CC sign)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Section 4 - Hurricane Pavement Markings:
Assume that you are evacuating on a major interstate, and you see the following pavement markings.

Option 1: Elongated blue symbol

1. Based on the picture you just saw, what lanes are available for you to drive in?
   All (including shoulder) Right Center Left Shoulder Other _____________

2. How did you know what lanes you could drive in? ______________________________________
____
____

3. Do you need any additional information to know that the shoulder is open as a travel lane?
   Yes No

If yes: What additional information would you need? _____________________________________
____
____

RATE Section 4: The pictures you are about to see are different options that could be used in the same situation you just viewed. Please rate the pavement markings on how well they let you know that the shoulder lane is available for use during a hurricane evacuation, with 1 doing an excellent job and 5 doing a terrible job.

Option 1: (Elongated blue symbol)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Option 2: (Different Orientation)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Option 3: (No color - Corpus)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Option 4: (Symbol with arrows - as per new Houston spec)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Option 5: (Symbol with arrow ONLY in blue rectangle)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Option 6: (No color with arrow)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Section 5 - DMS Abbreviations:
Now, we are going to look at some abbreviations that may be used on signs during a hurricane evacuation. Please tell me what you think the following abbreviations mean:

1a. EVAC TRAF - ______________________ 2. TO SHLTR - ______________________

3. FUEL AVAIL - ______________________ 4a. CONTRA LANE - ________________

Section 6 - Contraflow
Assume that you are evacuating on a major interstate and that you are currently traveling in the right lane of the freeway when you see the next sign.

Option 1: Houston Contraflow Sign

1. What information did the sign provide to you? ______________________________________
____
____

2. Based on the information provided in the sign, what action would you take (if any)? _______
____
Why? ____
____
____

3. When you pass the sign, how far are you from the start of a contraflow area? ____________
How did you know? ____
____
____
____

RATE Section 6: The pictures you are about to see are different options that could be used in the same situation you just viewed. Please rate the different combinations of information on how well they let you know that the contraflow lanes are open, with 1 doing an excellent job and 5 doing a terrible job.

Option 1: (Houston Contraflow Sign)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

Option 2: (Contraflow Lane Focus Group Sign)
1 – Excellent 2 – Good 3 – OK 4 – Bad 5 – Terrible

That completes the survey; thank you for participating.

APPENDIX C: CONTRAFLOW BROCHURES

Important Tips

Your needs and those of your family should be the primary factors considered when determining the timing of your evacuation. If you must evacuate, do not delay your departure in anticipation of the opening of the contraflow lanes. Should the contraflow be activated, citizens will be advised through local radio and television stations.

All citizens should prepare a plan well in advance of the evacuation.

The following steps are recommended:

- ✓ Assemble your disaster supplies kit with items such as flashlights, cell phones, extra batteries, battery chargers, portable radio, first aid kit, emergency water and food, medical supplies and equipment, non-electric can opener, highway map, important documents, such as insurance and medical information, etc.
- ✓ Secure your home against disaster to help reduce damages. Cover windows with shielding materials. Secure or put up any loose objects from around your home.
- ✓ If you cannot take your pets with you, make provisions for them.
- ✓ Know your area's evacuation plan/routes before you leave home (www.texasonline.com).
- ✓ Fill your vehicle with gas as early as possible. Take only the vehicle necessary to transport you and your family to safety. Extra vehicles create congestion.
- ✓ Bring extra cash in case banks are closed and ATMs are not working.
- ✓ Notify family and friends (especially those out the area) of your plan and your destination.
- ✓ Develop an emergency plan in case family members are separated. Instruct all evacuating family members of the name and contact information of your designated out-of-area friend or family.
- ✓ Ensure children know how and when to call 9-1-1.
- ✓ Evacuate, traveling safely to your destination.
- ✓ Expect travel times to destinations to be significantly longer than normal.

After the storm, listen to local officials for the all-clear signal before returning home. Check for information at www.texasonline.com.

Do not try to drive through standing water. Just a few inches can float a vehicle.

Fender-Bender?

State law requires motorists to move fender-bender accidents out of the travel lanes to the shoulder of the road. To keep all travel lanes and shoulders clear, however, disabled vehicles on the shoulder will be relocated to the next exit ramp where further assistance may be available.

More information on hurricane preparedness and evacuation safety is available from the following:

Evacuation routes, shelter, and special needs:
Call 2-1-1

Emergency Alert Station:
Houston: KTRH 740 AM
San Antonio: WOAI 1200 AM

State of Texas:
www.texasonline.com

Texas Department of Transportation:
www.dot.state.tx.us
Highway Road Conditions: 1-800-452-9292

Texas Department of Public Safety:
www.txdps.state.tx.us

Governor's Division of Emergency Management:
www.txdps.state.tx.us/dem

American Red Cross:
www.redcross.org
1-866-GET-INFO (438-4636)
(This number will function only after landfall.)

Rev. 8/15/06

HOUSTON TO SAN ANTONIO

TEXAS

INTERSTATE 10

2006
Hurricane Evacuation
Contraflow Route

Motorist Advisory

Evacuation Plans May or May Not Include Activating Contraflow Lanes

Texas Department of Transportation

Figure C - 1. I-10 (Houston to San Antonio) Contraflow – Side A – English

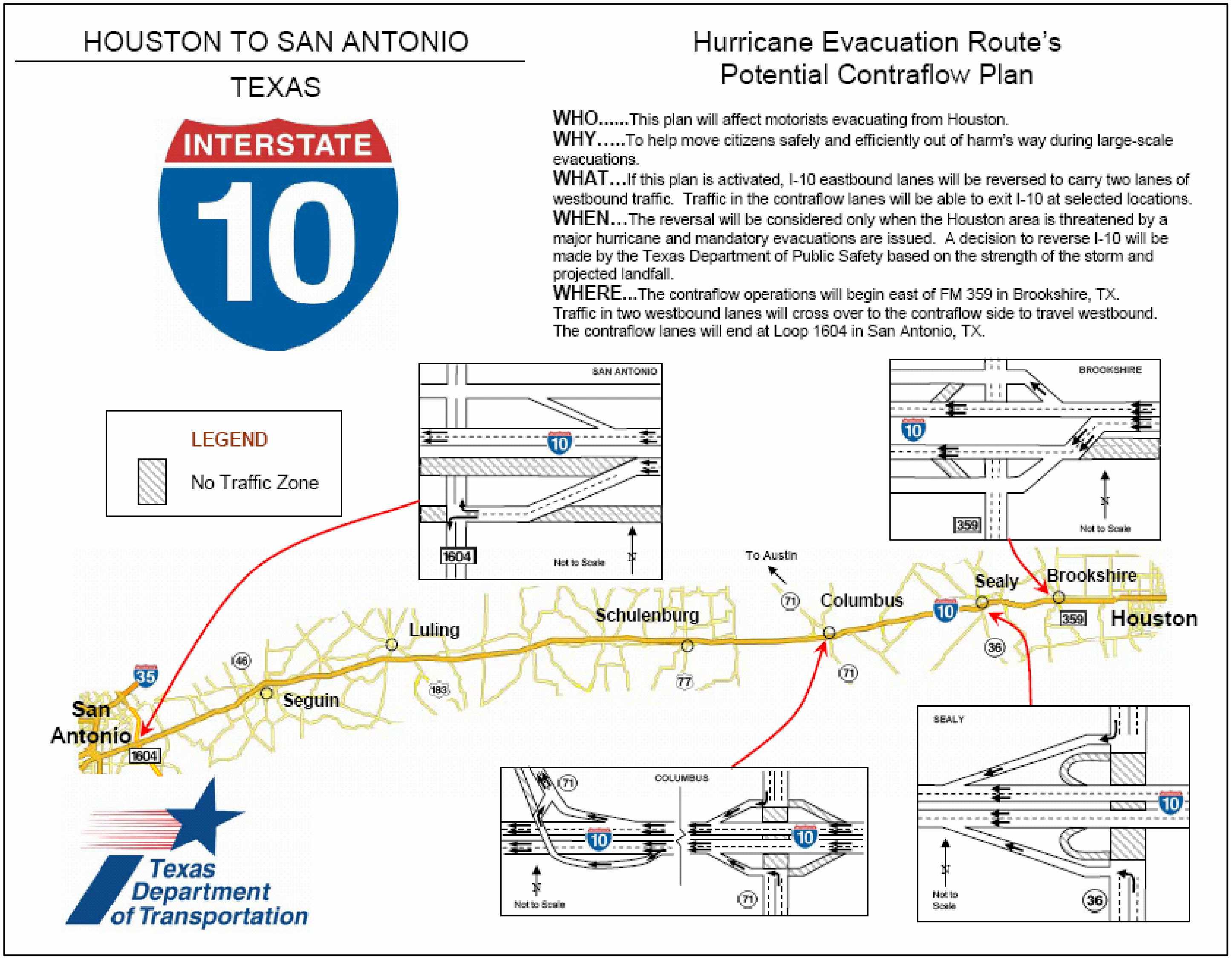


Figure C - 2. I-10 (Houston to San Antonio) Contraflow – Side B – English.

Sugerencias Importantes

Sus necesidades y las de su familia deben de ser los factores más importantes al determinarse el tiempo de su evacuación. Si usted debe evacuar, no espere a que el contra flujo sea abierto. Cuando el contra flujo sea activado, los ciudadanos van a ser advertidos por medio de la radio y la televisión locales. Todos los ciudadanos deben de prepararse con anticipación.

Los siguientes pasos son recomendados:

- ✓ Construya su botiquín de materiales para desastres con cosas tales como linternas, celulares, baterías extras, cargadores de baterías, radios portátiles, botiquín de primeros auxilios, agua y comida de emergencia, materiales y equipos médicos, abrelatas no eléctrico, un mapa, documentos importantes como su seguro e información médica, etc.
- ✓ Asegure su casa contra desastres para disminuir daños. Cubra sus ventanas con materiales de protección. Asegure o suba del piso cualquier cosa que pueda moverse alrededor de su casa.
- ✓ Si no puede llevarse sus mascotas (animales) deje provisiones para ellos (agua y comida).
- ✓ Aprenda sus rutas de evacuación en su área antes de salir de casa. (www.texasonline.com).
- ✓ Llene su tanque de gasolina lo antes posible. Solo lleve un vehículo que pueda transportar con seguridad a usted y a su familia. Más vehículos generan congestión (tráfico).
- ✓ Traiga dinero en efectivo extra en caso de que los bancos estén cerrados y los cajeros automáticos no funcionen.
- ✓ Avise a familiares y amigos (especialmente los que se encuentren fuera de su área) de su plan y destino.
- ✓ Desarrolle un plan de emergencia en caso de que sus familiares estén separados. Dé instrucciones a todos sus familiares del nombre y la información de contacto de su amigo o familiar designado que se encuentra fuera del área.
- ✓ Asegúrese de que los niños sepan como y cuando hablar al 9-1-1.
- ✓ Evacué viajando con cuidado a su destino.
- ✓ Espere tiempos significativamente prolongados de viaje a su destino.

Después de la tormenta, escuche a los oficiales locales para la señal de que todo esta bien antes de regresar a casa. Cheque más información en www.texasonline.com.

No trate de manejar por agua estancada. Solo unas pocas pulgadas son necesarias para que un vehículo flote.

Un accidente menor?

La Ley del Estado requiere que los conductores deben de mover sus vehículos al carril de emergencia (lateral) cuando un accidente menor ha ocurrido. Para mantener todos los carriles de viaje y el carril de emergencia abiertos, los vehículos serán movidos a la próxima salida, donde asistencia pueda estar a la mano.

Más información para la preparación en un huracán y una evacuación segura esta disponible en los siguientes lugares:

Rutas de Evacuación, refugio, y necesidades especiales:
Llame al 2-1-1

Estación para Alertas de Emergencia:
Houston: KTRH 740 AM
San Antonio: WOAI 1200 AM

Estado de Texas:
www.texasonline.com

Departamento de Transporte de Texas (Texas Department of Transportation):
www.dot.state.tx.us
Condición de carreteras: 1-800-452-9292

Departamento de Seguridad Pública de Texas:
www.txdps.state.tx.us

División de Manejo de Emergencia del Gobernador.
www.txdps.state.tx.us/dem

Cruz Roja Americana
www.redcross.org
1-866-GET-INFO (438-4636)
(Este número funcionará solamente después de la tormenta.)

Rev. 8/15/06

HOUSTON a SAN ANTONIO

TEXAS

INTERSTATE 10

2006
Evacuación de Huracanes
Ruta de Contra Flujo

Consejos para el Conductor

Planes de Evacuación pueden o no incluir la Activación de Carriles Contra Flujo

Texas Department of Transportation

Figure C - 3. I-10 (Houston to San Antonio) Contraflow – Side A – Spanish.

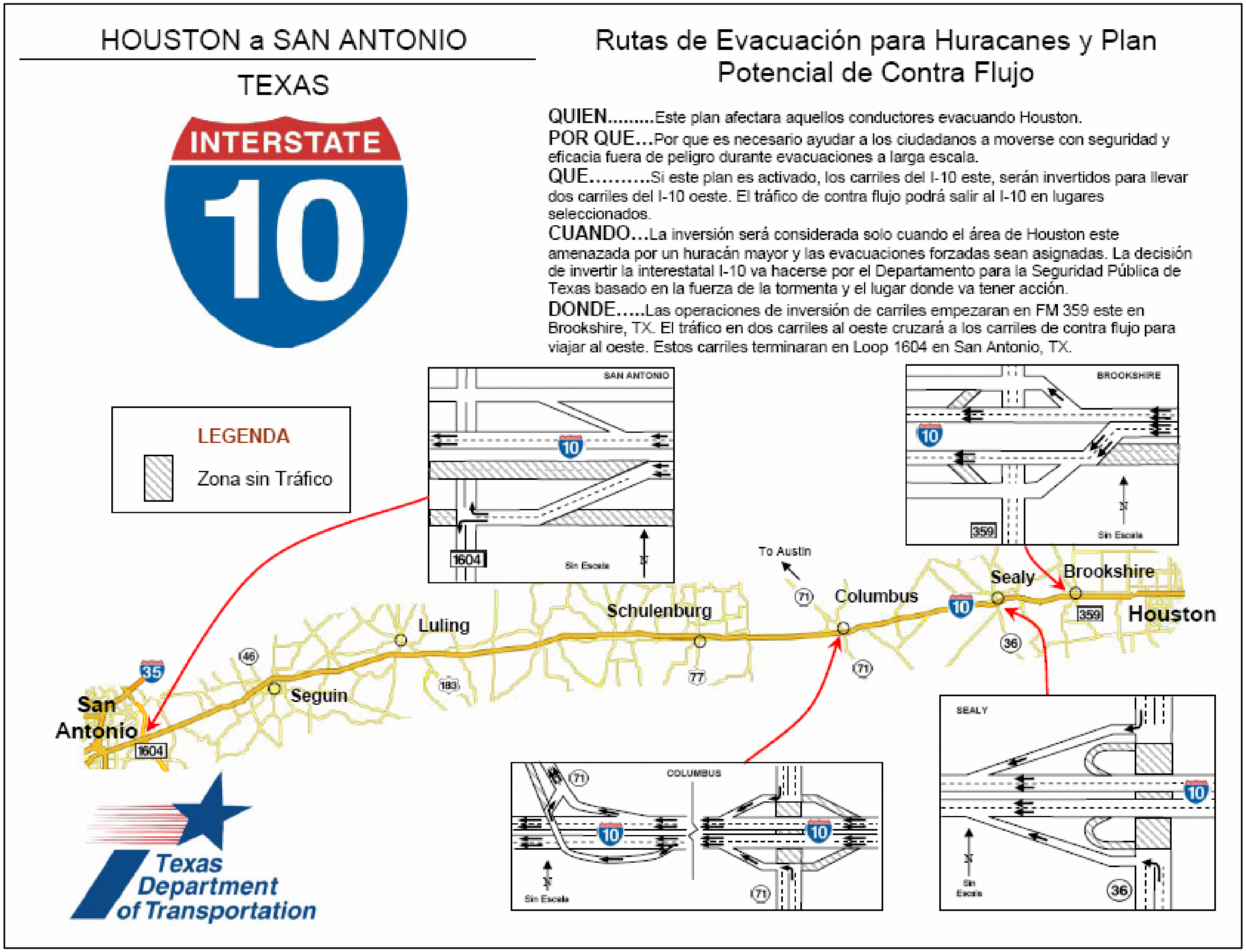


Figure C - 4. I-10 (Houston to San Antonio) Contraflow – Side B – Spanish.

Important Tips

Your needs and those of your family should be the primary factors considered when determining the timing of your evacuation. If you must evacuate, do not delay your departure in anticipation of the opening of the contraflow lanes. Should the contraflow be activated, citizens will be advised through local radio and television stations.
All citizens should prepare a plan well in advance of the evacuation.

The following steps are recommended:

- ✓ Assemble your disaster supplies kit with items such as flashlights, cell phones, extra batteries, battery chargers, portable radio, first aid kit, emergency water and food, medical supplies and equipment, non-electric can opener, highway map, important documents, such as insurance and medical information, etc.
- ✓ Secure your home against disaster to help reduce damages. Cover windows with shielding materials. Secure or put up any loose objects from around your home.
- ✓ If you cannot take your pets with you, make provisions for them.
- ✓ Know your area's evacuation plan/routes before you leave home (www.texasonline.com).
- ✓ Fill your vehicle with gas as early as possible. Take only the vehicle necessary to transport you and your family to safety. Extra vehicles create congestion.
- ✓ Bring extra cash in case banks are closed and ATMs are not working.
- ✓ Notify family and friends (especially those out the area) of your plan and your destination.
- ✓ Develop an emergency plan in case family members are separated. Instruct all evacuating family members of the name and contact information of your designated out-of-area friend or family.
- ✓ Ensure children know how and when to call 9-1-1.
- ✓ Evacuate, traveling safely to your destination.
- ✓ Expect travel times to destinations to be significantly longer than normal.

After the storm, listen to local officials for the all-clear signal before returning home. Check for information at www.texasonline.com.

Do not try to drive through standing water. Just a few inches can float a vehicle.

Fender-Bender?

State law requires motorists to move fender-bender accidents out of the travel lanes to the shoulder of the road. To keep all travel lanes and shoulders clear, however, disabled vehicles on the shoulder will be relocated to the next exit ramp where further assistance may be available.

More information on hurricane preparedness and evacuation safety is available from the following:

Evacuation routes, shelter, and special needs:
Call 2-1-1

Emergency Alert Station:
Corpus Christi: KLUX 89.5 FM
San Antonio: WOAI 1200 AM

State of Texas:
www.texasonline.com

Texas Department of Transportation:
www.dot.state.tx.us
Highway Road Conditions: 1-800-452-9292

Texas Department of Public Safety:
www.txdps.state.tx.us

Governor's Division of Emergency Management:
www.txdps.state.tx.us/dem

City of Corpus Christi
www.cctexas.com/eoc

American Red Cross:
www.redcross.org
1-866-GET-INFO (438-4636)
(This number will function only after landfall.)

Rev. 8/15/06

CORPUS CHRISTI TO SAN ANTONIO

TEXAS

INTERSTATE 37

2006
Hurricane Evacuation Contraflow Route

Motorist Advisory

Evacuation Plans May or May Not Include Activating Contraflow Lanes

Texas Department of Transportation

Figure C - 5. I-37 (Corpus Christi to San Antonio) Contraflow – Side A – English.

CORPUS CHRISTI TO SAN ANTONIO

TEXAS

INTERSTATE 37

Hurricane Evacuation Route's Potential Contraflow Plan

WHO...... This plan will affect motorists evacuating from Corpus Christi.

WHY..... To help move citizens safely and efficiently out of harm's way during large-scale evacuations.

WHAT... If this plan is activated, I-37 southbound lanes will be reversed to carry two lanes of northbound traffic. Traffic in the contraflow lanes will be able to exit I-37 at US 59.

WHEN... The reversal will be considered only when the Corpus Christi area is threatened by a major hurricane and mandatory evacuations are issued. A decision to reverse I-37 will be made by the Texas Department of Public Safety based on the strength of the storm and projected landfall.

WHERE.. The contraflow operations will begin north of the Nueces River at US 77. Some northbound traffic will cross over to the contraflow side to travel northbound. The contraflow lanes will end at SH 97 and FM 3006 near Pleasanton, TX. The left contraflow lane will exit at SH 97 and the right contraflow lane will exit at FM 3006.

Texas Department of Transportation

LEGEND

No Traffic Zone

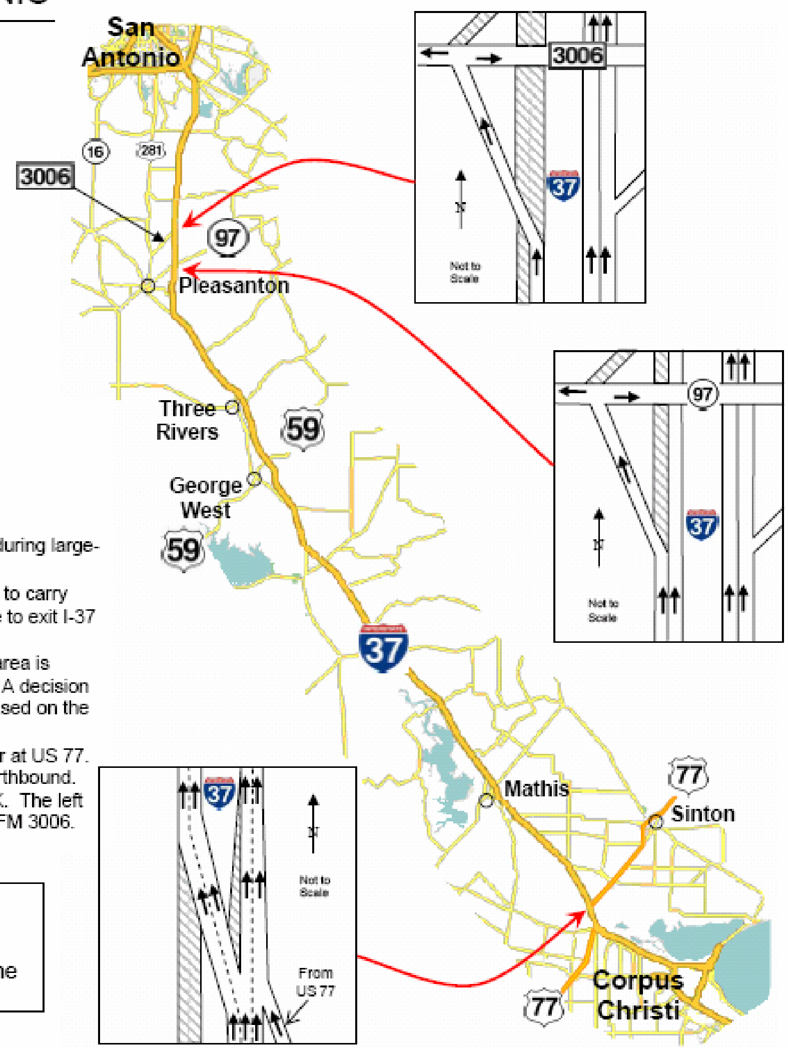


Figure C - 6. I-37 (Corpus Christi to San Antonio) Contraflow – Side B – English.

Sugerencias Importantes

Sus necesidades y las de su familia deben de ser los factores más importantes al determinarse el tiempo de su evacuación. Si usted debe evacuar, no espere a que el contra flujo sea abierto. Cuando el contra flujo sea activado, los ciudadanos van a ser advertidos por medio de la radio y la televisión locales. Todos los ciudadanos deben de prepararse con anticipación.

Los siguientes pasos son recomendados:

- ✓ Construya su botiquín de materiales para desastres con cosas tales como linternas, celulares, baterías extras, cargadores de baterías, radios portátiles, botiquín de primeros auxilios, agua y comida de emergencia, materiales y equipos médicos, abrelatas no eléctrico, un mapa, documentos importantes como su seguro e información médica, etc.
- ✓ Asegure su casa contra desastres para disminuir daños. Cubra sus ventanas con materiales de protección. Asegure o suba del piso cualquier cosa que pueda moverse alrededor de su casa.
- ✓ Si no puede llevarse sus mascotas (animales) deje provisiones para ellos (agua y comida).
- ✓ Aprenda sus rutas de evacuación en su área antes de salir de casa. (www.texasonline.com).
- ✓ Llene su tanque de gasolina lo antes posible. Solo lleve un vehículo que pueda transportar con seguridad a usted y a su familia. Más vehículos generan congestión (tráfico).
- ✓ Traiga dinero en efectivo extra en caso de que los bancos estén cerrados y los cajeros automáticos no funcionen.
- ✓ Avise a familiares y amigos (especialmente los que se encuentren fuera de su área) de su plan y destino.
- ✓ Desarrolle un plan de emergencia en caso de que sus familiares estén separados. Dé instrucciones a todos sus familiares del nombre y la información de contacto de su amigo o familiar designado que se encuentra fuera del área.
- ✓ Asegúrese de que los niños sepan como y cuando hablar al 9-1-1.
- ✓ Evacué viajando con cuidado a su destino.
- ✓ Espere tiempos significativamente prolongados de viaje a su destino.

Después de la tormenta, escuche a los oficiales locales para la señal de que todo esta bien antes de regresar a casa. Cheque más información en www.texasonline.com.

No trate de manejar por agua estancada. Solo unas pocas pulgadas son necesarias para que un vehículo flote.

Un accidente menor?

La Ley del Estado requiere que los conductores deben de mover sus vehículos al carril de emergencia (lateral) cuando un accidente menor ha ocurrido. Para mantener todos los carriles de viaje y el carril de emergencia abiertos, los vehículos serán movidos a la próxima salida, donde asistencia pueda estar a la mano.

Más información para la preparación en un huracán y una evacuación segura esta disponible en los siguientes lugares:

Rutas de Evacuación, refugio, y necesidades especiales:
Llame al 2-1-1

Estación para Alertas de Emergencia:
Corpus Christi: KLUX 89.5 FM
San Antonio: WOAI 1200 AM

Estado de Texas:
www.texasonline.com
Departamento de Transporte de Texas (Texas Department of Transportation):
www.dot.state.tx.us
Condición de carreteras: 1-800-452-9292

Departamento de Seguridad Pública de Texas:
www.txdps.state.tx.us

División de Manejo de Emergencia del Gobernador.
www.txdps.state.tx.us/dem

Ciudad Corpus Christi:
www.cctexas.com/eoc

Cruz Roja Americana
www.redcross.org
1-866-GET-INFO (438-4636)
(Este número funcionará solamente después de la tormenta.)

Rev. 8/15/06

CORPUS CHRISTI a SAN ANTONIO

TEXAS

INTERSTATE 37

2006
Evacuación de Huracanes
Ruta de Contra Flujo

Consejos para el Conductor

Planes de Evacuación pueden o no incluir la Activación de Carriles Contra Flujo

Texas Department of Transportation

Figure C - 7. I-37 (Corpus Christi to San Antonio) Contraflow – Side A – Spanish.

CORPUS CHRISTI a SAN ANTONIO

TEXAS

INTERSTATE 37

Rutas de Evacuación para Huracanes y Plan Potencial de Contra Flujo

QUIEN.........Este plan afectara aquellos conductores evacuando Corpus Christi.

POR QUE…Por que es necesario ayudar a los ciudadanos a moverse con seguridad y eficacia fuera de peligro durante evacuaciones a larga escala.

QUE……....Si este plan es activado, los carriles del I-37 sur, serán invertidos para llevar dos carriles hacia el norte. El tráfico de contra flujo podrá salir del I-37 en US 59.

CUANDO…La inversión será considerada solo cuando el área de Corpus Christi este amenazada por un huracán mayor y las evacuaciones forzadas sean asignadas. La decisión de invertir I-37 va hacerse por el Departamento para la Seguridad Pública de Texas basado en la fuerza de la tormenta y el lugar donde va tener acción.

DONDE…..Las operaciones de inversión de carriles empezarán al norte del Rió Nueces en US 77. Parte del tráfico viajando al norte cruzara al contra flujo para viajar al norte. Los carriles del contra flujo terminaran en SH 97 y en FM 3006 cerca de Pleasanton, TX. El carril izquierdo del contra flujo saldrá a SH 97 y el carril derecho del contra flujo saldrá a FM 3006.

Texas Department of Transportation

LEGENDA

Zona sin Tráfico

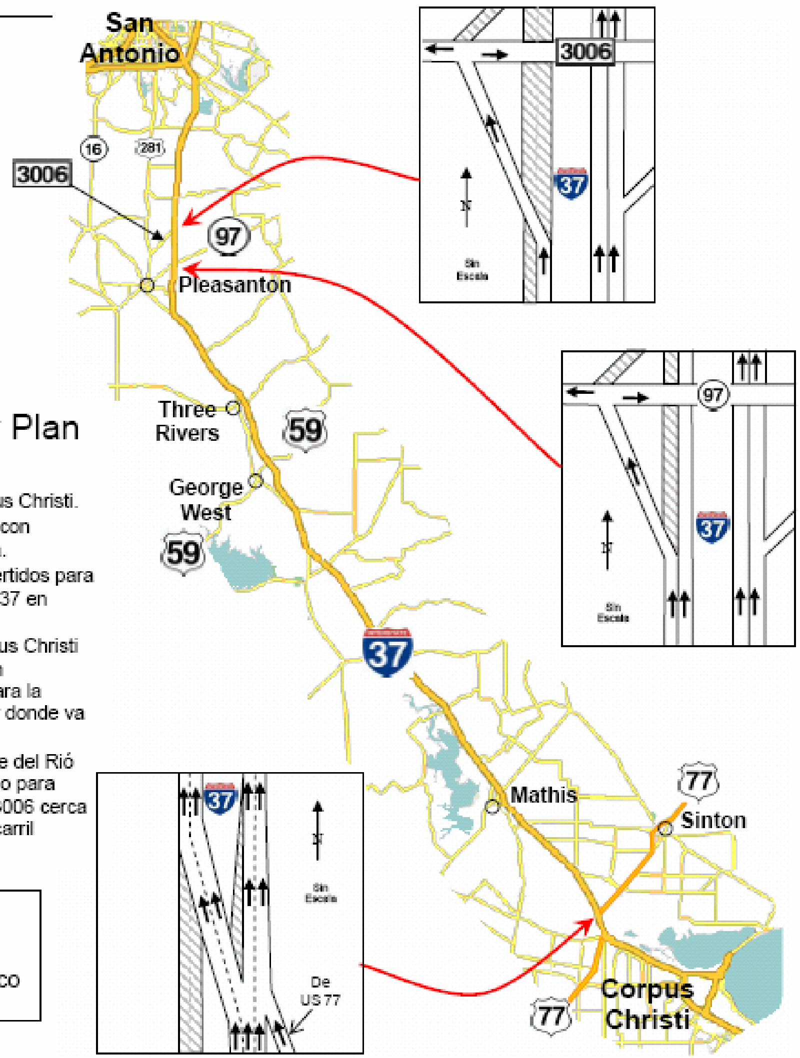


Figure C - 8. I-37 (Corpus Christi to San Antonio) Contraflow – Side B – Spanish.

Important Tips

Your needs and those of your family should be the primary factors considered when determining the timing of your evacuation. If you must evacuate, do not delay your departure in anticipation of the opening of the contraflow lanes. Should the contraflow be activated, citizens will be advised through local radio and television stations.

All citizens should prepare a plan well in advance of the evacuation.

The following steps are recommended:

- ✓ Assemble your disaster supplies kit with items such as flashlights, cell phones, extra batteries, battery chargers, portable radio, first aid kit, emergency water and food, medical supplies and equipment, non-electric can opener, highway map, important documents, such as insurance and medical information, etc.
- ✓ Secure your home against disaster to help reduce damages. Cover windows with shielding materials. Secure or put up any loose objects from around your home.
- ✓ If you cannot take your pets with you, make provisions for them.
- ✓ Know your area's evacuation plan/routes before you leave home (www.texasonline.com).
- ✓ Fill your vehicle with gas as early as possible. Take only the vehicle necessary to transport you and your family to safety. Extra vehicles create congestion.
- ✓ Bring extra cash in case banks are closed and ATMs are not working.
- ✓ Notify family and friends (especially those out the area) of your plan and your destination.
- ✓ Develop an emergency plan in case family members are separated. Instruct all evacuating family members of the name and contact information of your designated out-of-area friend or family.
- ✓ Ensure children know how and when to call 9-1-1.
- ✓ Evacuate, traveling safely to your destination.
- ✓ Expect travel times to destinations to be significantly longer than normal.

After the storm, listen to local officials for the all-clear signal before returning home. Check for information at www.texasonline.com.

Do not try to drive through standing water. Just a few inches can float a vehicle.

Fender-Bender?

State law requires motorists to move fender-bender accidents out of the travel lanes to the shoulder of the road. To keep all travel lanes and shoulders clear, however, disabled vehicles on the shoulder will be relocated to the next exit ramp where further assistance may be available.

More information on hurricane preparedness and evacuation safety is available from the following:

Evacuation routes, shelter, and special needs:
Call 2-1-1

Emergency Alert Station:
Houston: KTRH 740 AM
Dallas: WBAP 820 AM

State of Texas:
www.texasonline.com

Texas Department of Transportation:
www.dot.state.tx.us
Highway Road Conditions: 1-800-452-9292

Texas Department of Public Safety:
www.txdps.state.tx.us

Governor's Division of Emergency Management:
www.txdps.state.tx.us/dem

American Red Cross:
www.redcross.org
1-866-GET-INFO (438-4636)
(This number will function only after landfall.)

Rev. 8/15/06

HOUSTON TO DALLAS

TEXAS

2006
Hurricane Evacuation
Contraflow Route

Motorist Advisory

Evacuation Plans May or May Not Include Activating Contraflow Lanes

Texas Department of Transportation

Figure C - 9. I-45 (Houston to Dallas) Contraflow – Side A – English.

HOUSTON TO DALLAS

TEXAS

Hurricane Evacuation Route's
Potential Contraflow Plan

WHO...... This plan will affect motorists evacuating from the Houston area.

WHY..... To help move citizens safely and efficiently out of harm's way during large-scale evacuations.

WHAT... If this plan is activated, I-45 southbound lanes will be reversed to carry two lanes of northbound traffic. Traffic in the contraflow lanes will be able to exit I-45 at selected locations.

WHEN... The reversal will be considered only when the Houston area is threatened by a major hurricane and mandatory evacuations are issued. A decision to reverse I-45 will be made by the Texas Department of Public Safety based on the strength of the storm and projected landfall.

WHERE... The contraflow operations will begin north of SH 242. Some northbound traffic will cross over to the contraflow side to travel northbound. Contraflow and other I-45 motorists will have access to fuel stations at multiple locations along I-45. The contraflow lanes will end at US 287 near Ennis, TX, 40 miles south of Dallas, TX.

Texas Department of Transportation

LEGEND

No Traffic Zone

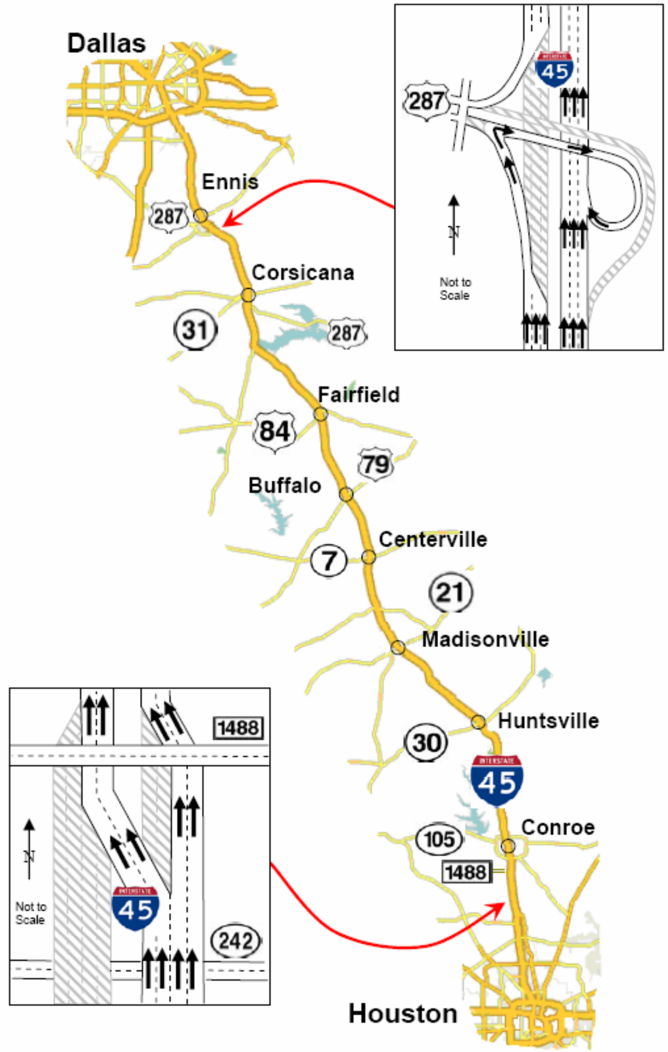


Figure C - 10. I-45 (Houston to Dallas) Contraflow – Side B – English.

Sugerencias Importantes

Sus necesidades y las de su familia deben de ser los factores más importantes al determinarse el tiempo de su evacuación. Si usted debe evacuar, no espere a que el contra flujo sea abierto. Cuando el contra flujo sea activado, los ciudadanos van a ser advertidos por medio de la radio y la televisión locales. Todos los ciudadanos deben de prepararse con anticipación.

Los siguientes pasos son recomendados:

- ✓ Construya su botiquín de materiales para desastres con cosas tales como linternas, celulares, baterías extras, cargadores de baterías, radios portátiles, botiquín de primeros auxilios, agua y comida de emergencia, materiales y equipos médicos, abrelatas no eléctrico, un mapa, documentos importantes como su seguro e información médica, etc.
- ✓ Asegure su casa contra desastres para disminuir daños. Cubra sus ventanas con materiales de protección. Asegure o suba del piso cualquier cosa que pueda moverse alrededor de su casa.
- ✓ Si no puede llevarse sus mascotas (animales) deje provisiones para ellos (agua y comida).
- ✓ Aprenda sus rutas de evacuación en su área antes de salir de casa. (www.texasonline.com).
- ✓ Llene su tanque de gasolina lo antes posible. Solo lleve un vehículo que pueda transportar con seguridad a usted y a su familia. Más vehículos generan congestión (tráfico).
- ✓ Traiga dinero en efectivo extra en caso de que los bancos estén cerrados y los cajeros automáticos no funcionen.
- ✓ Avise a familiares y amigos (especialmente los que se encuentren fuera de su área) de su plan y destino.
- ✓ Desarrolle un plan de emergencia en caso de que sus familiares estén separados. Dé instrucciones a todos sus familiares del nombre y la información de contacto de su amigo o familiar designado que se encuentra fuera del área.
- ✓ Asegúrese de que los niños sepan como y cuando hablar al 9-1-1.
- ✓ Evacué viajando con cuidado a su destino.
- ✓ Espere tiempos significativamente prolongados de viaje a su destino.

Después de la tormenta, escuche a los oficiales locales para la señal de que todo esta bien antes de regresar a casa. Cheque más información en www.texasonline.com.

No trate de manejar por agua estancada. Solo unas pocas pulgadas son necesarias para que un vehiculo flote.

Un accidente menor?

La Ley del Estado requiere que los conductores deben de mover sus vehículos al caril de emergencia (lateral) cuando un accidente menor ha ocurrido. Para mantener todos los cariles de viaje y el caril de emergencia abiertos, los vehículos serán movidos a la próxima salida, donde asistencia pueda estar a la mano.

Más información para la preparación en un huracán y una evacuación segura esta disponible en los siguientes lugares:

Rutas de Evacuación, refugio, y necesidades especiales:
Llame al 2-1-1

Estación para Alertas de Emergencia:
Houston: KTRH 740 AM
San Antonio: WOAI 1200 AM

Estado de Texas:
www.texasonline.com

Departamento de Transporte de Texas (Texas Department of Transportation):
www.dot.state.tx.us
Condición de carreteras: 1-800-452-9292

Departamento de Seguridad Pública de Texas:
www.txdps.state.tx.us

División de Manejo de Emergencia del Gobernador:
www.txdps.state.tx.us/dem

Cruz Roja Americana
www.redcross.org
1-866-GET-INFO (438-4636)
(Este número funcionará solamente después de la tormenta.)

Rev. 1/18/07

HOUSTON a DALLAS

TEXAS

INTERSTATE 45

2006 Evacuación de Huracanes Ruta de Contra Flujo

Consejos para el Conductor

Planes de Evacuación pueden o no incluir la Activación de Carriles Contra Flujo

Texas Department of Transportation

Figure C - 11. I-45 (Houston to Dallas) Contraflow – Side A – Spanish.

HOUSTON a DALLAS

TEXAS

INTERSTATE 45

Rutas de Evacuación para Huracanes y Plan Potencial de Contra Flujo

QUIEN......... Este plan afectara aquellos conductores evacuando Houston.

POR QUE... Por que es necesario ayudar a los ciudadanos a moverse con seguridad y eficacia fuera de peligro durante evacuaciones a larga escala.

QUE.......... Si este plan es activado, los carriles del I-45 sur, serán invertidos para llevar dos carriles hacia el norte. El tráfico de contra flujo podrá salir al I-45 en lugares seleccionados

CUANDO... La inversión será considerada solo cuando el área de Houston este amenazada por un huracán mayor y las evacuaciones forzadas sean asignadas. La decisión de invertir la I-45 va hacerse por el Departamento para la Seguridad Pública de Texas basado en la fuerza de la tormenta y el lugar donde va tener acción.

DONDE..... Las operaciones de contra flujo empezaran al norte de SH 242. Parte del tráfico hacia el norte cruzará a los carriles del contra flujo para viajar al norte. El contra flujo y otros conductores tendrán acceso a gasolineras en localidades múltiple a lo largo de la I-45. Los carriles de contra flujo terminaran en la US 287 cerca de Ennis, TX, 40 millas al sur de Dallas.

Texas Department of Transportation

LEGENDA

Zona sin Tráfico

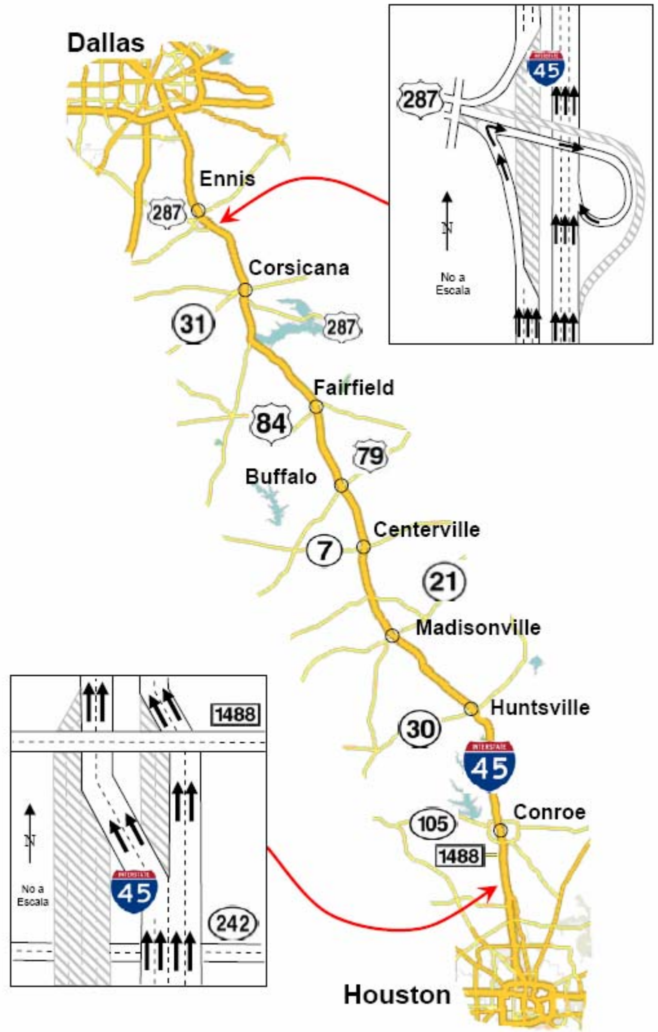


Figure C - 12. I-45 (Houston to Dallas) Contraflow – Side B – Spanish.

Important Tips

Your needs and those of your family should be the primary factors considered when determining the timing of your evacuation. If you must evacuate, do not delay your departure in anticipation of the opening of the contraflow lanes. Should the contraflow be activated, citizens will be advised through local radio and television stations.

All citizens should prepare a plan well in advance of the evacuation.

The following steps are recommended:

- ✓ Assemble your disaster supplies kit with items such as flashlights, cell phones, extra batteries, battery chargers, portable radio, first aid kit, emergency water and food, medical supplies and equipment, non-electric can opener, highway map, important documents, such as insurance and medical information, etc.
- ✓ Secure your home against disaster to help reduce damages. Cover windows with shielding materials. Secure or put up any loose objects from around your home.
- ✓ If you cannot take your pets with you, make provisions for them.
- ✓ Know your area's evacuation plan/routes before you leave home (www.texasonline.com).
- ✓ Fill your vehicle with gas as early as possible. Take only the vehicle necessary to transport you and your family to safety. Extra vehicles create congestion.
- ✓ Bring extra cash in case banks are closed and ATMs are not working.
- ✓ Notify family and friends (especially those out the area) of your plan and your destination.
- ✓ Develop an emergency plan in case family members are separated. Instruct all evacuating family members of the name and contact information of your designated out-of-area friend or family.
- ✓ Ensure children know how and when to call 9-1-1.
- ✓ Evacuate, traveling safely to your destination.
- ✓ Expect travel times to destinations to be significantly longer than normal.

After the storm, listen to local officials for the all-clear signal before returning home. Check for information at www.texasonline.com.

Do not try to drive through standing water. Just a few inches can float a vehicle.

Fender-Bender?

State law requires motorists to move fender-bender accidents out of the travel lanes to the shoulder of the road. To keep all travel lanes and shoulders clear, however, disabled vehicles on the shoulder will be relocated to the next exit ramp where further assistance may be available.

More information on hurricane preparedness and evacuation safety is available from the following:

Evacuation routes, shelter, and special needs:
Call 2-1-1

Emergency Alert Station:
Houston: KTRH 740 AM

State of Texas:
www.texasonline.com

Texas Department of Transportation:
www.dot.state.tx.us
Highway Road Conditions: 1-800-452-9292

Texas Department of Public Safety:
www.txdps.state.tx.us

Governor's Division of Emergency Management:
www.txdps.state.tx.us/dem

American Red Cross:
www.redcross.org
1-866-GET-INFO (438-4636)
(This number will function only after landfall.)

Rev. 8/15/06

HOUSTON TO NACOGDOCHES

TEXAS

59

2006 Hurricane Evacuation Contraflow Route

Motorist Advisory

Evacuation Plans May or May Not Include Activating Contraflow Lanes

Texas Department of Transportation

Figure C - 13. US 59 (Houston to Nacogdoches) Contraflow – Side A – English.

HOUSTON TO NACOGDOCHES

TEXAS

59

Hurricane Evacuation Route's Potential Contraflow Plan

WHO...... This plan will affect motorists evacuating from the Houston area.
WHY..... To help move citizens safely and efficiently out of harm's way during large-scale evacuations.
WHAT…If this plan is activated, US 59 southbound lanes will be reversed to carry two lanes of northbound traffic. Traffic in the contraflow lanes will be able to exit US 59.
WHEN…The reversal will be considered only when the Houston area is threatened by a major hurricane and mandatory evacuations are issued. A decision to reverse US 59 will be made by the Texas Department of Public Safety based on the strength of the storm and projected landfall.
WHERE.. The contraflow operations will begin south of Kingwood Drive and continue to Nacogdoches, TX.

Texas Department of Transportation

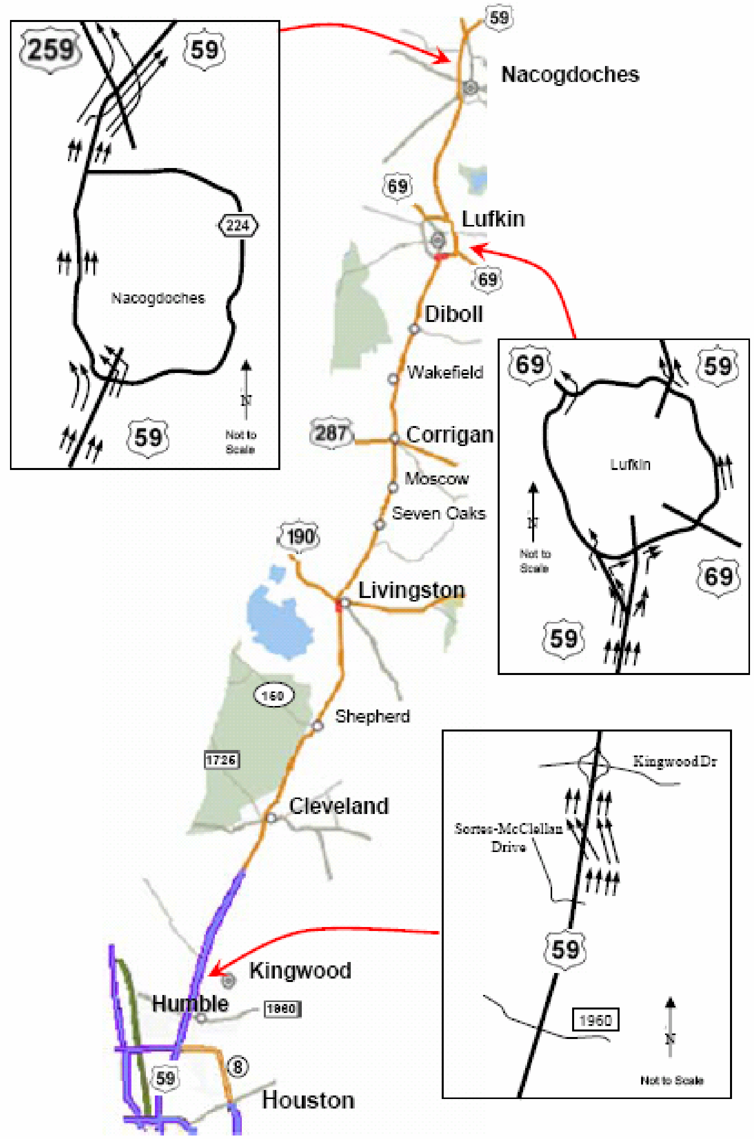


Figure C - 14. US 59 (Houston to Nacogdoches) Contraflow – Side B – English.

Sugerencias Importantes

Sus necesidades y las de su familia deben de ser los factores más importantes al determinarse el tiempo de su evacuación. Si usted debe evacuar, no espere a que el contra flujo sea abierto. Cuando el contra flujo sea activado, los ciudadanos van a ser advertidos por medio de la radio y la televisión locales. Todos los ciudadanos deben de prepararse con anticipación.

Los siguientes pasos son recomendados:

- ✓ Construya su botiquín de materiales para desastres con cosas tales como linternas, celulares, baterías extras, cargadores de baterías, radios portátiles, botiquín de primeros auxilios, agua y comida de emergencia, materiales y equipos médicos, abrelatas no eléctrico, un mapa, documentos importantes como su seguro e información médica, etc.
- ✓ Asegure su casa contra desastres para disminuir daños. Cubra sus ventanas con materiales de protección. Asegure o suba del piso cualquier cosa que pueda moverse alrededor de su casa.
- ✓ Si no puede llevarse sus mascotas (animales) deje provisiones para ellos (agua y comida).
- ✓ Aprenda sus rutas de evacuación en su área antes de salir de casa. (www.texasonline.com).
- ✓ Llene su tanque de gasolina lo antes posible. Solo lleve un vehículo que pueda transportar con seguridad a usted y a su familia. Más vehículos generan congestión (tráfico).
- ✓ Traiga dinero en efectivo extra en caso de que los bancos estén cerrados y los cajeros automáticos no funcionen.
- ✓ Avise a familiares y amigos (especialmente los que se encuentren fuera de su área) de su plan y destino.
- ✓ Desarrolle un plan de emergencia en caso de que sus familiares estén separados. Dé instrucciones a todos sus familiares del nombre y la información de contacto de su amigo o familiar designado que se encuentra fuera del área.
- ✓ Asegúrese de que los niños sepan como y cuando hablar al 9-1-1.
- ✓ Evacué viajando con cuidado a su destino.
- ✓ Espere tiempos significativamente prolongados de viaje a su destino.

Después de la tormenta, escuche a los oficiales locales para la señal de que todo esta bien antes de regresar a casa. Cheque más información en www.texasonline.com.

No trate de manejar por agua estancada. Solo unas pocas pulgadas son necesarias para que un vehículo flote.

Un accidente menor?

La Ley del Estado requiere que los conductores deben de mover sus vehículos al carril de emergencia (lateral) cuando un accidente menor ha ocurrido. Para mantener todos los carriles de viaje y el carril de emergencia abiertos, los vehículos serán movidos a la próxima salida, donde asistencia pueda estar a la mano.

Más información para la preparación en un huracán y una evacuación segura esta disponible en los siguientes lugares:

Rutas de Evacuación, refugio, y necesidades especiales:
Llame al 2-1-1

Estación para Alertas de Emergencia:
Houston: KTRH 740 AM
San Antonio: WOAI 1200 AM

Estado de Texas:
www.texasonline.com

Departamento de Transporte de Texas (Texas Department of Transportation):
www.dot.state.tx.us
Condición de carreteras: 1-800-452-9292

Departamento de Seguridad Pública de Texas:
www.txdps.state.tx.us

División de Manejo de Emergencia del Gobernador.
www.txdps.state.tx.us/dem

Cruz Roja Americana
www.redcross.org
1-866-GET-INFO (438-4636)
(Este número funcionará solamente después de la tormenta.)

Rev. 8/15/06

HOUSTON a NACOGDOCHES

TEXAS

59

2006
Evacuación de Huracanes
Ruta de Contra Flujo

Consejos para el Conductor

Planes de Evacuación pueden o no incluir la Activación de Carriles Contra Flujo

Texas Department of Transportation

Figure C - 15. US 59 (Houston to Nacogdoches) Contraflow – Side A – Spanish.

HOUSTON a NACOGDOCHES

TEXAS

59

Rutas de Evacuación para Huracanes y Plan Potencial de Contra Flujo

QUIEN.........Este plan afectara aquellos conductores evacuando Houston.
POR QUE…Por que es necesario ayudar a los ciudadanos a moverse con seguridad y eficacia fuera de peligro durante evacuaciones a larga escala.
QUE……….Si este plan es activado, los carriles del US 59 sur, serán invertidos para llevar dos carriles hacia el norte. El tráfico del contra flujo podrá salir en US 59.
CUANDO…La inversión será considerada solo cuando el área de Houston este amenazada por un huracán mayor y las evacuaciones forzadas sean asignadas. La decisión de invertir el US 59 va hacerse por el Departamento para la Seguridad Pública de Texas basado en la fuerza de la tormenta y el lugar donde va tener acción.
DONDE……Las operaciones del contra flujo empezarán al sur de Kingwood Drive y continuarán hasta Nacogdoches, TX.

Texas Department of Transportation

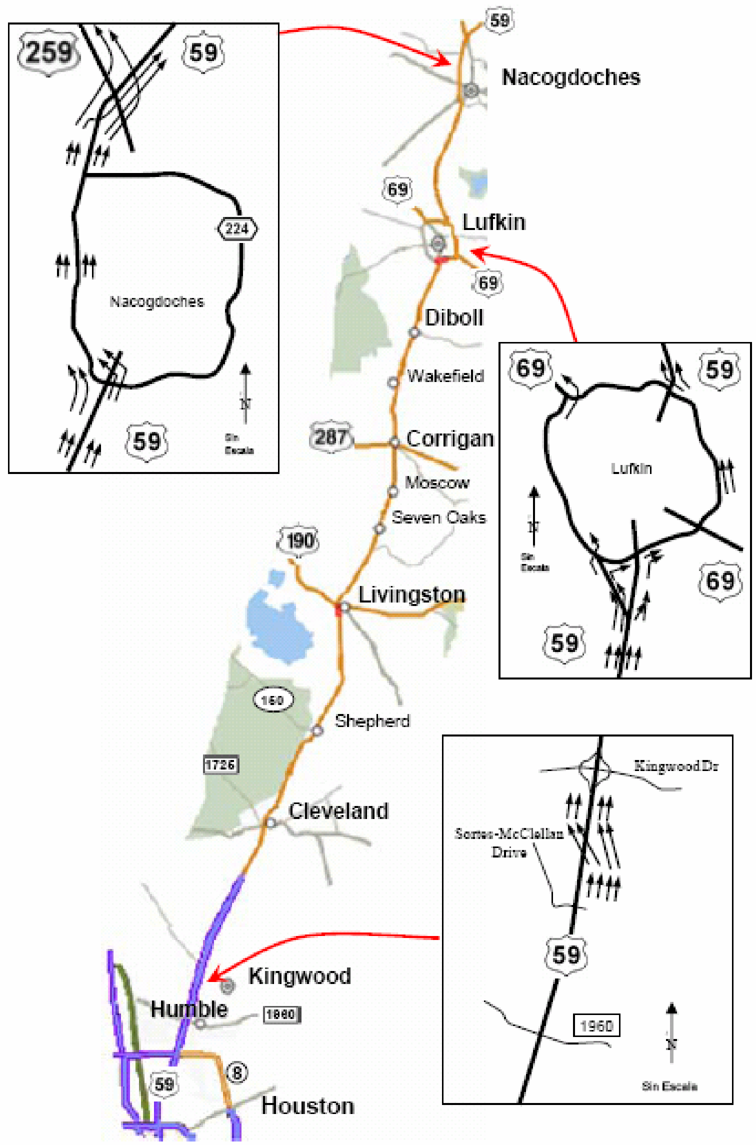


Figure C - 16. US 59 (Houston to Nacogdoches) Contraflow – Side B – Spanish.

Important Tips

Your needs and those of your family should be the primary factors considered when determining the timing of your evacuation. If you must evacuate, do not delay your departure in anticipation of the opening of the contraflow lanes. Should the contraflow be activated, citizens will be advised through local radio and television stations.
All citizens should prepare a plan well in advance of the evacuation.

The following steps are recommended:

- ✓ Assemble your disaster supplies kit with items such as flashlights, cell phones, extra batteries, battery chargers, portable radio, first aid kit, emergency water and food, medical supplies and equipment, non-electric can opener, highway map, important documents, such as insurance and medical information, etc.
- ✓ Secure your home against disaster to help reduce damages. Cover windows with shielding materials. Secure or put up any loose objects from around your home.
- ✓ If you cannot take your pets with you, make provisions for them.
- ✓ Know your area's evacuation plan/routes before you leave home (www.texasonline.com).
- ✓ Fill your vehicle with gas as early as possible. Take only the vehicle necessary to transport you and your family to safety. Extra vehicles create congestion.
- ✓ Bring extra cash in case banks are closed and ATMs are not working.
- ✓ Notify family and friends (especially those out the area) of your plan and your destination.
- ✓ Develop an emergency plan in case family members are separated. Instruct all evacuating family members of the name and contact information of your designated out-of-area friend or family.
- ✓ Ensure children know how and when to call 9-1-1.
- ✓ Evacuate, traveling safely to your destination.
- ✓ Expect travel times to destinations to be significantly longer than normal.

After the storm, listen to local officials for the all-clear signal before returning home. Check for information at www.texasonline.com.

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More information on hurricane preparedness and evacuation safety is available from the following:

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Emergency Alert Station:
Houston: KTRH 740 AM

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www.texasonline.com

Texas Department of Transportation:
www.dot.state.tx.us
Highway Road Conditions: 1-800-452-9292

Texas Department of Public Safety:
www.txdps.state.tx.us

Governor's Division of Emergency Management:
www.txdps.state.tx.us/dem

American Red Cross:
www.redcross.org
1-866-GET-INFO (438-4636)
(This number will function only after landfall.)

Rev. 8/15/06

HOUSTON TO AUSTIN, BRYAN, COLLEGE STATION, WACO

TEXAS

290

2006
Hurricane Evacuation Contraflow Route

Motorist Advisory

Evacuation Plans May or May Not Include Activating Contraflow Lanes

Texas Department of Transportation

Figure C - 17. US 290 (Houston to Austin, Bryan, College Station, Waco) Contraflow – Side A – English.

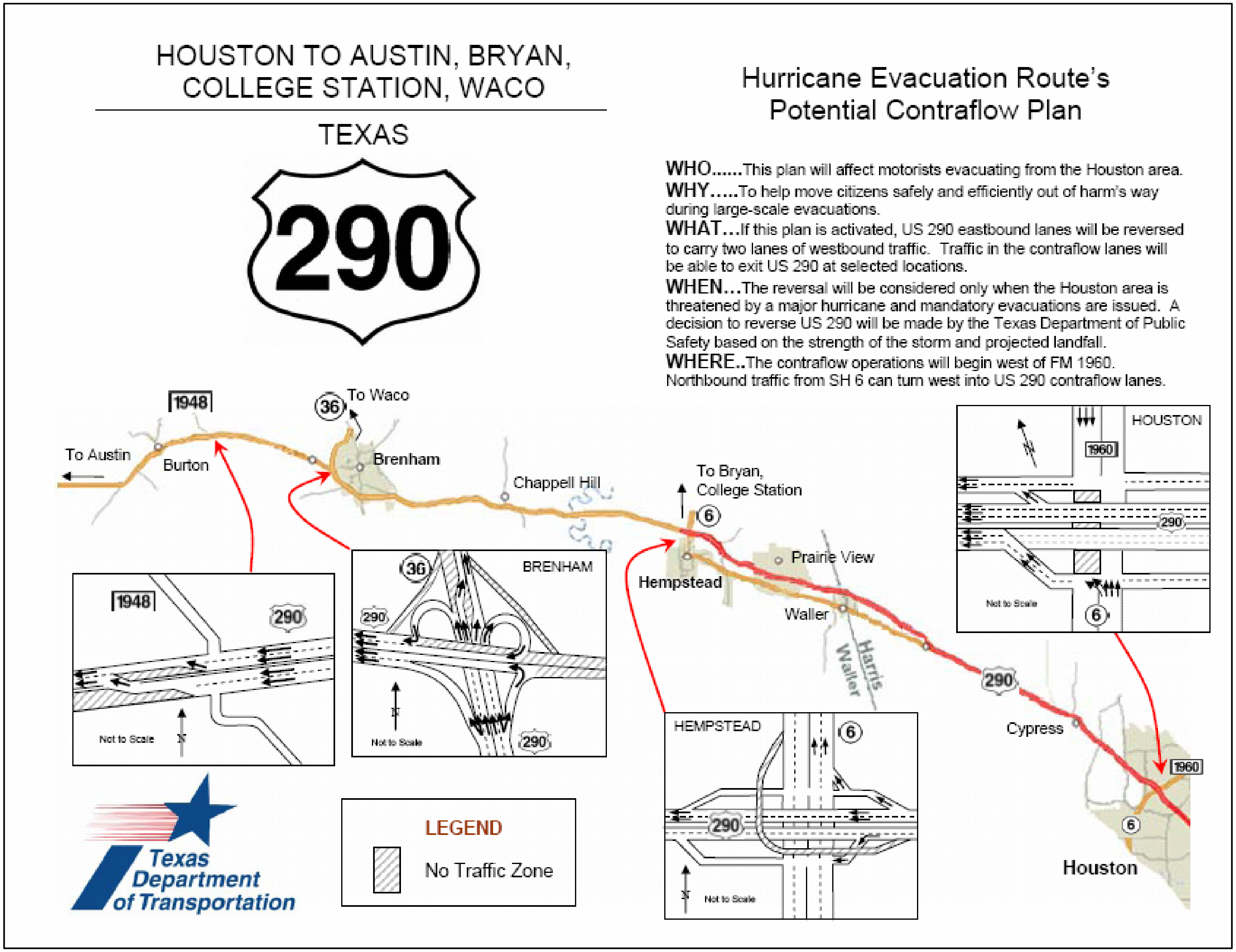

Figure C - 18. US 290 (Houston to Austin, Bryan, College Station, Waco) Contraflow – Side B – English.

Sugerencias Importantes

Sus necesidades y las de su familia deben de ser los factores más importantes al determinarse el tiempo de su evacuación. Si usted debe evacuar, no espere a que el contra flujo sea abierto. Cuando el contra flujo sea activado, los ciudadanos van a ser advertidos por medio de la radio y la televisión locales. Todos los ciudadanos deben de prepararse con anticipación.

Los siguientes pasos son recomendados:

- ✓ Construya su botiquín de materiales para desastres con cosas tales como linternas, celulares, baterías extras, cargadores de baterías, radios portátiles, botiquín de primeros auxilios, agua y comida de emergencia, materiales y equipos médicos, abrelatas no eléctrico, un mapa, documentos importantes como su seguro e información médica, etc.
- ✓ Asegure su casa contra desastres para disminuir daños. Cubra sus ventanas con materiales de protección. Asegure o suba del piso cualquier cosa que pueda moverse alrededor de su casa.
- ✓ Si no puede llevarse sus mascotas (animales) deje provisiones para ellos (agua y comida).
- ✓ Aprenda sus rutas de evacuación en su área antes de salir de casa. (www.texasonline.com).
- ✓ Llene su tanque de gasolina lo antes posible. Solo lleve un vehículo que pueda transportar con seguridad a usted y a su familia. Más vehículos generan congestión (tráfico).
- ✓ Traiga dinero en efectivo extra en caso de que los bancos estén cerrados y los cajeros automáticos no funcionen.
- ✓ Avise a familiares y amigos (especialmente los que se encuentren fuera de su área) de su plan y destino.
- ✓ Desarrolle un plan de emergencia en caso de que sus familiares estén separados. Dé instrucciones a todos sus familiares del nombre y la información de contacto de su amigo o familiar designado que se encuentra fuera del área.
- ✓ Asegúrese de que los niños sepan como y cuando hablar al 9-1-1.
- ✓ Evacué viajando con cuidado a su destino.
- ✓ Espere tiempos significativamente prolongados de viaje a su destino.

Después de la tormenta, escuche a los oficiales locales para la señal de que todo esta bien antes de regresar a casa. Cheque más información en www.texasonline.com.

No trate de manejar por agua estancada. Solo unas pocas pulgadas son necesarias para que un vehículo flote.

Un accidente menor?

La Ley del Estado requiere que los conductores deben de mover sus vehículos al carril de emergencia (lateral) cuando un accidente menor ha ocurrido. Para mantener todos los carriles de viaje y el carril de emergencia abiertos, los vehículos serán movidos a la próxima salida, donde asistencia pueda estar a la mano.

Más información para la preparación en un huracán y una evacuación segura esta disponible en los siguientes lugares:

Rutas de Evacuación, refugio, y necesidades especiales:
Llame al 2-1-1

Estación para Alertas de Emergencia:
Houston: KTRH 740 AM
San Antonio: WOAI 1200 AM

Estado de Texas:
www.texasonline.com

Departamento de Transporte de Texas (Texas Department of Transportation):
www.dot.state.tx.us
Condición de carreteras: 1-800-452-9292

Departamento de Seguridad Pública de Texas:
www.txdps.state.tx.us

División de Manejo de Emergencia del Gobernador.
www.txdps.state.tx.us/dem

Cruz Roja Americana
www.redcross.org
1-866-GET-INFO (438-4636)
(Este número funcionará solamente después de la tormenta.)

Rev. 8/15/06

HOUSTON a AUSTIN, BRYAN, COLLEGE STATION, WACO

TEXAS

290

2006 Evacuación de Huracanes Ruta de Contra Flujo

Consejos para el Conductor

Planes de Evacuación pueden o no incluir la Activación de Carriles Contra Flujo

Texas Department of Transportation

Figure C - 19. US 290 (Houston to Austin, Bryan, College Station, Waco) Contraflow – Side A – Spanish.

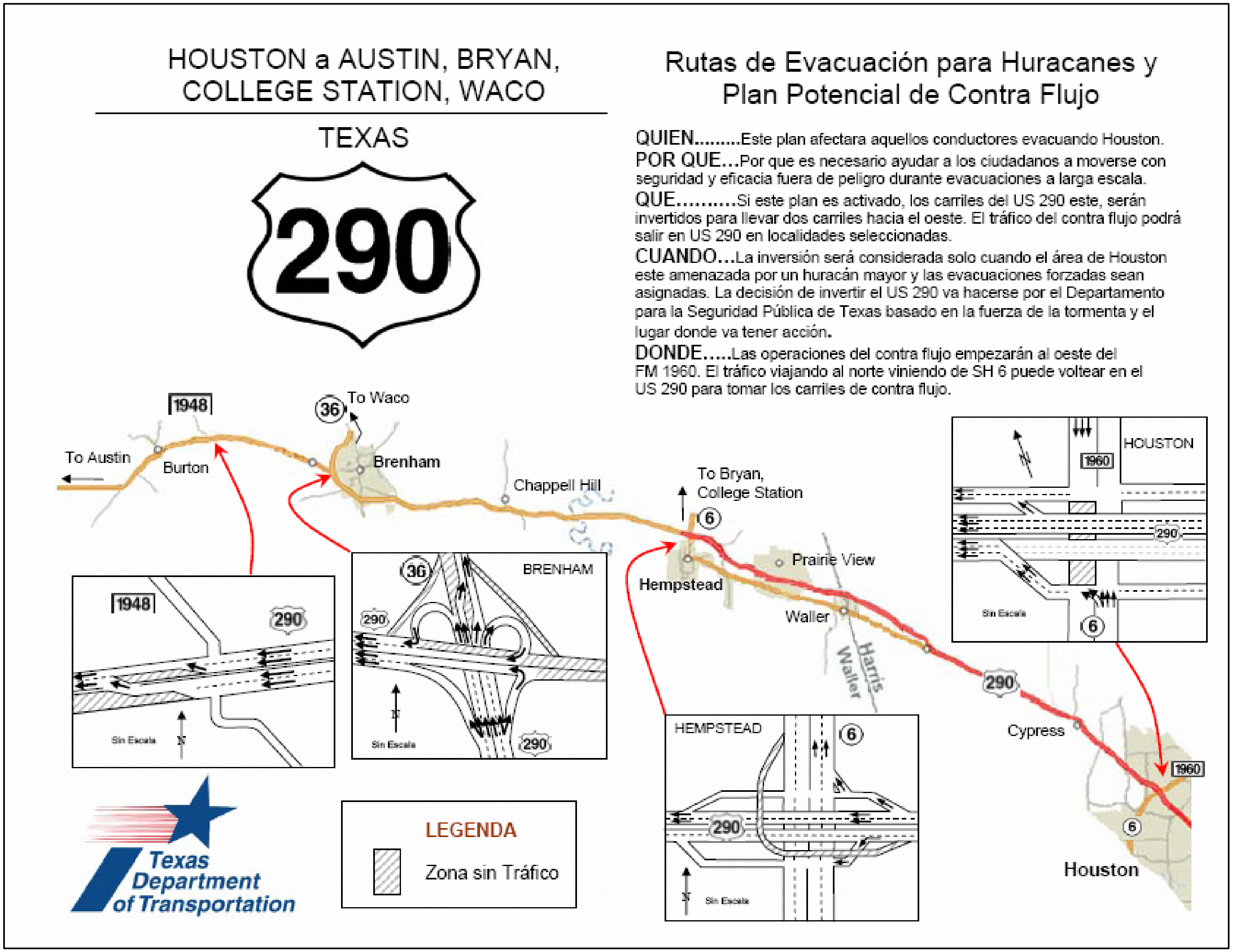

Figure C - 20. US 290 (Houston to Austin, Bryan, College Station, Waco) Contraflow – Side B – Spanish.